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RIBEIRO, GUILHERME FERNANDO; BASSETTO, PRISCILLA; ROCHA, RONY PETERSON DA; KACHBA, YSLENE ROCHA; BRAGHINI, ALDO

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Multicriteria classification: application of Electre TRI to demand forecasting methods for new products

GUILHERME FERNANDO RIBEIRO [1]
PRISCILLA BASSETTO [2]
RONY PETERSON DA ROCHA [2]
YSLENE ROCHA KACHBA [1]
ALDO BRAGHINI JUNIOR [1]

[1] Universidade Tecnológica Federal do Paraná (UTFPR) / Programa de Pós-Graduação em Engenharia de Produção (PPGEP), Ponta Grossa / Paraná – Brazil
[2] Universidade Estadual do Paraná (UNESPAR) / Departamento de Engenharia de Produção Agroindustrial, Campo Mourão / Paraná – Brazil

Abstract

This research proposed a multicriteria classification of demand forecasting methods for new products considering the characteristics of the Brazilian franchise system. Data was collected using a questionnaire validated by specialists and considered reliable and consistent based on Cronbach's alpha coefficient. Data was submitted to Electre TRI multi-criteria classification method, using the Iris 2.0 software. The analysis of the results was carried out on three franchise segments and adopted a classification of new products inclasssuch as 'adition to existing product lines' and 'new-to-the-firm products.' For the segment of bars, restaurants, bakeries, and pizzerias, in the class'additions to existing product lines,' the results showed that market research, historical analogy, scenario simulation, sales force research, Box-Jenkins (Arima), and regression analysis methods were considered as recommended. In the cosmetics and perfumery segment, in the class'additions to existing product lines,' the results showed that the market research, Delphi method, historical analogy, sales team research, moving average, and Box-Jenkins (Arima) methods were also considered as recommended. Finally, the results for the segment of bookstore, graphics, and signage, in the class'new-to-the-firm products,' showed that the market research, Delphi, historical analogy, scenario simulation and sales team research methods were considerd as recommended.

Keywords: Electre TRI. Franching. Forecasting of demand. New products.

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Classificação multicritério: aplicação do Electre TRI aos métodos de previsão de demanda para novos produtos

Resumo

A pesquisa tem como objetivo propor uma classificação multicritério aos métodos de previsão de demanda para novos produtos, considerando as características do sistema brasileiro de franquias. Utilizou-se a técnica de coleta dos dados do tipo questionário e realizou-se uma validação com especialistas da área, além da aplicação do coeficiente alfa de Cronbach, que demonstrou confiabilidade e consistência do questionário. Utilizou-se o apoio multicritério à decisão, Electre TRI, por meio do *software* Iris 2.0. A análise dos resultados foi realizada em três segmentos de franquias e adotou uma classificação de novos produtos em classes como 'adições a linhas de produtos existentes' e 'novos produtos para a empresa'. Para o de bares, restaurantes, padarias e pizzarias, na classe 'adições a linhas existentes de produtos', os resultados mostram que os métodos pesquisa de mercado, analogia histórica, simulação de cenários, pesquisa da equipe de vendas, Box-Jenkins (Arima) e análise de regressão foram considerados como recomendados. No segmento de cosméticos e perfumaria, na classe 'adições a linhas existentes de produtos', os resultados mostram que os métodos pesquisa de mercado e Delphi, analogia histórica, pesquisa da equipe de vendas, média móvel e Box-Jenkins (Arima) se enquadraram como recomendados. Por fim, os resultados para o segmento de livrarias, gráficas e sinalização, na classe 'novos produtos para a empresa', mostram que os métodos pesquisa de mercado e Delphi, analogia histórica, simulação de cenários e pesquisa da equipe de vendas foram considerados como recomendados.

Palavras-chave: Electre TRI. Franquias. Previsão de demanda. Novo produtos.

Clasificación multicriterio: aplicación de Electre TRI a los métodos de previsión de demanda de nuevos productos

Resumen

La investigación tuvo como objetivo proponer una clasificación multicriterio de los métodos de previsión de demanda de nuevos productos considerando las características del sistema de franquicias brasileño. Se utilizó la técnica de recolección de datos tipo cuestionario y se realizó su validación con especialistas del área, además de la aplicación del coeficiente alfa de Cronbach –lo que demostró la confiabilidad y consistencia del cuestionario–. Se utilizó el apoyo multicriterio a la decisión – Electre TRI –, por medio del *software* Iris 2.0. El análisis de los resultados se realizó en tres segmentos de franquicias y adoptó una clasificación de nuevos productos en clases como 'adiciones a las líneas de productos existentes› y ‹nuevos productos para la empresa›. Para el segmento de bares, restaurantes, panaderías y pizzerías, en la clasede 'adiciones a las líneas de productos existentes', los resultados muestran que los métodos de investigación de mercado, analogía histórica, simulación de escenarios, investigación del equipo de ventas, Box-Jenkins (Arima) y análisis de regresión fueron considerados como recomendados. Para el segmento de cosmética y perfumería, en la clasede 'adiciones a las líneas de productos existentes', los resultados indican que los métodos de investigación de mercado, Delphi, analogía histórica, investigación del equipo de ventas, media móvil y Box-Jenkins (Arima), se encuadran como recomendados. Finalmente, los resultados del segmento de librerías, gráficos y señalización, en la clasede 'nuevos productos para la empresa', los resultados demuestran que los métodos de investigación de mercado, Delphi, analogía histórica, simulación de escenarios e investigación del equipo de ventas fueron considerados como recomendados.

Palabras clave: Electre TRI. Franquicia. Previsión de demanda. Nuevos productos.

INTRODUCTION

Demand forecasting is a necessary prerequisite for most business activities (RITZMAN, KRAJEWSKI and MALHOTRA, 2009), considered the basis for the strategic planning of production, sales and finances of any company, in addition to, in the process of planning, be part of production programming and control. For Silva et al. (2021), the forecast consists of the determination of future values, obtained by a history of data used with a previously defined method.

Relating demand forecasting with the development of new products becomes vital for companies and is very important for the maintenance and marketing growth of the business. Researchers Sipper and Bulfin (1997), Makridakis, Wheelwright and Hyndman (1998), Thomas and Bollapragada (2010), Sarmiento and Soto (2014), Otha, Hiramoto and Kitamura (2014), Mas-Machuca, Sainz and Martinez-Costa (2014), as well as Cecatto and Belfiore (2015), point out that most companies do not use a specific method to forecast demand for new products. Thus, the interest in conducting research to find ways to improve the demand forecast for new products is justified, in order to minimize the error of these forecasts (OLIVEIRA, FUTAMI and OLIVEIRA, 2016).

The multicriteria decision support methods are applied in several studies that want to select, order, classify or describe alternatives present in a decision-making process in the presence of multiple criteria (ROY and BOUYSSOU, 1993).

As presented by Gomes, Araya and Carignano (2004), multi-criteria decision support is an activity based on presented models, but not necessarily formalized, which help in obtaining elements of response to a decision agent's questions.

According to Azevedo and Silva (2003), Mauro (2007) and Guetta et al. (2013), franchises have been fulfilling the mission of bringing new products and/or services to consumers and are always ahead in the market, predicting trends, creating and developing new products, anticipating crises.

This article presents a study on the application of the Electre TRI multi-criteria decision support method, proposed by Yu Wei, in 1992, to classify the demand forecast for new products in the Brazilian franchise system.

MULTI-CRITERIA DECISION SUPPORT METHODS

As several classification methods that make up multi-criteria decision support are available in the literature – Additive Discriminant Utility (an acronym in French Utilités Additives Discriminates – UTADIS), presented by Devaud, in 1980; Electre TRI; Interactive and Multicriteria Decision Making (an acronym in Portuguese Todim), proposed by Gomes and Lima, in 1992; Analytic Hierarchy Process (AHP), developed by Saaty in 1997; Dominance-based Rough Set Approach (DRSA), by Greco, in 2001 - and each one of them presents peculiar procedures and can be applied to specific problems, after carrying out an explanation of the multicriteria decision support method, it is intended to present characteristics and problems from multi-criteria support to the decision, aiming to justify the choice of the method that is aligned with this research problem.

CONCEPTS OF MULTI-CRITERIA DECISION SUPPORT

The basic concepts that involve multicriteria as support for decision making are decision maker, analyst, set of alternatives (or set of choices), criteria and weights. In Box 1, the description for these concepts is presented.

