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Contaduría y Administración

Accounting & Management

Contaduría y Administración 68 (3), 2023, 1-20

Assessment of business intelligence platforms using a multicriteria hierarchy process

Evaluación de plataformas de inteligencia de negocios con un proceso multicriterio jerárquico

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Received March 9, 2022; accepted April 3, 2023
Available online August 23, 2024

Abstract

The article presents the evaluation of business intelligent platforms as a multicriteria decision-making problem to support an expert working in a company with multiple services. The present work focuses on identifying the decision criteria and the business intelligent platforms (BIP). The study is focused on the evaluation of the business intelligent platforms through a multicriteria hierarchy process regarding the preferences of an expert in BIP working in the company. The outcomes of the research regard the formal methodological procedure for the selection of the BIP. Besides that, the generation of a ranking of BIP regarding the expert's preferences and the company's needs.

JEL Code: D81, D83, G41
Keywords: business intelligence platform, multicriteria decision analysis, multiple criteria hierarchy process, ELECTRE-III

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Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.22201/fca.24488410e.2023.4587

Resumen

Este artículo presenta la evaluación de plataformas de inteligencia de negocios cómo un problema de decisión multicriterio apoyando a un experto de una empresa de multiples servicios. El trabajo se centra en la identificación de los criterios de decisión y plataformas de inteligencia de negocios. El estudio se enfoca también, en la evaluación de plataformas de inteligencia de negocios con un enfoque multicriterio jerárquico considerando las preferencias del experto en plataformas de inteligencia de negocios que labora en la empresa. El resultado obtenido corresponde a la definición de un procedimiento metodológico para el problema de la evaluación de plataformas de inteligencia de negocios, y a una recomendación para la empresa en forma de ordenamiento de plataformas inteligencia de negocios identificadas. Este ordenamiento se genera considerando las preferencias del experto en relación a las plataformas.

Código JEL: D81, D83, G41
Palabras clave: plataformas de inteligencia de negocios; análisis multicriterio; proceso multicriterio jerárquico; ELECTRE-III

Introduction

Business intelligence’s main objective is to contribute to making decisions to improve a company’s performance and thus obtain a competitive advantage in the market. Business intelligence (BI) is the corporate ability to make decisions. This is derived from using methodologies, applications, and technologies to gather, clean, and transform data, and applying analytical techniques for knowledge extraction (Parr, 2000).

BI allows companies to combine and analyze data from various sources and obtain a complete and updated view to gain a competitive advantage. Consequently, business intelligence gathers, cleans, and transforms data from systems, converting unstructured information from internal and external sources into structured information for storage, analysis, and reports on the company’s performance and evolution.

BI plays an important role in decision making in companies since it enables the collection, storage, and processing of data generated by the company’s operations. Therefore, it is necessary to professionalize this activity and recognize the most important criteria that help in decision making.

From an operational point of view based on IT, BI can be defined as the set of methodologies, applications, and technologies that allow gathering, cleaning, and transforming data from a company’s transactional systems. This makes it possible to structure relevant information, which can be converted into knowledge to the extent that it is used for analysis and financial decision making. BI is a strategic factor for a company or organization, generating a competitive advantage that provides privileged information to respond to business problems (Azita, 2011).

Choosing a suitable BI platform for an organization should consider technological, financial, and quality points of view. These elements make it possible to generate a set of BI platforms (Gartner, 2019). Accordingly, Gartner shows the market situation of a technological product. On the one hand, it considers the supplier's innovation. On the other hand, it considers the ability in product development. Nonetheless, adequate procedures and analytical models are required to assess BI platforms that consider various important aspects of the company and the decision maker responsible for the selection.

A suitable approach for assessing a set of BI platforms can be carried out using a multicriteria analysis approach since it allows the objective and subjective characteristics of the platforms to be assessed with a coherent family of decision criteria. This approach also incorporates the preferences of the expert or decision maker into the decision model.

This approach has an advantage over other models that do not assess the preferences or experience of the expert since those decision models that do not assess the preferences of the decision maker and their value system are of limited practical use (Doumpos & Zopounidis, 2002). Rodriguez and Cortes (2012) assessed four BI platforms with the method known as AHP (Analytic Hierarchy Process) (Saaty T., 1980).

A set of BI platforms can be assessed as a platform ordering problem with a Multiple Criteria Hierarchy Process (MCHP) to analyze platform features by categories as criteria groups. The category analysis of BI platform features entails a hierarchical structure of criteria, similar to the MCHP approach proposed by Corrente, Greco, and Słowiński (2012).

The AHP method differs from the MCHP because the AHP method requires a comparison of criteria to propose global priorities of alternatives concerning the whole problem. Nevertheless, in the MCHP process, the hierarchy allows grouping criteria to find interactions between them and thus generate an ordering of alternatives in each node. In this regard, with the information available so far, there is no research on analyzing the interaction of criteria such as MCHP in the BI platform assessment.

