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Multi-Criteria Decision-Making for Supplier Selection: A Comparative Evaluation of AHP and ELECTRE I in an Industrial Case Study

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Abstract

INTRODUCTION: In a continuously demanding market, informed decisions must be rapidly taken to ensure competitiveness, requiring decision support systems capable of handling sizeable volumes of data. In supply chain management, supplier selection requires establishing contracts that create more competitive solutions.
OBJECTIVES: In this paper, two Multi-criteria Decision-Making methods are addressed for supplier selection: AHP and ELECTRE I. Both are applied in a real case scenario and compared to understand their suitability and constraints regarding the problem specificity, data clarity and criteria definition.
METHODS: AHP is a seven-step process that may deal with quantitative and qualitative criteria; this more subjective evaluation is then converted to a numerical scale for comparison. ELECTRE I, on the other hand, establishes a pair-wise comparison between alternatives to create agreement and disagreement matrices, defining the level of similarity between them. Dashboards were developed in Python programming language, allowing the user to define the problem properties (number of alternatives and criteria) and input the necessary information through a simple and intuitive interface. After executing the model, the dashboard offers the user a visual representation of the suppliers' selection results.
RESULTS: AHP ranked A first; ELECTRE I retained supplier A and B as non-outranked. Yet these models diverge in supplier's sorting: AHP prioritizes alternatives by defining numerical classification values, whereas the ELECTRE I defines an aggregated matrix to indicate the suppliers' dominance, without establishing a dominance strength level.
CONCLUSION: AHP rigidly ranks alternatives while the method ELECTRE I allows for a more flexible analysis, considering agreement and disagreement between criteria, making it more suitable for complex industrial contexts.

Keywords: Multi-criteria Decision Making, Supplier Selection, AHP, ELECTRE I, Industrial Application

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1. Introduction

Procurement has been defined as the act of purchasing. Yet, this conception does not capture the true complexity and strategic nature of the process. Procurement should be understood as the process of acquiring goods and services, for which a set of coordinated activities that goes far beyond the transactional dimension, encompasses all the tasks from the needs definition and sourcing to post-acquisition evaluation

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[1]. It also refers to the systematic process studied and optimized through formal, evidence-based methods rather than purely intuitive practice.

Within this integrated approach, two fundamental dimensions that structure the procurement process are distinguished: sourcing and purchasing, corresponding, respectively, to the strategic and operational aspects of the process. Sourcing comprises the four initial phases, which aim to identify, analyse, and select the most suitable suppliers based on previously established technical, economic, and strategic criteria. Purchasing encompasses the four subsequent stages, focused on the actual acquisition process, including order placement, logistical monitoring, receipt of goods or services and performance evaluation. Figure 1 presents a schematic and sequential representation of the procurement process and its component phases.

Sourcing begins with the definition of acquisition requirements, considering the organization's critical parameters, which guide the next phase: supplier selection. This stage is particularly important, being widely recognized in the literature as one of the most crucial for the success of the procurement process. A rigorous and well-founded selection process not only ensures compliance with technical and qualitative requirements but also mitigates operational and strategic risks, promoting the creation of sustainable value [2]. Once the selection process is complete, the negotiation and contract formalization phase begins, establishing the terms and conditions that will govern the commercial relationship between the parties. This concludes the sourcing phase and conducts to the purchasing phase, during which the order is executed, its fulfilment is monitored, and, finally, the process is evaluated. A rigorous evaluation of the process provides valuable feedback into the system, enabling the identification of opportunities for continuous improvement and the optimization of procurement practices in future cycles. Although procurement is extremely important and helps companies in the decision-making process, it represents a complex process, which is why all its stages are rarely applied in practice.

Since procurement success largely depends on the quality and reliability of supply sources, it is essential to analyse the strategic role played by suppliers in the acquisition process. A supplier is defined as an entity (person or organization) capable of delivering goods or services to another organization, based on a contractual relationship, to meet operational needs. Therefore, supply increasingly depends on the quality of the goods or services, so it is crucial to use suitably qualified suppliers capable of efficiently meeting the organization's needs [3]. Competitive and purchasing strategies must be aligned, as market demands (quality, speed, cost) increase, companies need to adjust their supplier selection criteria and supply chain initiatives to maintain performance. Supply chain management promotes integration and partnerships with suppliers, but this relationship is not always symmetrical. At one end lies the open market, with short-term contracts and low commitment, and at the other, vertical integration, with a high degree of shared risk, reward, and assets. Between these two extremes lie partnerships, where trust, flexibility, and shared control are balanced, and formal medium-term contracts, which mitigate risks without requiring full integration [4].