BOX 1

Basic concepts of multi-criteria decision support

Concepts	Description
Decision maker	It is the individual (or group of individuals) that, directly or indirectly, provides the final value judgment that can be used when evaluating the available alternatives, in order to identify the best choice (GOMES, 2007).
Analyst	It is a person (or group of people) in charge of providing the data that will be used to model the problem and make recommendations regarding the final selection (GOMES, ARAYA and CARIGNANO, 2004).
Alternatives (*A*)	It is a set of choices that constitutes the object of the decision. All alternatives should be considered, even if their implementation is not feasible, whenever there is interest in relating it to the decision-making process (ROY, 1991).
Criteria (*K*)	It is a function that reflects the preferences of the decision maker. It can be seen as a model, according to which it is possible to justify a proposition of the type: $u_j(x_1) > u_j(x_2) \leftrightarrow x_1 P_j x_2$, where P_j represents a binary relation that expresses that "x_1 is preferable to x_2 in relation to criterion j" (GOMES, ARAYA and CARIGNANO, 2004).
Weights	They serve as a scale to compare the criteria. In each criterion, a weight is assigned, which must be proportional to the importance of the criterion (BELTON and STEWART, 2002).

Source: Elaborated by the authors.

The functions performed by the decision maker and the analyst are complementary, even if, ultimately, the responsibility for each decision rests with the decision maker, and not with the analyst.

In order to choose some of the alternatives from the set of alternatives, it is assumed that the decision maker has some evaluation axes that are the elements that guide the analysis and must be established so that they represent the relevant dimensions of the problem. Gomes, Araya and Carignano (2004) emphasize that, based on such axes, it is possible to make comparisons between the alternatives. In this case, the criteria represent properties or capabilities of alternatives to satisfy needs.

For Gomes, Araya and Carignano (2004), the measure of relative importance of the criteria for the decision maker is called weight, which is when some criteria will have greater importance than others. Thus, it can be said that, due to a decision problem, a problem is addressed by multi-criteria decision support. Next, the types of problems are presented.

Not all multicriteria methods require these basic concepts in their implementations, as is the case with multicriteria methods that do not use weight in their calculation procedures - for example, the Technique for Order Preference by Similarity to Ideal Solution (Topsis), which evaluates the performance of multiple alternatives through similarity to the ideal solution.

TYPES OF PROBLEMS

The term "problematic" is used to describe the kind of help that can be obtained with the decision problem. A multi-criteria modeling can be different, depending on the problem that will be chosen. Four types of problems were described and presented by Roy (1996), each offering a different result to the decision maker. Box 2 presents the description of these problems.

BOX 2

Types of multi-criteria decision support issues

Denotation	Problem type	Function and result
Problematic α (Pα)	Selection	It makes the decision maker choose the best action, suggesting the smallest set of alternatives. The result is to perform, based on a set of alternatives, a procedure for selecting the best alternatives.
Problematic β (Pβ)	Classification	It presents a classification of alternatives, each one being allocated in categories defined by previously established norms. The result is a classification procedure, allocating the alternatives in previously defined categories.
Problematic γ (Pγ)	Ordination	It generates a ranking of alternatives, a list from the best to the worst, clarifying the decision by grouping the alternatives into equivalence classes. The result is a procedure for determining an ordering of the alternatives.
Problematic δ (Pδ)	Description	It displays the alternatives and their consequences, so that the decision maker can discover, understand and evaluate them. The result is a detailed description of alternatives to facilitate the decision.

Source: Elaborated by the authors based on Pereira (2012) and Simões (2013).

The choice of type of problem for a work can be one of four, a special case of one of them, a sequence of one or more or a mixed problem, that is, not independent of each other (ROY, 1996). In order to support the decision-making process, it is necessary to establish some conditions that can express the preferences of decision-makers. In the following subsection, these conditions are presented.

MODELING THE PREFERENCES

Given a set of alternatives (A), the decision maker is considered to be able to declare his preference or indifference between them. According to Gomes, Araya and Carignano (2004), the expression of the decision maker's preferences, when performing comparisons, is given by binary relations ($\Re$). Box 3 presents the properties of some examples of binary relations.

BOX 3

Properties of some examples of binary relations

Examples of some binary relationships	Condition
Reflexivity	If $\forall\ a \in X$, we have $(a, a) \in \Re$
No reflexivity	If $\forall\ a \in X$, we have $(a, a) \notin \Re$
Symmetry	If $(a, b) \in \Re$, it is also assumed that $(b, a) \in \Re$
Asymmetry	If $(a, b) \in \Re$, it is also assumed that $(b, a) \in \Re^{-}$
Transitivity	If $(a, b) \in \Re$, $(b, c) \in \Re$ imply $(a, c) \in \Re$

Source: Elaborated by the authors based on Gomes, Araya and Carignano (2004).

According to Roy (1996), when a decision maker is faced with two alternatives and knows their consequences, he is able to reveal his preference between them according to four fundamental preference situations. These situations are presented in Box 4.

BOX 4

Fundamental situations of the decision maker's preferences

Situation	Description	Expression	Binary relation
Indifference (*I*)	The decision maker is indifferent between the alternatives.	*aIb*	Symmetrical and reflective
Strict preference (*P*)	The decision maker strictly and undoubtedly prefers one alternative to another.	*aPb*	Asymmetrical and unreflective
Weak preference (*Q*)	The decision maker cannot define whether he prefers one alternative to another or whether they are indifferent.	*aQb*	Asymmetrical and unreflective
Incomparability (*R* ou *NC*)	There are no clear and positive reasons that justify one of the three preceding situations.	*aRb*	Symmetrical and unreflective

Source: Elaborated by the authors based on Gomes, Araya and Carignano (2004).

The combination of fundamental situations gave rise to other important situations. It creates new situations that better reflect what happens in the practice of decision-makers. Box 5 includes the description and condition of each of the situations of particular interest.

BOX 5

Important situations of the decision maker's preferences

Situation	Description	Condition (binary relation)
No preference (~)	The alternatives are indifferent or incomparable to the decision maker.	$a \sim b$ if, and only if, *aIb* or *aRb*
Preference (in the broad sense) ($\succ$)	The decision maker is not able to define whether there is a strong or weak preference between two alternatives.	$a \succ b$ if, and only if, *aPb* or *aQb*
Presumption of preference (*J*)	When the decision maker has a weak preference for an alternative and can reach indifference.	*aJb* if, and only if, *aQb* or *aIb*
K-preference (*K*)	The decision maker is faced with a situation in which he has a strict preference for an alternative or identifies an incomparability between the alternatives.	*aKb* if, and only if, *aPb* or *aRb*
Resilience (*S*)	It combines three situations – strict preference, weak preference and indifference – without the decision maker being able to distinguish them.	*aSb* if, and only if, *aPb* or *aQb* or *aIb*

Source: Elaborated by the authors based on Gomes, Araya and Carignano (2004).

Based on the binary relations and their properties, in the following subsection, the main preference structures over a set of alternatives are stated.

PREFERENCE STRUCTURES

The main preference structures of multi-criteria decision support over a set of alternatives are described in Box 6.

BOX 6

Description of preference structures

Structure	Description
Complete order	A relationship in which there is an intuitive notion of classification of alternatives without the possibility of a tie.
Pre-order complete	A relationship in which there is an intuitive notion of classification of alternatives with the possibility of a tie by similarity.
Almost order and range order	Both take into account the possibility that the symmetric relation is not perfectly transitive in extreme cases, usually defined by the limit of indifference (*q*). The difference between quasi-order and range order is that the former is a constant range order.

Continue

Structure	Description
Partial pre-order	The complete preorder generalization relies on three binary relations in a set of alternatives. They maintain transitivity and incomparability in classification.
Pseudo-order	Corresponds to weak preference and occurs through the introduction of a preference threshold *p*. The pseudo-order is the structure used in Electre methods in which three types of situations are admitted: indifference (*I*), strict preference (*P*) and weak preference (*Q*), delimited by the limits of indifference (*q*) and preference (*p*).

Source: Elaborated by the authors based on Gomes, Araya and Carignano (2004).

An important feature in multi-criteria decision support methods, relevant to the choice of methods, is linked to the trade-off that may exist between the criteria. As a result, the methods can be classified as compensatory and non-compensatory.