This paper aims to identify the business intelligence platforms (BIPs) available in the market, characterize their relevant attributes for knowledge management, and analyze the BIPs with a hierarchical multicriteria approach, ordering them from the most preferred to the least preferred. The assessment and analysis of the BIPs is carried out as an outranking approach using the ELECTRE-III method (Roy, 1990) that considers the expert's preferences. This methodology considers the preferences of an expert working in the BI area of a Mexican department company. According to the Corporate Reputation Business Monitor, this company is second in its ranking of Companies in Ibero-America (Merco, 2020).

This paper is structured as follows. Section 2 presents a review of the literature related to business intelligence. The methodology for assessing business intelligence platforms (BIPs) is addressed in Section 3. Section 4 develops the characterization, assessment, and analysis of BIPs. Finally, Section 5 describes the conclusions.

Background

Integrating various tools makes it possible to handle the growing volume of data and the increasing complexity of decisions. The term defining this trend emerged in the mid-1990s and is known as Business Intelligence (BI).

In business, decision makers need access to accurate and timely information to achieve their objectives. Historically, BI has been used by analysts to process data using complex tools and spreadsheets. Today, decision making involves a wide range of business roles. Ballard et al. (2006) identify that the major BI vendors focus on providing complete suites, allowing decision makers to access source data in almost any environment.

BI has several interesting functions, including data storage, integration, analysis, query, and control (Schiff, 2010). Although these platforms have similar functionalities, they also have some differences. Each platform has its own strengths and weaknesses, so it is somewhat complex to adopt one or the other.

Rodríguez and Cortés (2012) use the AHP method, which improves the decision process due to the great deal of information it provides and the help it gives in understanding the problem. This generated a recommendation to select a suitable BI platform that fits the company and allows the implementation of the Management Information System.

For Negash (2004), BI is a set of methodologies, applications, and technologies that allow gathering, cleaning, and transforming data from transactional systems and unstructured information (internal and external to the company) into structured information for its direct exploitation or for its analysis and conversion into knowledge (Negash, 2004).

Jourdan, Rainer, and Marshall (2008) suggest that BI is both a process and a product. It is a process because it consists of methods companies use for the applicable development that will allow them to advance in a competitive and globalized world. It is also a product because it is information that will allow companies to predict the behavior of competitors, customers, suppliers, technology, markets, products, services, and the behavior of the business environment in general with greater accuracy.

Gameiro (2011) states that BI comprises a set of systems that combine the collection, acquisition, and storage of data from different sources with analytical tools, presenting them in the order and logical form of decision makers and generating a quick view of the business situation in the past, present, and future. Azma and Mostafapour (2012) define BI as a dynamic and complex process that discovers new knowledge and includes information analysis and decision support that directly affect the future performance of organizations.

http://dx.doi.org/10.22201/fca.24488410e.2023.4587

When considering the definition of various authors, it can be summarized that BI results from the close relation between methodologies and tools that allow the complete processing of data (capture, storage, treatment, and visualization) until its conversion into information. All this procedure is carried out to provide information to decision makers with the necessary analysis to know and study the past, control the present, and foresee the future of organizations.

Different studies have been conducted using the ELECTRE method from the multicriteria analysis methodology for decision making. López, Carrillo, and Valenzuela (2018) carried out the group decision-making procedure using ELECTRE-III. In the study, a group of decision makers assesses the technological packages of an agricultural company to select the most appropriate one. Alvarez, Morais, Leyva Lopez, and de Almeida (2020) applied the same method in a group decision process to prioritize municipal districts in constructing a water supply system. Commercial premises are assessed for a coffee franchise in a group decision process (Alvarez Carrillo & Leyva López, 2016).

The multicriteria hierarchy process has been implemented in different studies related to financial markets of the stock market, such as Alvarez, Bernal, and Muñoz (2020), Bernal et al. (2021), Munoz Palma et al. (2022), and Muñoz-Palma et al. (2023). Other studies on innovation and competitiveness have been developed by Alvarez, Valdez, and Dutta (2022) and Alvarez, Muñoz-Palma, Miranda-Espinoza, Lopez-Parra, and León-Castro (2020), respectively.

Methodology for assessing business intelligence platforms

Multicriteria decision-making process

Based on Simon's (1947) decision model, the decision-making process is structured in five stages. In the first stage, the problem is defined, and the actors or decision makers are identified as part of the decision-making process. In the second stage, the alternatives to be assessed are described and ordered. During the third stage, the criteria and the scale of assessment of each one concerning the alternatives are established. In the fourth stage, the alternatives are assessed with the data for each criterion and the decision maker's preferences using the model parameters. In stage five, the ordering of the BI platforms is generated. Figure 1 shows the process layout divided into the 5 stages mentioned above.