In this context, supplier selection based on multiple criteria becomes an essential element of strategic supply chain management. Multi-criteria tools such as AHP (Analytic Hierarchy Process) and ELECTRE I (*ELimination Et Choix Traduisant la Réalité*) offer methodological support for making purchasing decisions aligned with the organization's strategic priorities.

As organizations become more dependent on their suppliers, poorly informed decisions can have significant impacts. Thus, it's crucial to adopt a structured supplier selection process, based on criteria aligned with corporate strategy. The supplier qualification, selection and evaluation are essential pillars of both the purchasing process and supply chain management. Each of these phases involves specific criteria that help to identify and maintain strategic elements that meet the organization's needs [5]. Therefore, supplier selection includes four steps: *i)* problem definition and strategic priorities; *ii)* definition of the selection criteria; *iii)* qualification of suppliers; *iv)* selection of suppliers.

Supplier qualification aims to filter and narrow the pool of candidates, ensuring that only those who meet the minimum requirements advance to the next phases. This stage is based on the analysis of essential criteria, such as compliance with standards and regulations, financial strength, performance history and industry experience. Suppliers that do not present adequate conditions to meet the organization's demands are therefore excluded [5].

The supplier selection process, especially in complex industrial environments involving ambiguous parameters and high competitiveness, requires rigorous qualification as an initial step. This phase is essential to ensure that the supplier meets minimum standards of performance, quality, and compliance with current regulations. A lack of effective qualification represents a vulnerability and can lead to the selection of unsuitable partners. This results in increased waste, additional operating costs, and the risk of compromising the quality of the final product delivered to the customer. Failures in this process often stem from a lack of time for detailed analysis or the assumption that expectations will be met without proper verification. To minimize these risks, qualification must be thorough, including an assessment of the supplier's performance history, technical capabilities, document compliance, specifications, and financial stability. Implementing a structured methodology increases supply chain reliability, improves efficiency, and fosters the establishment of lasting and sustainable partnerships [6], [7]. The selection process continues with an in-depth analysis of pre-qualified suppliers, using previously established strategic criteria. At this stage, the evaluation focuses on the candidates' effective performance, their adherence to organizational objectives, and their demonstrated ability to generate added value for the business. The final decision may result in the selection of a single partner or a diversified portfolio, depending on the complexity and specific requirements of the supply chain. This structured approach is essential for mitigating risks,

optimizing supply chain management and ensuring that the selection process is linked to corporate strategy [5].