COMPENSATORY AND NON-COMPENSATORY METHODS

In compensatory methods, a lower performance of an alternative in a given criterion is compensated by a better performance in another criterion, but the same does not occur in non-compensatory methods. Roy (1996) defines that a binary relation *P* is non-compensatory when the preferences between *x* and *y* depend only on the subsets of criteria that favor *x* and *y*. In this case, the preference relationship between *x* and *y* does not depend on differences in preferences between the various levels in each criterion. As presented by Roy (1996), an asymmetric binary relation *P* over *X*, $P(x, y) = \{i\colon x_i\ P_i\ y_i\}$ applies if the relation *P* is non-compensatory, as in equation (1):

$$\left\{ \begin{matrix} (P\,(x, y) = P\,(z, w) \\ P\,(y, x) = P\,(w, z) \end{matrix} \right\} = > [xPy \Leftrightarrow zPw]\ \forall\, x, y, z, w \in X. \qquad (1)$$

DOMINANCE AND NON-DOMINANCE RELATIONSHIP

The dominance relationship *D*, between two elements *a* and *b*, represented by *aDb*, occurs when, for *m* criteria, considering g_j the value function for criterion *j*, we have at least one of the criteria *j* strict inequality (>), seen in equation (2) (ROY, 1996):

$$g_j\,(a) \geq g_j\,(b), j = 1, 2, 3, m \qquad (2)$$

Before analyzing a multi-criteria problem, the first task to be developed is the elimination of all dominated elements (ROY, 1996). The concept of dominance or non-dominance can be illustrated by the studies of Cohon (1978), who states that a non-dominated solution is one in which the improvement of an objective function can only be achieved at the expense of degrading other objective functions.

This analysis, through various methods, makes it possible to support the decision-making process in choosing the most appropriate of the non-dominated solutions, under the adopted evaluation criteria and for the specific conditions of each problem. Each of the problems is measured through its objective function, with no need for them to use the same unit of measurement.

The Electre family methods are characterized by the use of the French concept *súrclassente* – translated into English as *outranking* and into Portuguese as "overcoming", "subordination", "superclassification", "prevalence" and "domination". According to the idea, a generic alternative a_n dominates the generic alternative b_n *(aSb),* if there are not enough arguments to say that a_n is worse than b_n. As a basic principle, in these methods, the alternative that *loses* to the others or is worse in a greater number of criteria is considered dominated (GOMES, ARAYA and CARIGNANO, 2004).

CLASSIFICATION OF DECISION SUPPORT METHODS

As presented by Gomes and Gomes (2019), multicriteria decision support problems can be divided into three large groups or families of approaches: single-criteria synthesis, overclassification and interactive judgment approach.

Among the methods of the single criterion approach, the theory of multi-attribute utility – Multiple Attribute Utility Theory (Maut) –, proposed for the first time by Keeney and Raiffa, in 1976, and the Analytic Hierarchy Process (AHP), applied when the criteria are of the compensatory type. Maut presents an axiomatic structure and a compensatory logic between the criteria, in order to obtain a synthesis function that aggregates all the criteria in a single analytical function, while the AHP decomposes the problem into several factors, with relationships between them, for through the construction of a hierarchy (KEENEY and RAIFFA, 1976).

Regarding the methods of the outranking approach, the Elimination Et Choice Traidusaint la Realité (Electre) family, first presented by Roy Bernard, in 1968, and the Preference Ranking Organization Method for Enrichment Evaluations (Promethee), introduced by Brans and Vincke, in 1985 These methods are more flexible, without compensation between criteria (non-compensatory), and accept incomparability between alternatives. They are also based on a pairwise comparison between them, exploring an overclassification relationship (SAATY, 1994).

The interactive judgment approach involves the use of computational tools, in which alternating steps of dialogue and calculations are developed, such as the Step Method (Stem) and the Interval Criterion Weights (ICW). After the decision maker has chosen the questions presented, the model can reduce the space of alternatives and proceed to the immediate stage of a new interaction (ALMEIDA, 2011).

To address multi-criteria decision problems, two schools that study the multi-criteria decision support method are found in the literature: the French and the American (GOMES and GOMES, 2019).

In this research, it was defined that the method used would be that of the French school, composed of outranking methods, prevalence or subordination. Its analysis does not admit trade-offs and is used for a finite set of alternatives. The French school is more flexible as it does not require a hierarchical classification of alternatives from the decision-maker.

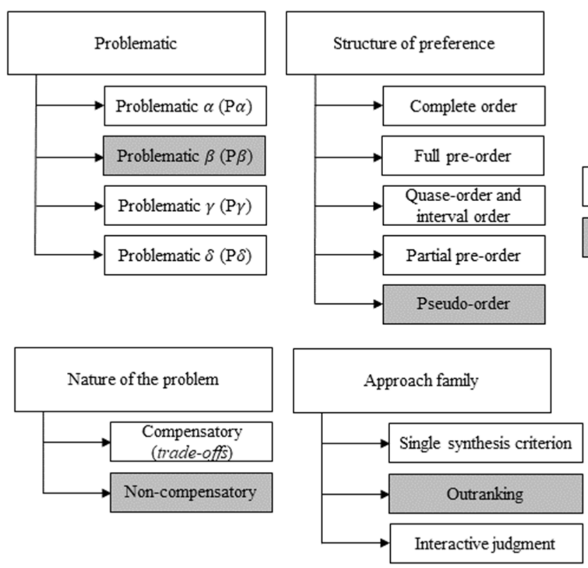
The French school is essentially divided into two groups: Promethee and the Electre family. Multicriteria methods exist with the aim of clarifying a problem related to the classification, ordering or selection of alternatives (ROY, 1991). In this research, it was defined that the model used would be the classification model.

In order to choose the methodology to be used in the problem of classifying the demand forecast for new products in the Brazilian franchise system, it was defined that it should be non-compensatory, as it does not present compensation between the evaluation criteria. So, the Electre and Promethee methods proved to be adequate for the problem.

Next, highlighted in Figure 1, the characteristics of multi-criteria decision support adopted in this work are presented, in order to justify the choice of multi-criteria based on this research problem.

FIGURE 1

Characteristics of multi-criteria decision support adopted in this work



Source: Elaborated by the authors.

The problem addressed was framed in the type β (Pβ), problem, in which alternatives that seem good must be accepted and those that seem bad must be discarded, that is, a classification of alternatives must be performed. Below are some preconditions for the Electre TRI method.

In this specific case, a preference structure is considered based on overclassification models that are characterized by not presenting compensation between the evaluation criteria. The Electre TRI method is suitable for this problem, being also compatible with the scale of the considered criteria (ordinal scale), in addition to meeting the classification problem.

Thus, the methods that present a classification as a result proved to be more adequate to the problem. Among them, Electre TRI was used. Among the various versions developed so far, Electre TRI aims to address problems that are intended to be designated as a set of pre-established category alternatives, configured based on multiple criteria and on comparing the alternative with the limits of each category.

ELECTRE TRI METHOD

Once the reference alternatives $\{a_1, a_2, ..., a_n\}$ and the criteria $\{c_1, c_2, ..., c_n\}$, are known, the categories $\{k_1, k_2, ..., k_n\}$ are defined. For a given criterion c, alternative a will be located in a certain category k, depending on its evaluation $T_i(a)$ (MOUSSEAU, SLOWINSKI and ZIELNIEWICZ, 2000).

Electre TRI is the most used multicriteria decision support method in classification problems. The procedure for assigning the performance of a generic alternative results from the comparison of this performance with the standard values that define the upper bounds and lower bounds of the categories, according to Mousseau, Slowinski and Zielniewicz (2000).

According to Gomes, Araya and Carignano (2004), the criteria considered in the Electre TRI establish a relationship of overcoming an alternative a, to be located in each of the references. According to Roy (1991), the preconditions to be observed to establish the method are:

- If the alternatives performance table is built;
- If, for each reference alternative a_{ni}, the indifference limits q_i (a_i), preferably p_i (a_i) and veto v_i (a_i) are known for each criterion i;
- If the criteria weights are defined, for each reference alternative, as $w = (w_1, w_2, ..., w_n)$, where $w_i > 0, \forall i$;
- If, for the aggregation procedure, a real value must be set, situated in the range of 0.5 and 1, called the cut-off level.

For Gomes, Araya and Carignano (2004), the cut-off level, denoted by λ, is the lowest value of the degree of credibility, denoted by σ_s (a, b), which allows us to state that "a surpasses b".

As presented by Figueira, Greco and Ehrgott (2005), based on the concordance indices for each criterion, the global concordance indexes $G(a, b)$ and $G(b, a)$, are calculated, indicating "a surpasses b" for $G(a, b)$ and "b outperforms a" for $G(b, a)$. And, based on the discordance indices of each criterion, the global discordance values $H(a, b)$ and $H(b, a)$ are calculated.