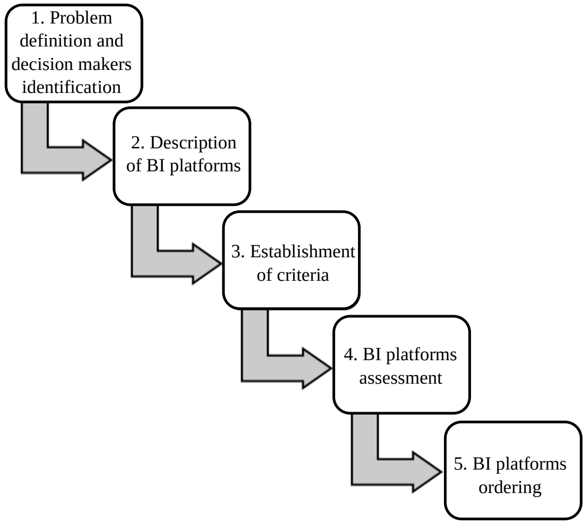

Figure 1. Methodological layout for assessing BI platforms
Source: created by the authors.

Multicriteria hierarchy process

Conventionally, in multicriteria decision-making problems, the decision criteria are considered at a single level, and thus, it is possible to assess (or compare) the decision alternatives. This is known as a flat level or a single level of assessment.

Analyzing a multicriteria problem in a hierarchical approach corresponds to separating the global problem into subproblems based on subsets of criteria. A subproblem is a macrocriterion containing a subset of criteria to assess that problem. If a criterion $g_{(r,1)}$ belonging to a higher criterion (macrocriterion, g_r) contains in turn subcriteria, then $g_{(r,1)}$ is also a macrocriterion. The criteria at the final level are known as elementary criteria. The meaning of the elementary criteria is that they are the sets of criteria used to assess the subproblems (macrocriteria) of the higher levels.

Macrocriteria, then, represent a part of the problem from one point of view, without considering the rest of the family of criteria defined for the main problem. Therefore, the problem can be broken down into smaller problems and analyzed in more detail.

The MCHP approach was introduced by Corrente, Greco, and Słowiński (2012). The basic idea of MCHP is based on considering preference relations at each node of the hierarchical tree of criteria. Corrente, Figueira, Greco, and Słowiński (2017) integrated the MCHP with the ELECTRE III method. The following notation based on Angilella et al. (2018) will be used to explain it.

http://dx.doi.org/10.22201/fca.24488410e.2023.4587

- G is the set of criteria at all levels considered in the hierarchy.
- G_0 is the root criterion.
- I_G is the set of indices of the criteria in G.
- $E_G \subseteq l_G$ is the set of elementary criteria indices.
- g_r is the generic non-root criterion (where r is a vector with a length equal to the level of the criterion).
- $g_{(r,1)}, \dots, g_{(r,n(r))}$ are the immediate subcriteria of the criterion g_r (located at the level below g_r).
- $E(g_r)$ is the set of indices of all elementary criteria descending from g_r.
- E(F) is the set of indices of the elementary criteria that descend from at least one criterion in the subfamily $F \subseteq G$ (i.e., $E(F) = U_{g_r \in F} E(g_r)$).
- G_r^I is the set of sub-criteria of g_r located at level l of the hierarchy (below g_r).
- L is the number of levels in the hierarchy, $l = 1, \dots, L$.

To better understand the above notation, Figure 2 represents the hierarchical structure where Level 1 contains the macrocriteria g_1, g_2 and g_3. The elementary criteria $g_{(1,1)}, g_{(1,2)}, g_{(1,3)}$ descending from g_1 are represented by $E(g_1)$, and are decomposing the subproblem g_1. In g_2, two elementary criteria $g_{(2,1)}$ and $g_{(2,2)}$ integrate the subproblem in g_2 and are represented by $E(g_2)$. And the elementary criteria of $E(g_3)$ are $g_{(3,1)}$ and $g_{(3,2)}$. The whole set of elementary criteria is contained in E_G. In a hierarchical structure, it is possible to obtain a different approach to the problem, focusing on specific parts or more complete information, and this is possible when a hierarchy is presented in the family of criteria.

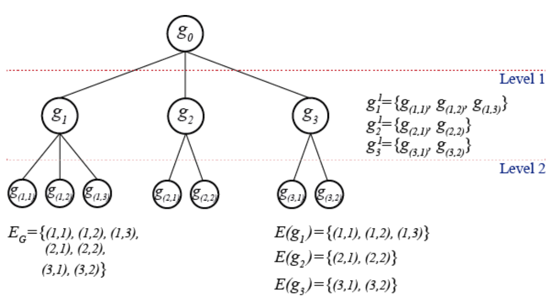

Figure 2. Problem structure in the multicriteria hierarchy process
Source: created by the authors.