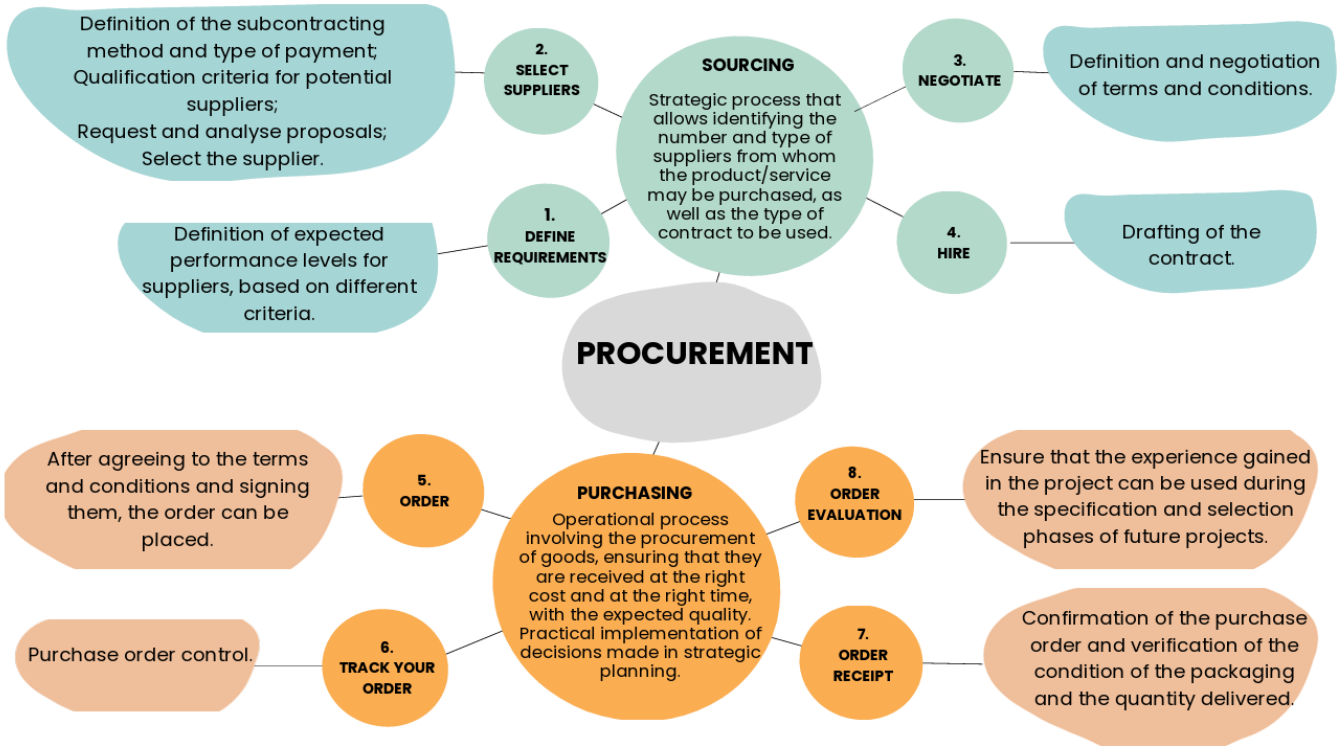

Figure 1. Elements of the procurement process

Supplier evaluation consists of a systematic analysis of their performance, based on criteria such as the quality of products or delivered services, deadlines, responsiveness, and compliance with previously defined requirements. This practice not only allows for the identification of strengths and weaknesses in current suppliers but also generates valuable insights for improving the specification and selection processes in future projects, contributing to more effective supply chain management [8]. Furthermore, structured evaluation supports decision-making, enabling the reduction of acquisition costs and the mitigation of purchasing-related risks. Therefore, continuous supplier evaluation favours the optimization of partnerships and the strengthening of the organization's purchasing strategy [9].

Table 1 presents fundamental criteria for supplier qualification, selection and evaluation. Since the qualification phase focuses on ensuring that the supplier meets the supply requirements, criteria such as compliance with standards and legislation, financial capacity, prior experience, workplace safety, reputation, and sustainability are considered to ensure that the supplier meets the basic conditions to operate according to the company's requirements. In the selection phase, factors that differentiate between previously qualified suppliers are analysed. Here, price, quality, quantity of resources, delivery time, and support are decisive criteria, as they directly impact the company's operational performance. This phase involves comparing suppliers to choose the most appropriate option, based on the company's interests.

Evaluation occurs after the supplier is selected, and it is important to conduct a continuous analysis of supplier performance after selection and during contract execution to ensure the maintenance of required standards. Therefore, it is crucial to verify that the cost of purchased goods remains competitive and in line with expectations, as well as the quality. Furthermore, it's crucial to evaluate the supplier's consistency and reliability over time, as well as the technical assistance and the provided after-sales support. This step allows to identify improvements for future selections and reduce procurement risks, strengthening purchasing strategy and optimizing supplier relationships.

Analytical methods for the supplier selection process in industry consist of approaches, whether qualitative or quantitative, that aim to support decision-making in the supplier selection process [10]. The main methods include MCDM, optimization models, simulation, scenario analysis and data science models:

- MCDM: Allow for the evaluation and selection of suppliers based on multiple criteria, such as sustainability, quality, cost, and others [11]. Examples of multi-criteria decision models include AHP, Fuzzy TOPSIS, and Fuzzy AHP [12].

- Optimization models: Aim to identify the best possible solution for a specific problem, maximizing or minimizing a specific objective (such as cost, time, or quality), while respecting the involved constraints [13].
- Simulation models: Allow for the modelling and observation of the behaviour of complex systems over time. Using scenarios based on random variables, simulation helps to predict the outcomes of decisions under conditions of uncertainty [14].
- Scenario analysis: Involves creating multiple forecasts based on different hypotheses about the future, helping to understand how uncertain variables affect outcomes. It is widely used for strategic planning and risk management [15].
- Data science models: Arises from the need to address the limitations of conventional methods regarding the complexity of today's unstructured collected data, such as texts and sensor streams, which traditional analytical approaches struggle to process, interpret and scale. Its objective is to frame the data science process within its broader context, considering technical and business objectives, organizational and societal impacts, and the theoretical requirements that underpin the choice and validation of each model. In doing so, it provides a structured basis for aligning methodological decisions with strategic goals, ensuring reproducibility, ethical and responsible use of data, and the ability to adapt to evolving needs, thereby enabling more effective, informed and sustainable action aligned with contemporary challenges. [12], [16].

The adoption of analytical supplier selection methods enables a better risk assessment, a diversified supplier base, cost reduction, and delivery times, among other factors.