In order for the method to establish an overcoming relationship between an alternative a and a reference b, the following indices must be calculated: of agreement by criterion $c_i(a, b)$ and $c_i(b, a)$, of global agreement $G(a, b)$ and $G(b, a)$, of disagreement by criterion $h_i(a, b)$ and $h_i(b, a)$, of global disagreement $H(a, b)$ and $H(b, a)$, as well as of credibility σ_s (a, b) (ROY, 1991).

For Roy (1991), all these indices make it possible to verify to what extent alternative a outperforms reference b. Similarly, the credibility index σ_s (a, b) allows us to assess how the reference alternative b outperforms a.

According to Figueira, Greco and Ehrgott (2005), to calculate the agreement indices $g_i(a, b)$, $g_i(b, a)$, $G(a, b)$ and $G(b, a)$, the following should be considered: $c_i(a, b)$ = agreement index under criterion i of the proposition "a is as good as b"; $c_i(b, a)$ = agreement index under criterion i of the proposition "b is as good as a"; $G(a, b)$ = global agreement index of the proposition "a is as good as b"; $G(b, a)$ = global agreement index of the proposition "b is as good as a"; p_i = preference threshold defined for criterion i; q_i = indifference threshold defined for criterion i; and t_i = evaluation function of criterion i.

The calculation of $g_i(a, b)$ is performed as follows:

a) If $t_i(a) \leq t_i(b) - p_i$, then $c_i(a, b) = 0$.
b) If $t_i(a) > t_i(b) - q_i$, then $c_i(a, b) = 1$.
c) If $t_i(b) - p_i < t_i(a) \leq, t_i(b) - q_i$ then $0 < g_i(a, b) \leq 1$.

In the formulas above, $g_i(a, b)$ is obtained through linear interpolation, according to equation (3):

$$g_i(a,b) = \frac{p_i - [t_i(a) - t_i(b)]}{p_i - q_i} \quad (3)$$

For Figueira, Greco and Ehrgott (2005), the same procedure should be used to calculate $g_i(b, a)$. The global agreement indices $G(a, b)$ and $G(b, a)$ are obtained by equation (4), where w_i is the weight of criterion i:

$$G(a,b) = \frac{\sum_{i=1}^{n} w_i c_i(a,b)}{\sum_{i=1}^{n} w_i} \quad (4)$$

For Roy (1991), when calculating the discordance indices $h_i(a, b)$, $h_i(b, a)$, $H(a, b)$ and $H(b, a)$, one should consider: $h_i(a, b)$ = discordance index under criterion i of the proposition "*a* is as good as *b*"; $h_i(b, a)$ = discordance index under criterion i of the proposition "*b* is as good as *a*"; and v_i = veto threshold defined for criterion i.

The calculation of $h_i(a, b)$ is performed as follows:

a) If $t_i(a) > t_i(b) - p_i$, then $h_i(a, b) = 0$.
b) If $t_i(a) < t_i(b) - v_i$, then $h_i(a, b) = 1$.
c) If $t_i(b) - v_i < t_i(a) \leq, t_i(b) - p_i$ then $0 < h_i(a, b) \leq 1$, on what $h_i(a, b)$ is obtained through linear interpolation, according to equation (5):

$$h_i(a,b) = \frac{[t_i(b) - t_i(a)] - p_i}{v_i - p_i} \quad (5)$$

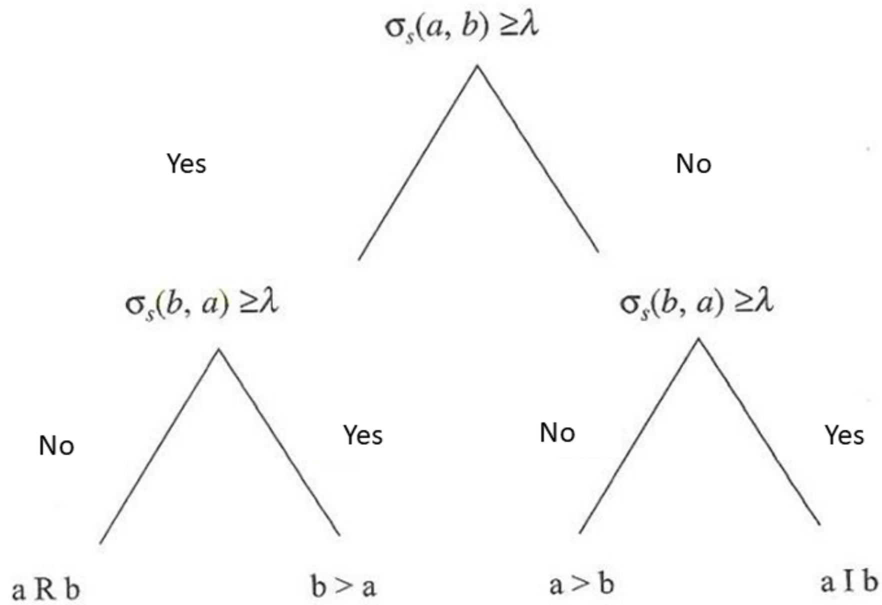
According to Roy (1991), to show how alternative *a* surpasses reference *b*, considering the agreement indices $g_i(a, b)$ and disagreement $h_i(a, b)$, the credibility index is determined, represented by $\sigma_s(a, b)$. On the occasion of the set of criteria whose index $h_i(a, b)$ exceeds $g_i(a, b)$, the credibility index $\sigma_s(a, b)$ will be obtained according to equation (6):

$$\sigma_s\,(a,b) = c_i(a,b).\pi \left[\frac{1 - h_i(a,b)}{1 - g_i(a,b)}\right] \quad (6)$$

After defining the credibility index, the cut-off level must be included, which, according to Figueira, Greco and Ehrgott (2005), is the lowest value that the credibility index can assume to affirm that *aSb*. Its preference relationship will be obtained through comparison, in which the assumed value must be between 0.5 and 1. In Figure 2, one can observe the procedures carried out in the overcoming relationship between the alternatives *a* and reference *b*, based on in the credibility indices $\sigma_s(a, b)$ and $\sigma_s(b, a)$ and in the cut-off level (λ) considered.

FIGURE 2

Relationship between *a* and *b* from σ_s (*a*, *b*) and σ_s (*b*, *a*)



Source: Gomes, Araya and Carignano (2004).

The procedure for calculating σ_s (*a*, *b*) and σ_s (*b*, *a*) must be repeated for each reference alternative. The number of preference relations between *a* and *b* corresponds to the number of reference alternatives in the set *A*. Next, we must proceed to the procedure for allocating the alternative a_n in one of the predefined categories k_n. The presentation of the elements of sets *A* (of the alternatives), *K* (of the criteria) and *C* (of the categories) can be found in the Electre TRI application section.

METHODOLOGY

For the classification of this research, Gil (2008) was used. Box 7 presents, in general, this research classifications. The characteristics adopted in this work, in each classification of this research, are highlighted.

BOX 7

Research classifications adopted in this work

Search classification	Characteristics adopted in this work		
Object	Bibliographic	Laboratory	Field
Nature	Basic		Applied

Continue

Search classification	Characteristics adopted in this work		
Problem approach	Quantitative		Qualitative
Objective	Exploratory	Descriptive	Explanatory
Technical procedure	Bibliographic	Documentary	*Ex-post-facto*
	Participant	Case study	Action research
	Experimental	Survey	

Source: Elaborated by the authors based on Gil (2008).

Among the delimitations, the model was developed for the franchise segments: bars, restaurants, bakeries, and pizzerias; cosmetics and perfumery; bookstore, graphics, and signage, in which the questionnaires were returned in sufficient numbers for treatment and statistical analyses, that is, data were collected through a research questionnaire.

In each franchise segment, the number of participants was 15, 11 and 13, respectively. That is, an individual decision of each franchisor can be considered, which, when entering data and information in the model, became a result of a group decision, taking characteristics and peculiarities of each market segment.

In this research, it is worth noting that the analyst is the author of this work and that the decision makers are the brands of the franchises that responded to the survey questionnaire. That is, decision-makers are responsible for franchises (franchisees), not franchisees (units). This set of people (franchisors) will be responsible for the data that was collected and, later, used by the analyst to model the problem.

When sending the questionnaire link to the franchisors, it was suggested, according to the topics covered, that it be answered preferably by the Production Planning and Control Department (an acronym in Portuguese PCP), or by this Research and Development Department (an acronym in Portuguese P&D). It was highlighted in the contacts that the questionnaire should be sent to those responsible for forecasting demand and/or developing new products.