The adapted version of the hierarchical ELECTRE III was first introduced by Corrente, Figueira, Greco, and Słowiński (2017) and systematized into the computational tool by Alvarez, Valdez, and Dutta (2022). For each elementary criterion g_t, $t \in E_g$.

1. Elementary concordance index for each elementary criterion g_t

$$c_t(a,b) = \begin{cases} 1, & \text{if} \quad g_t(b) - g_t(a) \leq q_t, (aS_tb) \\ \dfrac{p_t - \big(g_t(b) - g_t(a)\big)}{p_t - q_t} & \text{if} \quad q_t < g_t(b) - g_t(a) < p_t, (aQ_tb) \\ 0, & \text{if} \quad g_t(b) - g_t(a) \geq p_t, (bP_ta) \end{cases} \tag{1}$$

where q_t is the indifference threshold of the elementary criterion g_t, p_t is the preference threshold of the elementary criterion g_t, $g_t(a)$ is the performance value of alternative a in the elementary criterion g_t.

2. Elementary mismatch index for each elementary criterion g_t

$$d_t(a,b) = \begin{cases} 1, & \text{if} \quad g_t(b) - g_t(a) \geq v_t, \\ \dfrac{\big(g_t(b) - g_t(a)\big) - p_t}{v_t - p_t} & \text{if} \quad p_t < g_t(b) - g_t(a) < v_t, \\ 0, & \text{if} \quad g_t(b) - g_t(a) \leq p_t \end{cases} \tag{2}$$

where v_t is the veto threshold of the elementary criterion g_t.

3. Partial concordance index for each macrocriterion g_r

$$C_r(a,b) = \frac{\sum\limits_{t \in E(g_r)} w_t c_t(a,b)}{\sum\limits_{t \in E(g_r)} w_t} \tag{3}$$

where $E(g_r)$ is the set of indices of all elementary criteria descending from g_r, w_t is the importance value (weight) of elementary criterion g_t, $C_t(a, b)$ is the elementary matching index of criterion g_t, $\sum_{t \in E(g_r)} w_t$ corresponds to the sum of each weight w_t of elementary criterion g_t belonging to macrocriterion g_r.

4. Partial credibility index for each non-elementary criterion g_r

$$\sigma_r(a,b) = \begin{cases} C_r(a,b) \times \prod_{g_t \in E(g_r)} \frac{1 - d_t(a,b)}{1 - C_r(a,b)} & \text{if} \quad d_t(a,b) > C_r(a,b) \\ \\ C_r(a,b), & \text{if} \quad De\ otro\ modo \end{cases} \tag{4}$$

To explain the relation of Equations (1-4) with the hierarchy of criteria, the following description will be made regarding Figure 2.

The concordance index $C_t(a,b)$ and elementary discordance index $d_t(a,b)$ are applied at the last level of the hierarchy (Level 2 in Figure 2). Accordingly, these two indices are only applied on the elementary criteria g(1,1), ..., g(1,3) up to g(3,1), ..., g(3,2). Once the indices have been calculated at Level 2, partial concordance $C_r(a,b)$ is calculated at Level 1 for each macrocriterion. For example, in macrocriterion g1, the index $C_t(a,b)$ is first applied to the elementary criteria g(1,1), g(1,2), g(1,3). This process is repeated for the following macrocriteria g2 and g3. Then, Equations (1) and (2) are applied on the elementary criteria of Level 2 and Equation (3) on the macrocriteria of Level 1.

The partial credibility index $\sigma_r(a,b)$ (see Equation (4)) is also applied at Level 1 considering the partial concordance $C_r(a,b)$ and the elementary discordance $d_t(a,b)$.

Cut-off level in the MCHP distillation method

The distillation method is used to exploit the preferential model; this corresponds to the second stage of the ELECTRE-III method. The method is based on the degree of credibility of each pair of actions $\sigma_r(a,b)$ to obtain a partial or complete final preorder resulting from the intersection of two complete preorders. Bottom-up and top-down distillation builds a complete preorder, and the combination (intersection) of the two preorders gives the final ordering (complete or partial preorder). The complete preorders are established based on a rating of each alternative. A brief description of the distillation procedure in five simple steps can be found in the work of Marzouk (2011).

The distillation method is adapted to the hierarchical process to generate final orderings at each node in the hierarchy from top-down and bottom-up distillation. For pairs $a_i, a_l \in A$ in the hierarchical process, the alternatives are ordered in partial or complete preorder on the non-elementary criterion g_r as follows:

- $a_i P_r a_l$: a_i is strictly preferred to a_l in the macrocriterion g_r if in at least one of the orderings a_i is ordered ahead of a_l, and if in the other a_i is at least as good as a_l.
- $a_i I_r a_l$: a_i is indifferent to a_l in the macrocriterion g_r if the two actions belong to the same equivalence class in the two orders.
- $a_i R_r a_l$: a_i is incomparable to a_l in the macrocriterion g_r if a_i is ordered higher than a_l in the upstream distillation and a_l is ordered higher than a_i in the downstream distillation or vice versa.