Table 1. Supplier qualification, selection and evaluation criteria

Criterion	Description	Qualification	Selection	Evaluation
Price	Cost of acquisition of the purchased asset	☑	☑	☑
Legal and Regulatory Requirements	Compliance with applicable laws and regulations	☑		☑
Financial Capacity	Economic stability and investment ability to handle fluctuations in order volume	☑		
Previous Experience	History of similar supply engagements	☑		
Quality	Compliance with quality standards	☑	☑	☑
Workplace Safety	Safety practices and certifications	☑		☑
Relationship History	Existence of a prior relationship with the company	☑		☑
Resource Availability	Productive and logistical capacity	☑		☑
Sustainability	Environmental and social practices	☑	☑	
Delivery Time	Ability to meet agreed deadlines	☑		☑
Reputation	Market perception	☑		
Organizational History	Years of operation and credibility	☑		☑
Support	Technical assistance and after-sales support		☑	☑

The present research of this paper aims to improve the supplier selection process in the industry, in a context of increasing complexity in supply chains and growing demand for greater operational efficiency. To this end, it analyses the application of MCDM, especially AHP and ELECTRE I, widely used in the literature, evaluating their contribution to the competitiveness of companies. The study addresses the role of procurement in companies, the

stages of the supplier selection process, and the benefits of analytical methods, using the analysis of a case study in a business context, comparing the two methods under analysis, AHP and ELECTRE I.

Regarding the research contribution, although AHP and ELECTRE I are well established, they are usually combined in hybrid procedures in which AHP supplies weights to ELECTRE, so their behaviour as alternative decision models is rarely examined on identical information. This paper addresses that gap. Its contributions are: *i)* a controlled comparison of a compensatory ranking method (AHP) and a non-compensatory choice method (ELECTRE I) for the same real industrial dataset; *ii)* a reproducible procedure for converting AHP pairwise judgements, including qualitative criteria, into ELECTRE I inputs; *iii)* a sensitivity analysis of the agreement between methods under variations in weights and thresholds; and *v)* two open Python dashboards that make both methods usable by non-specialists.

The paper is organized in five main sections: Section 1 presented the procurement process and the importance of supplier selection in the supply chain management. In Section 2, Materials and Methods, the selected analytical supplier selection methods are presented, presenting their main steps. Section 3 describes the case study and presents the parameterization. Here it is also described the methods and calculus used to enable a fair comparison between the selected models. On Section 4 the main results and their discussion are presented. Lastly, Section 5 presents the conclusions, limitations and future work perspectives.

2. Material and Methods

This section presents the materials and methods used in the study, with particular emphasis on the application of the AHP and ELECTRE I multi-criteria decision support methods, selected for their relevance and suitability to the supplier selection process in an industrial context.

2.1. Analytic Hierarchy Process

The AHP method supports the supplier selection process in a structured and objective way, aligned with the strategic objectives of organizations, by decomposing a complex problem into a hierarchy of objectives, criteria, and alternatives, facilitating the detailed analysis of each element [17].

The method consists of seven steps. Initially, the problem is structured hierarchically, allowing its disaggregation into smaller, logically organized components. Next, a pairwise comparison of the elements at each level of the hierarchy is performed, based on their relative importance. From these comparisons, the relative weights of the criteria and alternatives are calculated, converting qualitative judgments into numerical values.

In a later step, the consistency of the comparisons is verified using the consistency rate, ensuring the coherence of the judgments made. The weights are then aggregated into a ranking matrix, where all alternatives are evaluated against the defined criteria. By calculating the composite priority, the overall weights of the alternatives are determined, ultimately leading to a decision in which the alternative with the highest overall weight is selected as the most appropriate option. This method combines subjectivity associated to the judgments of decision-makers with the objectivity of numerical calculations, ensuring a structured and reliable analysis for complex decision-making processes.

2.2. ELECTRE I

ELECTRE I is a multi-criteria decision support method, developed by Roy (1968) [18], used to compare alternatives based on multiple criteria, allowing the elimination of less favourable options and the identification of the most suitable solutions [19].

The method is developed in eight steps. Initially, the problem, the alternatives, and the evaluation criteria are defined, followed by the construction of the decision matrix, where the performance of the alternatives against each criterion is presented.

Due to the diversity of units of the criteria, the matrix is normalized and subsequently weighted according to the relative importance of each criterion. Next, the agreement and disagreement indices are calculated, which evaluate the preference relationships between pairs of alternatives, giving rise to the respective matrices. Based on these, an aggregate dominant matrix is constructed, which highlights the strongest alternatives. Finally, the least suitable alternatives are eliminated, resulting in a final set of options represented in a dominance graph, which supports structured and multi-criteria decision-making. The ELECTRE I method integrates subjective judgments with quantitative analysis, using a dominance graph to highlight the best alternatives.