APPLICATION OF ELECTRE TRI

For the application of Electre TRI in the classification of demand forecast for new products in the Brazilian franchise system, as the Iris 2.0 software was used, *k* was used to present the criteria and for the categories, thanks to the particularities of the software, which uses the fixed for the categories, allowing you to edit only the criteria.

DEFINITION OF ALTERNATIVES

The set of alternatives was named $A = \{a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}\}$,, consisting of eleven demand forecasting methods. Box 8 presents the set of alternatives.

BOX 8

Alternatives for application in Electre TRI

Demand forecasting methods		Alternatives (*A*)
Qualitative	Market research	a_1
	Delphi method	a_2
	Historical analogy	a_3
	Scenario simulation	a_4
	Sales team research	a_5
Quantitative (Projection)	Moving average	a_6
	Exponential smoothing	a_7
	Box Jenkins (Arima)	a_8
Quantitative (correlation)	Regression analysis	a_9
	Econometric models	a_{10}
	Subjective bootstrapping	a_{11}

Source: Elaborated by the authors.

In this research, not all demand forecasting methods available in the literature were used. We sought to select the most used in the studies of Chambers, Mullick and Smith (1971), Georgoff and Murdick (1986), Yokum and Armstrong (1995), Armstrong (2001), Kahn (2002), Armstrong and Fildes (2006), most cited in the literature.

DEFINITION OF CRITERIA

The six criteria used in this research for the selection of each demand forecasting method are denoted by the set $K = \{k_1, k_2, k_3, k_4, k_5, k_6\}$ and presented in Box 9. They were identified in this research questionnaire.

BOX 9

Criteria selected for application in Electre TRI

Criteria (K)	
k_1	Prediction degree of accuracy
k_2	planning horizon
k_3	Costs for implementing and maintaining the method
k_4	Need for consistent historical data
k_5	Need for computing resources (softwares)
k_6	Knowledge of math resources and experience

Source: Elaborated by the authors.

After defining the criteria used in this research, it is necessary to establish the items evaluated in each of them, as shown in Box 10.

BOX 10

Items evaluated in the criteria

Criteria (K)	Items evaluated in the criteria
k_1	Not very accurate (reasonable)
	Accurate (good)
	Very accurate (excellent)
k_2	Long term (over 2 years)
	Medium term (up to 2 years)
	Short term (up to 3 months)
k_3	Method input data is not available
	Quantitative method
	Used sporadically (occasionally)
	Qualitative method
	Used with frequencies
	Method input data is available
k_4	Data from similar situations are used
	Past historical data are used
	Data from analogous situations and past historical data are used
k_5	Do not use
	Electronic spreadsheets
	Generic-use statistical computing packages
	Specific computational packages for demand forecasting

Continue

Criteria (K)	Items evaluated in the criteria
k_6	Decision makers with no calculation skills and/or no experience in demand forecasting
	Decision makers with calculation skills
	Decision makers with experience in demand forecasting
	Decision makers with calculation skills and experience

Source: Elaborated by the authors.

These criteria judgment items were identified in the survey questionnaire.

DEFINITION OF CRITERIA WEIGHTS

The weights assigned to the criteria were defined based on the collection of data with the decision makers, which corresponds to the respondents to the questionnaire of the franchisors included in the analysis of the three segments of operation of the franchises. In equation (7), the calculation of the normalized weight is shown, where P_n = normalized weight and P_a = assigned weight.

$$P_n = \frac{P_a}{\sum Pa} \tag{7}$$

Box 11 shows the weights assigned by decision-makers to each criterion. As the proposal is to classify the demand forecasting methods for new products in three distinct segments of operation of the franchises, all the criteria were considered by the decision makers in their analyses, differentiating the weights of the criteria in each segment. A simple arithmetic mean was used to quantify the weights of the criteria, as it was not considered just one decision-maker, but a set of decision-makers – consensus among those involved in the analysis process –, in order to ensure that the weights assigned reflect the context of this research.

BOX 11

Criteria weights assigned by decision makers

Criteria (k_j)	Segments	
	Bars, restaurants, bakeries, and pizzerias	
	Assigned weight	Normalized weight
k_1	3	0.13
k_2	4	0.17
k_3	4	0.17
k_4	5	0.23
k_5	4	0.17
k_6	3	0.13
Total		**1**

Continue

Criteria (k_j)	Cosmetics and perfumery	
	Assigned weight	Normalized weight
k_1	3	0.13
k_2	5	0.21
k_3	3	0.13
k_4	4	0.17
k_5	4	0.17
k_6	5	0.21
Total		**1**
Criteria (k_j)	**Bookstore, graphics, and signage**	
	Assigned weight	**Normalized weight**
k_1	4	0.17
k_2	3	0.13
k_3	3	0.13
k_4	5	0.21
k_5	5	0.21
k_6	4	0.17
Total		**1**

Source: Elaborated by the authors.

DEFINITION OF CATEGORIES

After identifying the criteria and assigning their respective weights, the categories that provided an action recommendation for the analyst of this research were identified. Three categories were established, denoted by the set $C = \{c_1, c_2, c_3\}$,, as shown in Box 12, with category c_1 representing unfavorable results and c_3 representing favorable results.

BOX 12

Categories established for application in Electre TRI

Categories (C)	
c_1	Not recommended
c_2	Little recommended
c_3	Recommended

Source: Elaborated by the authors.

With the objective of improving the demand forecast for new products in the Brazilian franchise system, the analyst chose to use these three categories in the analysis, because, within c_3 (*recommended*), decision makers will have options for methods and forecasting demand that best match a given category of new products. Furthermore, categories c_3 and c_2 will allow the combination of methods for forecasting demand, which can lead to more accurate forecasts than using a single method, improving forecast accuracy, since with different techniques, one can add useful information, as opposed to a single template. That is, it can be said that companies use these techniques to make their predictions, in order to obtain more accurate results (OLIVEIRA, FUTAMI and OLIVEIRA, 2016). According to Guimarães and Lange (2020), the combination of methods for forecasting demand for new products can lead to greater accuracy when estimating the demand for sales of a given product and/or service.

For the Electre TRI method, the Interactive Robustness analysis and parameters' Inference for multicriteria Sorting problems (Iris) software, version 2.0 demo – available for testing and development of academic papers, presented by Dias and Mousseau (2002) was used. Iris 2.0 was responsible for helping the analyst to represent the preferences of decision makers (franchisers).

IRIS 2.0 AND ITS INTERFACE

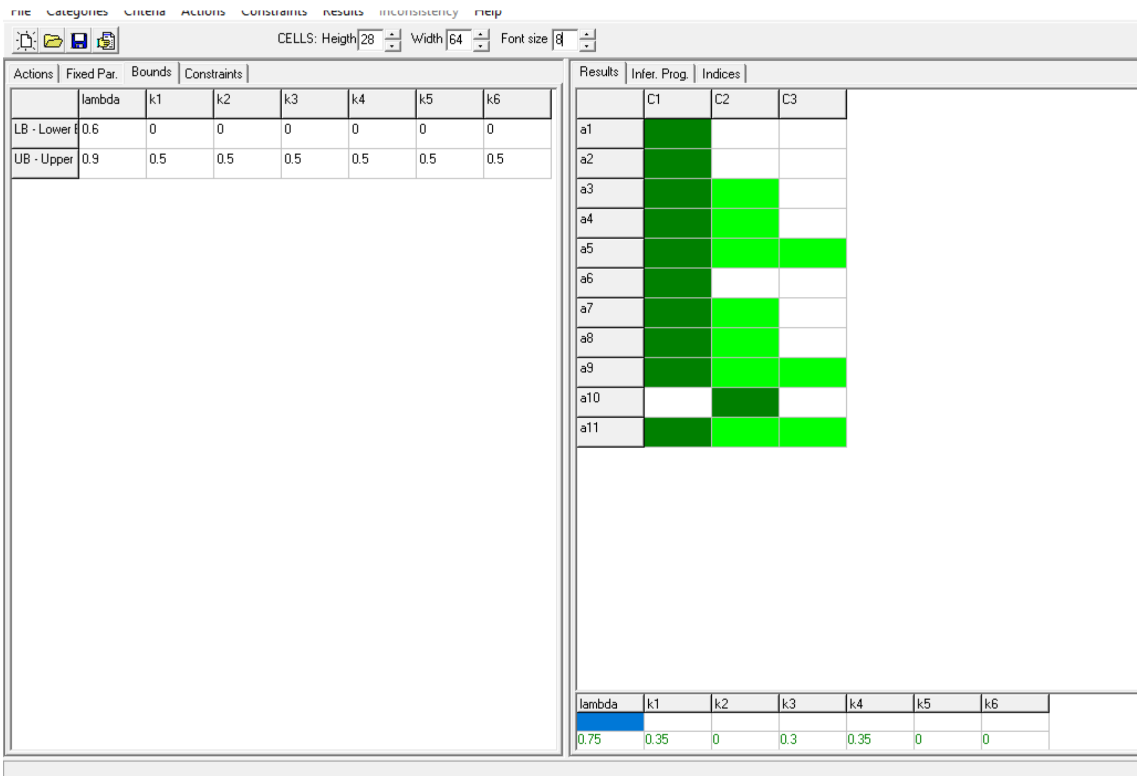
According to Dias and Mousseau (2002), Iris 2.0 was designed for the problem of multicriteria ordinal classification in which there is a set of actions – in this case, the alternatives – described by their performance in multiple evaluation criteria – the degree of precision of the forecast, the planning horizon, the costs for the implementation and maintenance of the method, the need for consistent historical data, the knowledge of mathematical resources and the need for computational resources –, according to a set of predefined categories – those of not recommended methods, little recommended and recommended.