The MCHP proposed by Corrente, Greco, and Słowiński (2012), including the distillation method, was computationally implemented by Alvarez, Valdez, and Dutta (2022), and called Hierarchical-ELECTREIII. It is available on GitHub (https://github.com/paac80/hierarchical-ELECTREIII). The Hierarchical-ELECTREIII method is systematized and shared as a computational tool for professionals dealing with a multicriteria hierarchical process (MCHP), so it was easily possible to adapt the problem to BI platforms by using this tool.

Analysis of the BI platforms

This section describes the stages of the decision process for BI platform selection.

Decision alternatives

The decision problem corresponds to the ordering of BI platforms. For this purpose, seven platforms were identified that have licensed software: IBM Cognos Business Intelligence (A1), Microsoft Power BI (A2), MicroStrategy (A3), Qlik (A4), Tableau (A5), Oracle BI (A6), and SAP BI (A7). The expert who participates in the selection of business platforms discards free software platforms due to their weak technical support, an important factor to carry out the company's knowledge management adequately.

The expert (decision maker)

The expert who also serves as a decision maker for the selection of BI platforms is an experienced employee in a Mexican department company. He is responsible for the BI area and will express his preferences to build a preferential model of the platforms.

Decision criteria

In the design phase and Stage 3 of the multicriteria decision-making process, the relevant criteria were identified and validated based on Gartner's analysis (Gartner, 2019). With this, an initial proposal of the criteria was presented to the person in charge of the BI area.

Gartner is a company based in Stamford, Connecticut, United States, that specializes in consulting and research in IT. To carry out its study, it takes as a reference a large number of companies from different sectors, such as finance, marketing, sales, and operations, among others, and its purpose is to make a comparative analysis of the strengths and weaknesses of the different brands in each of the information technology areas.

In addition to the Gartner analysis, other relevant aspects were included for selecting the criteria chosen by the manager. Considering the above, the criteria selected were as follows:

- Technological criterion (C1)

This criterion groups the technical aspects to specifically identify the organization's needs as a user of a BI platform.

  - Alternate database generation (C1.1)

This sub-criterion refers to creating an alternate database to synchronize with the language of the platform to be assessed. This sub-criterion is scored on a scale of 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

  - Data volume scalability (C1.2)

This sub-criterion assesses the platform's capacity to change its configuration or size according to the future demands it may generate. It is assessed from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

  - Sophisticated SQL support (C1.3)

This sub-criterion assesses the provision of a fast and simple programming model for developers, eliminating database administration for standard operations and providing sophisticated tools for more complex operations. It is assessed from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

  - Interactive report (C1.4)

This sub-criterion assesses the ability to create formatted and interactive reports with a highly scalable layout and optimal scheduling capabilities. It is scored from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

  - Integration (C1.5)

This sub-criterion assesses the design and implementation capacity of the functionality, the application's linking capacity (custom software or software package), the volume of data flow, and the capacity of the technological infrastructure. It is assessed from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

- Financial reports to monitor business performance (C1.6)

This sub-criterion assesses the platform's ability to handle a wide range of financial reporting styles, performance dashboards, and indicators, among others. It is assessed from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

- Mobile device support (C1.7)

This sub-criterion assesses the platform's ability to enable access to smart mobile devices with GSM, GPRS, EDGE, WCDMA, High-Speed Downlink Packet Access (HSDPA), High-Speed Uplink Packet Access (HSUPA), LTE, cdma2000 1xRTT, cdma2000 EV-DO, and digital cellular (PDC) features. It is assessed from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

- Financial Criteria (C2)
  - Main license cost (C2.1)

This sub-criterion verifies the cost to be paid by the company to install, access, and structure the platform. It is assessed in US dollars.

- Additional licenses cost (C2.2)

This sub-criterion corresponds to an increase in licenses different from that initially agreed. It is assessed in U.S. dollars.

- Training cost (C2.3)

This sub-criterion verifies the cost of training by the consultancy to instruct future platform users. It is assessed in US dollars.

- External consultant cost for basic reporting (C2.4)

This sub-criterion assesses the value of the consultancy to be hired to generate reports and dashboards. It is assessed in US dollars.

- Maintenance cost (C2.5)

This sub-criterion assesses the value to be paid as a platform maintenance item. It is assessed in US dollars.

- Quality criterion (C3)
  - Knowledge of the supplier (C3.1)

This sub-criterion refers to the supplier's knowledge of the operation of the company that will implement the platform, the supplier's own experience, and knowledge of the detailed operations of the business, among others. It is assessed from 1 to 5, where 5 is better than 1 as the sub-criterion is to be maximized.

Assessing BI platforms

Table 1 presents the assessment of the alternatives for each criterion. The assessment elements of the BI platforms correspond to the decision criteria explained in the previous section. With this, each BI platform was assessed for each decision criterion.

Table 1
Assessing BI platforms for each criterion

Platforms	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C1.7	C2.1	C2.2	C2.3	C2.4	C2.5	C3.1
A1	2.1	3.0	2.9	3.5	2.8	2.1	3.0	3 240	900	6 700	85 000	648	4.0
A2	5.0	3.3	3.5	3.5	3.8	2.6	4.0	2 800	840	6 100	82 000	720	4.2
A3	5.0	4.5	4.2	4.0	4.6	3.5	4.5	2 000	600	5 400	81 000	440	4.2
A4	4.0	4.0	3.4	4.0	4.1	3.0	3.5	2 500	650	5 500	65 000	730	3.9
A5	4.0	2.8	3.7	4.0	4.0	3.0	5.0	1 600	800	3 100	74 000	400	4.2
A6	3.0	3.3	3.4	4.0	0.0	2.1	4.0	2 000	1 200	4 200	73 000	440	3.8
A7	2.6	2.0	2.9	3.1	0.0	2.6	3.0	1 750	800	5 200	92 000	360	4.0

Source: created by the authors.

Criteria C1 and C3 are measured on an ordinal scale between 1 and 5, where 1 is poor (the defined requirement for a capability is not met), 2 is fair (the requirement is half met), 3 is good (the requirement is met), 4 is excellent (the requirement meets and exceeds expectations), and 5 is exceptional (the requirement significantly exceeds expectations). The sub-criteria belonging to C2 are measured in terms of cost in US dollars.

The intercriteria parameters form a set of input data for the hierarchical ELECTRE III method. These are made up of relative importance of the criteria (w), indifference thresholds (q), preference thresholds (p), and veto thresholds (v). These parameters are part of the preferences of the expert, the person in charge of the BI area of the company for the construction of a model that considers his or her preferences, called the decision maker’s preferential model.

The weights were defined by adapting the revised version of the chart method procedure (Figueira & Roy, 2002) for the hierarchical version of the ELECTRE-III method. The procedure requires ordering the criteria from the least important to the most important for each group of criteria.

In modeling preferences, these input data were used to apply the hierarchical ELECTRE III method to build a preferential model of the company’s BI manager. This model represents the preferences of the person in charge of the area for assessing BI platforms. After an interactive process with the person in charge of the BI area to obtain the intercriteria parameters, the values in Table 2 were defined.

Table 2
Inter-criteria parameters as preferential information

	C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C1.7	C2.1	C2.2	C2.3	C2.4	C2.5	C3.1
Dir.	Max	Max	Max	Max	Max	Max	Max	Min	Min	Min	Min	Min	Max
q	1	0.5	1	1	0.7	0.5	2	300	100	1 200	6 000	120	0.15
p	3	1.5	2.5	3	1.5	1.5	4	650	250	2 200	11 000	250	0.3
v	No veto	No veto	No veto	No veto	No veto	No veto	No veto	No veto	No veto	No veto	No veto	No veto	No veto

Source: created by the authors.

Table 3
Macrocriteria, elementary criteria labels, and weights

Index	Macrocriterion	Elementary criteria labels	Weight (w_r)
g1	Technological	g(1,1), g(1,2), g(1,3), g(1,4), g(1,5), g(1,6), g(1,7)	0.3333
g2	Financial	g(2,1), g(2,2), g(2,3), g(2,4), g(2,5)	0.4
g3	Quality	g(3,1)	0.2667

Source: created by the authors.

Table 4
Weights of elementary criteria

Macrocriteria Level 1	Labels Level 2	Elementary criteria	Weight (w_t)
g1	g(1,1)	Alternate database generation	0.0387
	g(1,2)	Data volume scalability	0.0740
	g(1,3)	Sophisticated SQL support	0.0476
	g(1,4)	Interactive report	0.0301
	g(1,5)	Integration	0.0565
	g(1,6)	Financial reports for monitoring business performance	0.0652
	g(1,7)	Mobile device support	0.0212
g2	g(2,1)	Main license Cost	0.1333
	g(2,2)	Additional licenses cost	0.1067
	g(2,3)	Training cost	0.0533
	g(2,4)	External consultant cost for basic reporting	0.0267
	g(2,5)	Maintenance cost	0.0800
g3	g(3,1)	Knowledge of the supplier	0.2667
		Sum of weights	1.0000

Source: created by the authors.

Aggregation of preferences

The aggregation process corresponds to the application of a multicriteria assessment model that integrates both the information of the alternatives for each decision criterion and the preferential information of the

http://dx.doi.org/10.22201/fca.24488410e.2023.4587

BI expert. The preferential model resulting from the hierarchical version of the ELECTRE-III method corresponds to a valued fuzzy relation matrix. Table 5 shows the matrices generated at each node (g_r) and the global node (g_0).