Iris 2.0 is based on Electre TRI, but does not require the decision maker to set values for all parameters. The software seeks to obtain some restrictions that such parameters must respect. If the ones indicated by the decision maker are not incompatible with each other, he will infer a set of values for the parameters, capable of reproducing all the examples, indicating the range of possible classifications given the indicated restrictions. If the constraints are incompatible, Iris 2.0 suggests values for the parameters that minimize an error measure and allows the identification of constraints that, when removed, lead to a constraint system with a solution (DIAS and MOUSSEAU, 2002).

The left part of the window is associated with the inputs, while the right part is used for the outputs, and the decision maker can move the line that divides these areas. Each window is organized according to the organizer, with multiple pages, as can be seen in Figure 3.

FIGURE 3

Iris 2.0 interface and sorting example



Source: Elaborated by the authors.

The left area allows editing inputs, such as actions performances; value of the fixed parameters, which are the limits of the categories and those of indifference of preference, disagreement and veto (fixed par.); upper and lower limits (bounds); and additional restrictions on those variables (constraints). The results only reflect changes in the inputs after the decision maker tells Iris 2.0 to recalculate them.

The right area allows viewing results (outputs) such as ranges of categories, inferred classification and inferred values for parameters (results); linear program for parameter inference (infer. prog.); and geometric mean of possible categories per share (indices).

The software allows the visualization of the results of the Electre TRI method through the classification of alternatives. Based on the indicators defined by the decision maker, the application results are shown in color, in order to define the proposed result. Dark green indicates the Electre TRI proposed in a certain category, while light green indicates a possible reallocation of the alternative in another category.

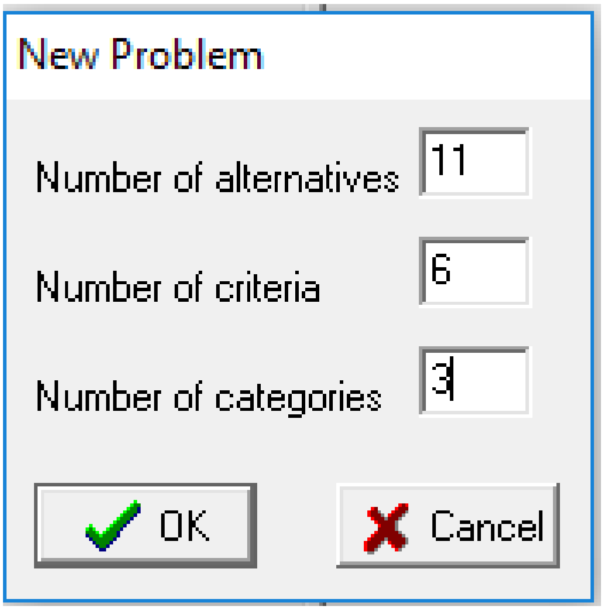
The applications already published involving Iris 2.0 and that will help in this research are: Neves et al. (2008); Queiroz (2011); Covas, Silva and Dias (2013); Chakhar and Saad (2014). In the following section, it is presented how the execution of Electre TRI happened in the proposed problem.

EXECUTION OF ELECTRE TRI IN IRIS 2.0

For the execution of the Electre TRI classification algorithm, initially, numbers of alternatives (A = 11), criteria (K = 6) and categories (C = 3) were entered as input, as shown in Figure 4.

FIGURE 4

Entry of alternatives, criteria and categories



Source: Elaborated by the authors.

Based on the survey responses, alternative evaluation matrices were constructed for each criterion of the three analyzed segments, which inform the decision-makers' evaluation and illustrate the performance of each alternative against the decision criteria. These data, after tabulation, served as input for the application of the Electre TRI method in IRIS 2.0. The treatment of the answers - relationship between alternatives, criteria and evaluated items - was carried out with the objective of building each of the evaluation matrices presented in Figure 5.

FIGURE 5

Evaluation matrices of the three analyzed segments

IRIS 2.0 - C:\Users\guilh\Desktop\DISSERTAÇÃO FINAL\BARES, RESTAURANTES, PADARIAS E PIZZARIAS

File Categories Criteria Actions Constraints Results Inconsistency Help

CELLS: Heigth 28 Width 64 Font size 8

Actions | Fixed Par. | Bounds | Constraints

Action	ELow	EHigh	k1	k2	k3	k4	k5	k6
a1	1	3	3	2	5	5	2	4
a2	1	3	2	1	3	2	2	1
a3	1	3	3	4	4	5	3	4
a4	1	3	5	5	5	5	5	4
a5	1	3	3	4	3	3	5	3
a6	1	3	1	4	4	1	2	2
a7	1	3	2	3	3	3	1	2
a8	1	3	5	4	5	5	5	3
a9	1	3	3	5	4	5	2	3
a10	1	3	1	1	1	1	1	1
a11	1	3	1	2	1	1	1	3

IRIS 2.0 - C:\Users\guilh\Desktop\DISSERTAÇÃO FINAL\BARES, RESTAURANTES, PADARIAS E PIZZARIAS

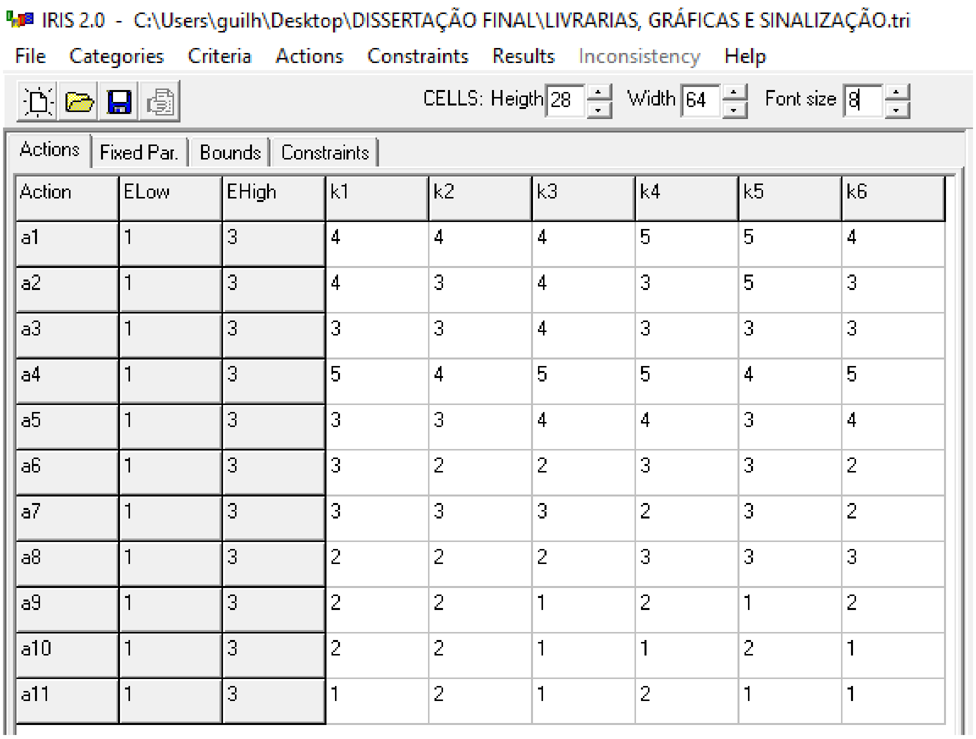
File Categories Criteria Actions Constraints Results Inconsistency Help