Table 5
Preferential model in each node of the criteria hierarchy

a) Global preferential model (g_0)

	A1	A2	A3	A4	A5	A6	A7
A1	1	0.80	0.38	0.61	0.54	0.73	0.77
A2	1	1	0.60	0.89	0.72	0.73	0.79
A3	1	1	1	0.97	0.90	0.99	1
A4	1	0.73	0.57	1	0.47	0.83	0.79
A5	1	1	0.85	0.90	1	1	1
A6	0.75	0.55	0.44	0.78	0.50	1	0.80
A7	0.90	0.74	0.62	0.80	0.75	0.91	1

b) Preferential model of technology sub-criteria (g_1)

	A1	A2	A3	A4	A5	A6	A7
A1	1	0.83	0.29	0.63	0.76	1	1
A2	1	1	0.74	0.95	1	1	1
A3	1	1	1	1	1	1	1
A4	1	1	1	1	1	1	1
A5	1	1	0.78	0.84	1	1	1
A6	0.83	0.77	0.44	0.71	0.75	1	1
A7	0.72	0.57	0.42	0.58	0.74	0.82	1

c) Preferential model of financial sub-criteria (g_2)

	A1	A2	A3	A4	A5	A6	A7
A1	1	0.87	0.25	0.33	0.27	0.33	0.43
A2	1	1	0.21	0.77	0.31	0.33	0.47
A3	1	1	1	0.93	0.76	0.97	1
A4	1	1	0.61	1	0.33	0.60	0.47
A5	1	1	0.82	0.87	1	1	1
A6	0.73	0.73	0.73	0.71	0.64	1	0.73
A7	0.99	0.95	0.75	0.84	0.81	0.93	1

d) Preferential model of quality subcriteria (g_3)

	A1	A2	A3	A4	A5	A6	A7
A1	1	0.67	0.67	1	0.67	1	1
A2	1	1	1	1	1	1	1
A3	1	1	1	1	1	1	1
A4	1	0	0	1	0	1	1
A5	1	1	1	1	1	1	1
A6	0.67	0	0	1	0	1	0.67
A7	1	0.67	0.67	1	0.67	1	1

Source: created by the authors.

The matrix is composed of the corresponding assessment comparing each of the BI platforms with the rest. The value is a fuzzy number between 0 and 1 corresponding to the assertion that platform *a* is at least as good as platform *b* in a set of BI platforms. Consequently, as the result of the value gets closer to one, this assertion is fulfilled to a greater extent.

Table 6 contains the orderings of each macrocriterion (g1, g2, and g3) and the global problem (g0). Each macrocriterion is assessed by a subset of sub-criteria (elementary criteria belonging to the last level of the hierarchy). The ordering generated results from the interaction of elementary criteria that assess the corresponding macrocriteria.

Table 6
Global sorting and sorting by subgroups (macrocriteria) of BI platforms

Position	Global problem g0	Technological Macrocriterion g1	Financial Macrocriterion g2	Quality Macrocriterion g3
1	A3,A5	A3	A3, A5	A2, A3, A5
2	A2, A4	A4	A7	A1, A7
3	A6, A7	A2	A4	A4
4	A1	A5	A6	A6
5		A1	A1, A2	
6		A6		
7		A7		

The graphical representation of the ordering is illustrated in Figure 3 (a), (b), (c), and (d). Global ordering (g0) assigns MicroStrategy (A3) and Tableau (A5) in the first position as the best BI platforms for the company's area manager. In the technological macrocriterion (subgroup) (g1), the first positions are shown for MicroStrategy (A3) > Qlik (A4) > Power BI Microsoft (A2). The financial macrocriterion (g2) shows {MicroStrategy (A3), Tableau (A5)} > SAP BI (A7). The quality macrocriterion (g3) shows top positions for {Power BI Microsoft (A2), MicroStrategy (A3), and Tableau (A5)}.

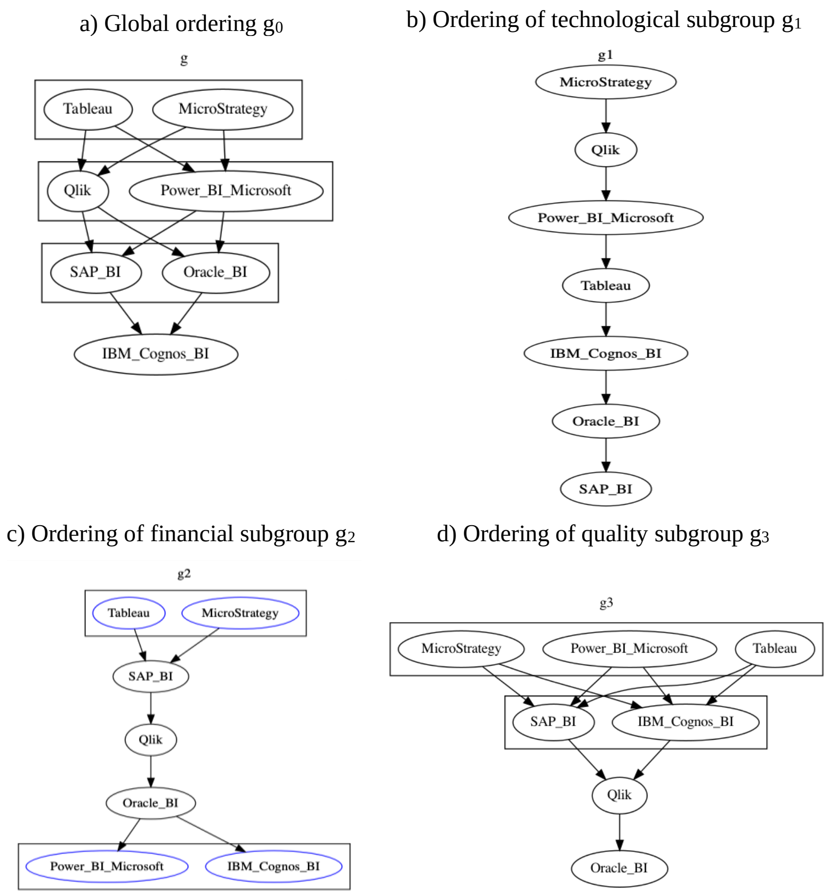

Figure 3. Hierarchical ordering of BI platforms
Source: created by the authors

The ordering shows that MicroStrategy (A3) appears in the first position in the three macrocriteria (g1, g2, and g3). Therefore, it is the best BI platform along with Tableau (A5), which is in first position both in the quality macrocriterion (g3) and in the financial macrocriterion (g2). Microsoft Power BI (A2) and Qlik (A4) are positioned in third place, after MicroStrategy (A3) and Tableau (A5). The A2 and A4 platforms are in third and second place, respectively, in the technological macrocriterion (g1). In turn, in the financial macrocriterion (g2), they appear in fifth and third position, respectively. In the quality macrocriterion (g3), A2 and A4 appear in the first and third positions, respectively.

In the global ordering (g0), the BI platforms that are at the bottom of the ordering are Oracle (A6), SAP (A7), and IBM (A1), in third and fourth place, respectively. An element of interest is highlighted in the SAP platform (A7). The platform obtained the second position in the financial macrocriterion (g2) and in the quality macrocriterion (g3). Nevertheless, in the global ordering, A7 appears at the bottom of the ordering. This is due to its low performance in the technological macrocriterion (g1), as it obtained the last place in this macrocriterion (position 7).

This analysis can be used to show the areas of opportunity that each BI platform has and thus be able to scale up the ordering. The methodology used in this study allows for addressing complex problems by analyzing BI's different points of view or variables. Experts can contribute with their criteria and assessments. An example of this is shown in the case of the SAP platform (A7) explained in the previous paragraph, where it appears in the last places of the final ordering and other positions in the ordering of other criteria subgroups.

The decision-making process assisted by a multicriteria tool provides decision support to the company's BI platform expert. The contribution to the decision process is based on problem definition, analysis, assessing, and ordering elements. All of the above helps in the understanding of the problem and solution for the selection of a BI platform.

The hierarchical multicriteria procedure in which the expert operated helped to understand two relevant phenomena. On the one hand, the interaction of the decision criteria of BI platforms. On the other hand, the changes in ordering (solution proposal) in relation to the expert's preferences considering the company's needs.

Conclusions

This study developed a decision-making process using a hierarchical multicriteria approach for assessing BI platforms with the participation of an expert in the area of a company that buys and sells clothing and furniture. As a result of this decision process, the assessment of BI platforms in an ordering format was obtained, considering the decision maker's preferences in the decision model. With this, it was possible to solve the problem of assessing BI platforms that meet the company's needs.

This is applied research that focuses on decision making through technology assessment. The methodological process, multicriteria techniques, and procedures can be transferred to other types of problems, such as ordering. On the other hand, they can also be implemented to assess and select other types of technologies required or used by the company.

Finally, the multicriteria analysis approach implemented in this study can be applied to various elements of analysis in public and private organizations. Some of the decision problems that can be adequately addressed with the approach developed here are: personnel selection, budget allocation, product and process evaluation, strategic business planning, resource allocation, and other problems.

The main limitation in this work is related to the availability of participation of members of the organization where only one representative of the BI area participated. A group decision environment where the preferences of other decision makers belonging to other areas of the organization are considered will make it possible to propose a solution that considers different points of view.

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