CELLS: Heigth 28 Width 64 Font size 8

Actions | Fixed Par. | Bounds | Constraints

Action	ELow	EHigh	k1	k2	k3	k4	k5	k6
a1	1	3	3	2	5	5	2	4
a2	1	3	2	1	3	2	2	1
a3	1	3	3	4	4	5	3	4
a4	1	3	5	5	5	5	5	4
a5	1	3	3	4	3	3	5	3
a6	1	3	1	4	4	1	2	2
a7	1	3	2	3	3	3	1	2
a8	1	3	5	4	5	5	5	3
a9	1	3	3	5	4	5	2	3
a10	1	3	1	1	1	1	1	1
a11	1	3	1	2	1	1	1	3

Continue



Action	ELow	EHigh	k1	k2	k3	k4	k5	k6
a1	1	3	4	4	4	5	5	4
a2	1	3	4	3	4	3	5	3
a3	1	3	3	3	4	3	3	3
a4	1	3	5	4	5	5	4	5
a5	1	3	3	3	4	4	3	4
a6	1	3	3	2	2	3	3	2
a7	1	3	3	3	3	2	3	2
a8	1	3	2	2	2	3	3	3
a9	1	3	2	2	1	2	1	2
a10	1	3	2	2	1	1	2	1
a11	1	3	1	2	1	2	1	1

Source: Elaborated by the authors.

After standardizing the evaluation matrices, it was necessary to establish reference boundaries between each of the established categories. Such boundaries represent the categories that the analyst and decision makers consider necessary for the distribution of alternatives and were represented by $\{b\}$.

Faced with the categories, the decision analyst sought to raise, together with the decision makers, the profiles that represented, for them, alternatives whose performance distinguished two consecutive categories. Box 13 shows the two reference boundaries (b_1 and b_2) that divide the three categories.

BOX 13

Boundaries of the boundaries of the criteria's reference categories

Categories (C)	Reference borders $\{b\}$	Border values in each criterion (K)					
		k_1	k_2	k_3	k_4	k_5	k_6
$c_1 - c_2$	b_1	1	2	2.5	2	1.5	2.5
$c_2 - c_3$	b_2	2	3	3.5	3	2.5	3.5

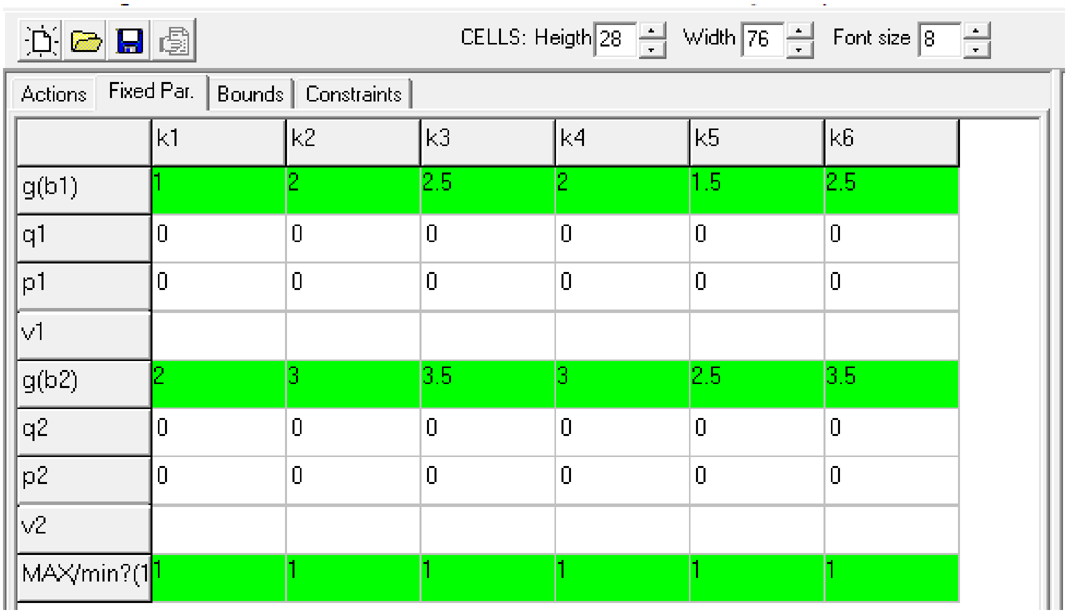
Source: Elaborated by the authors.

The limits between the categories is a necessary definition so that the alternatives can be framed without any doubt. The insertion of these values in Iris 2.0 is illustrated in Figure 6.

The thresholds of indifference (q), preference (p) and veto (v) were considered equal to zero, assuming true criteria for this context. This determination was considered due to the difficulty found by decision-makers in quantifying their preferences and qualitatively understanding the assessment of the categories. The entry of these values in Iris 2.0 is also found in Figure 6.

FIGURE 6

Limit profiles and thresholds of indifference, preference and veto



	k1	k2	k3	k4	k5	k6
g(b1)	1	2	2.5	2	1.5	2.5
q1	0	0	0	0	0	0
p1	0	0	0	0	0	0
v1						
g(b2)	2	3	3.5	3	2.5	3.5
q2	0	0	0	0	0	0
p2	0	0	0	0	0	0
v2						
MAX/min?(1	1	1	1	1	1	1

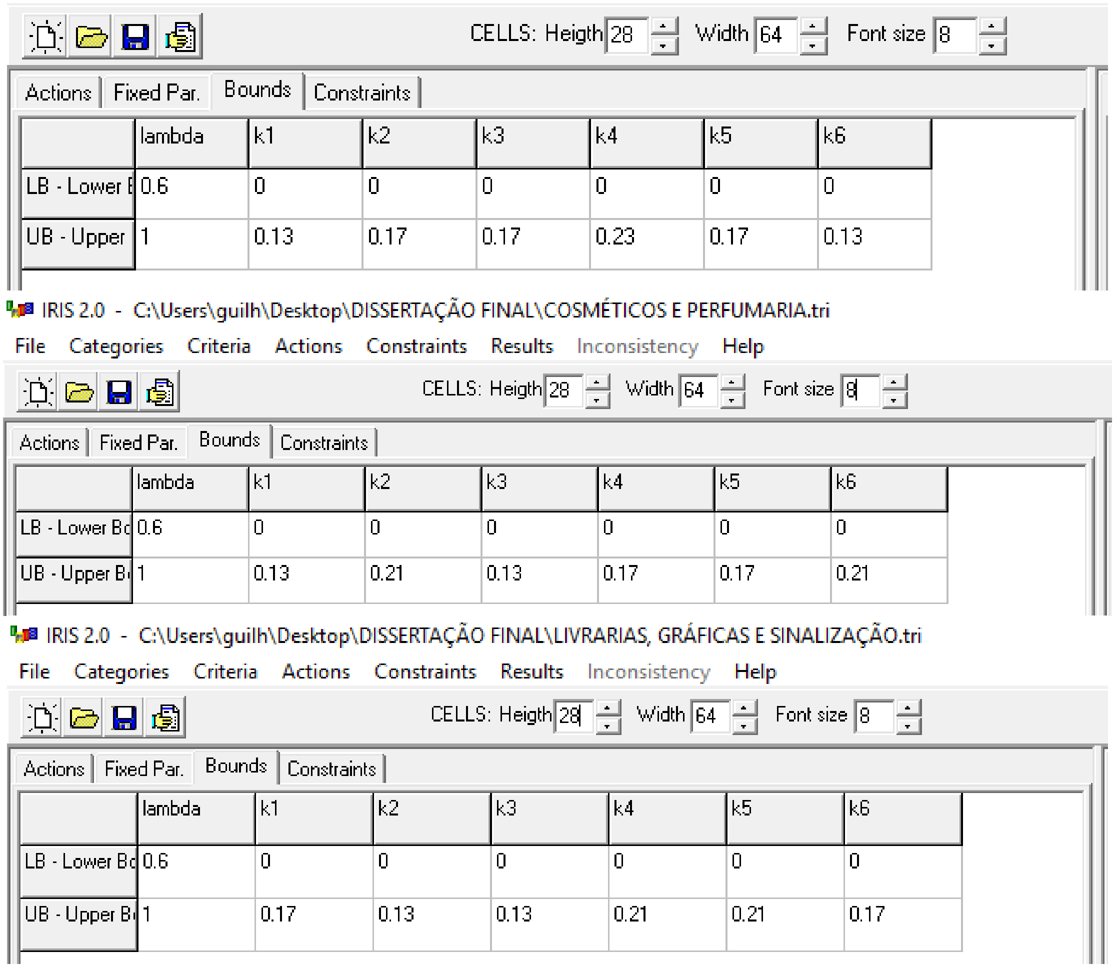
Source: Elaborated by the authors.

In the modeling, the veto limit was not used, since Electre TRI has a tendency to allocate an alternative in a lower category, and, in most criteria, the higher the performance of an alternative, the more critical its evaluation and allocation will be. in a certain category. Thus, vetoing the insertion of this alternative in a higher category could interfere with the final result of this research, allocating a demand forecasting method in a category of lower recommendation.

Iris 2.0 allows the criteria and the cut-off level to take on varying values within a range defined by the decision maker. Thus, the parameters were adjusted to best respond to the decision maker's preferences. The thresholds for the criteria were determined taking into account the degree of importance that each criterion exerts on the problem. Inserting these values into the software is illustrated in Figure 7.

FIGURE 7

Criteria weights of the three analyzed segments



	lambda	k1	k2	k3	k4	k5	k6
LB - Lower B	0.6	0	0	0	0	0	0
UB - Upper	1	0.13	0.17	0.17	0.23	0.17	0.13

	lambda	k1	k2	k3	k4	k5	k6
LB - Lower Bo	0.6	0	0	0	0	0	0
UB - Upper B	1	0.13	0.21	0.13	0.17	0.17	0.21

	lambda	k1	k2	k3	k4	k5	k6
LB - Lower Bo	0.6	0	0	0	0	0	0
UB - Upper B	1	0.17	0.13	0.13	0.21	0.21	0.17

Source: Elaborated by the authors.

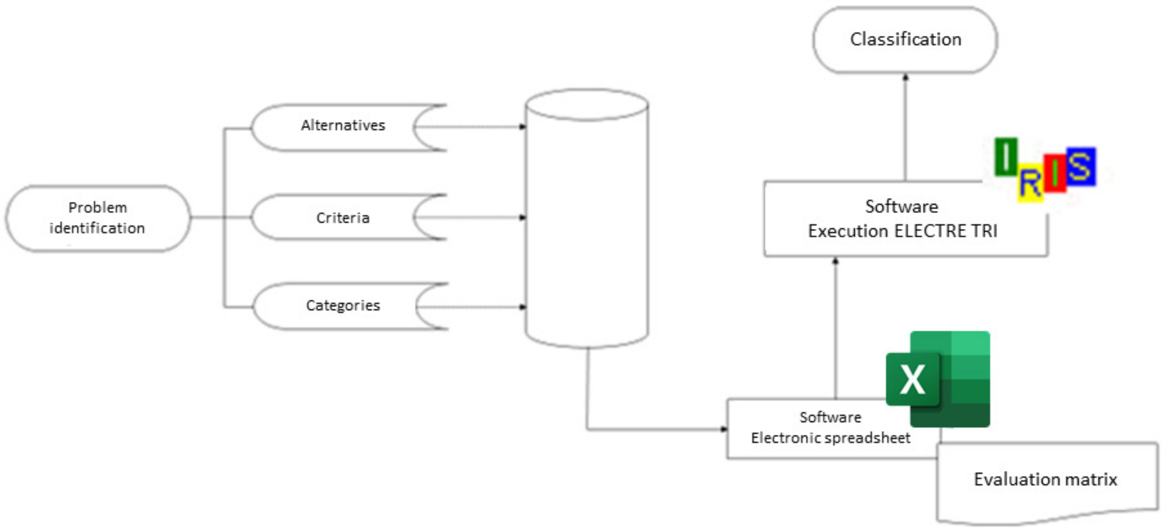
An analysis was performed to check the model's sensitivity regarding the credibility index (λ). This index refers to the minimum value of $\sigma_s(a, b)$ necessary to validate the overranking relationship between alternatives. For the modeling of the method, $\lambda = 0.6$ was assumed and the sensitivity analysis was performed for the level of credibility, adopting $\lambda = 0.7$, $\lambda = 0.8$ and $\lambda = 0.9$ because, as already quoted, the assumed value of λ must be between 0.5 and 1.

The second sensitivity analysis performed refers to the weights of the criteria. For this, all criteria were analyzed, giving the same weight, and a variation was made in the weights of the criteria, in order to verify how many percent of the criteria can be changed without impacting the classification of alternatives.

Both sensitivity analyzes were done in Iris 2.0, so the variations in the ranking of alternatives in each analysis are briefly discussed in the next section. Figure 8 shows a representation of the execution of Electre TRI in Iris 2.0.

FIGURE 8

Representation of the execution of Electre TRI in Iris 2.0



Source: Elaborated by the authors.

Multi-criteria decision support, specifically Electre TRI in Iris 2.0, promoted an objective analysis and helped decision-makers with the responsibility of making difficult and complex decisions, such as those involved in this research.

Finally, it can be said that, for the segment of bars, restaurants, bakeries, and pizzerias, in the class of 'adition to existing product lines,' the results show that the methods of market research, historical analogy, scenario simulation, research of the sales force, Box-Jenkins (Arima) and regression analysis fell into the category of recommended methods.

In the cosmetics and perfumery segment, in the class of 'adition to existing product lines,' the results show that the market research and Delphi, historical analogy, sales team research, moving average and Box-Jenkins (Arima) methods fit into the category of recommended methods.

The segment of bookstore, graphics, and signage, in the class of 'new-to-the-firm products,' show that the methods of market research and Delphi, historical analogy, simulation of scenarios and research of the sales team fit into the category of recommended methods.

FINAL CONSIDERATIONS

The proposal for classifying demand forecasting methods for new products in predefined categories appears to be applicable and consistent, respecting criteria and delimitations presented throughout the work.

Thus, by adding a multi-criteria decision support approach to the evaluation of demand forecasting methods for new products and/or new services, with Electre TRI resources, it was possible to assign each of the demand forecasting methods to a category.

Electre TRI was instrumental in classifying demand forecasting methods, under the focus of several criteria, aiming to present them in the class of new products and in the different segments of the franchises to support those responsible for these forecasts within the organizations.

The implementation of Electre TRI in this research is based on the use of Iris 2.0, which was fundamental for the development of the study, since the tool helped in the analysis of preferences of decision makers – in this case, the franchisors. This research contributed to the scientific community, as there are few published works involving Electre TRI applied to Iris 2.0.

As suggestions for future work, the following aspects and opportunities were identified: to develop the classification of demand forecasting methods for new products in the other segments of operation of franchises that were not covered in this research, as well as to use a method of multicriteria support to the decision to identify, select, order or classify the criteria used to expand franchising units, such as analysis of the commercial location and target audience.

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NOTE

This research in its entirety can be found in the Institutional Repository of the Federal Technological University of Paraná (UTFPR). Available at: <http://repositorio.utfpr.edu.br/jspui/handle/1/2299>.

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GUILHERME FERNANDO RIBEIRO
ORCID: https://orcid.org/0000-0002-2714-4560
Ph.D. candidate in Production Engineering at the Federal Technological University of Paraná (UTFPR).
E-mail: ribeiro.guilherme91@gmail.com

PRISCILLA BASSETTO
ORCID: https://orcid.org/0000-0002-9316-2337
Master's student in Production Engineering at the Federal Technological University of Paraná (UTFPR).
E-mail: pri_bass@hotmail.com

RONY PETERSON DA ROCHA
ORCID: https://orcid.org/0000-0001-6682-8407
Post-Doctor in Mechanical Engineering; Professor at the Department of Agroindustrial Production Engineering at the State University of Paraná (UNESPAR). E-mail: ronypeterson_eng@hotmail.com

YSLENE ROCHA KACHBA
ORCID: https://orcid.org/0000-0002-8320-4783
Ph.D. in Production Engineering; Professor at the Production Engineering Department at the Federal Technological University of Paraná (UTFPR). E-mail: yslener@utfpr.edu.br

ALDO BRAGHINI JUNIOR
ORCID: https://orcid.org/0000-0001-9388-3073
Post-Doctor in Engineering; Professor at the Department of Production Engineering at the Federal Technological University of Paraná (UTFPR). E-mail: aldo@utfpr.edu.br