2.3. Methodological Procedure

The flowchart presented by Figure 2 compares the structure of both methods applied. In sum, AHP is a hierarchical and compensatory method that uses pairwise comparisons to assign weights and rank alternatives, whereas ELECTRE I is a non-compensatory outranking method that uses concordance and discordance to identify whether one alternative can outrank another [20].

Thus, there are differences regarding the methods procedures: AHP turns pairwise comparisons of criteria and alternatives into priority weights (eigenvectors) and adds them up into one overall score for ranking. ELECTRE I instead compares alternatives in pairs using concordance and discordance indices against set thresholds, building outranking relations that pick out a set of preferred alternatives (the kernel) rather than a full ranking.

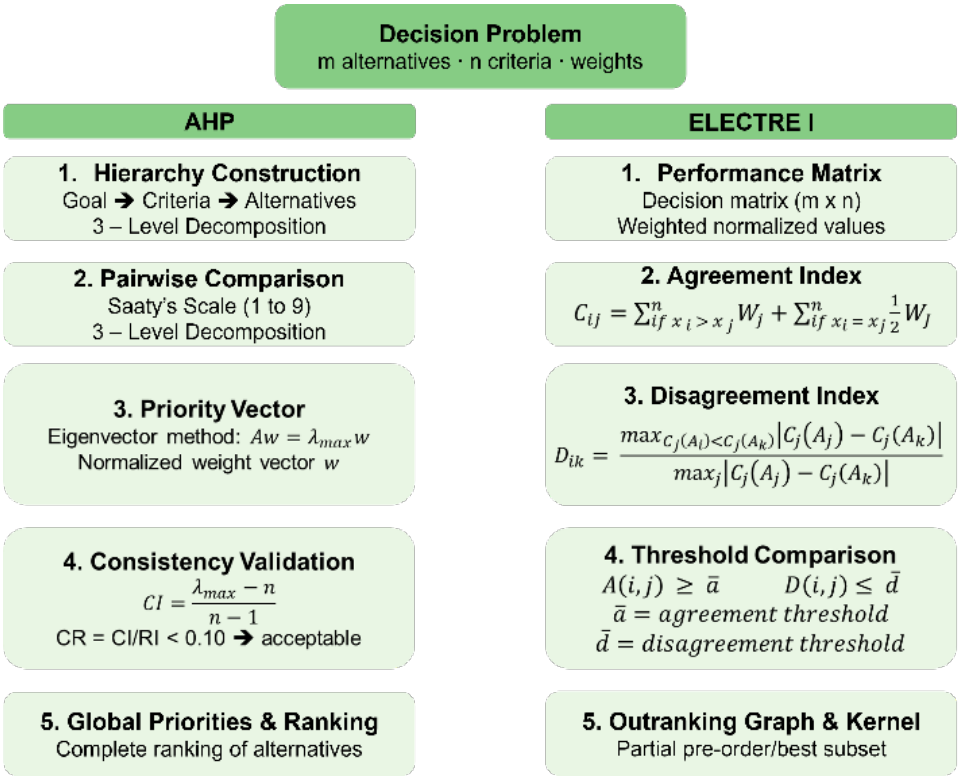

Figure 2. Structure of AHP and ELECTRE I methods

3. Case Study Modelling

Current industries increasingly need fast responses due to the growing complexity of supply chain systems and the large volume of data acquired in the industrial context. In this sense, Decision Support Systems (DSS) have become useful tools, dealing with large volumes of data to be transformed into information that enables more informed decision-making. In the selection of suppliers, AHP and ELECTRE I methods were used to rank and prioritize the most suitable suppliers of a real industrial case scenario, already described in a previous publication.

3.1. Problem Description

The case study, addressed by Ramos et al. in [21], is based on a real-life case involving a textile company specializing in dyeing, which uses reactive dyes primarily on fibers such as cotton and linen. One of these dyes was selected for analysis, supplied by four different suppliers (identified as A, B, C, and D for confidentiality reasons).

The main objective is to select the most suitable supplier to supply the company with the pigment. The selection of the most suitable supplier will be based on five criteria (Figure 3): cost, quality, partnership history, delivery time, and sustainability. Two of these criteria are qualitative and three are quantitative.

The presented problem aims not only to support the decision, but also to analyse the performance of two multi-criteria decision models that will allow the selection of the most suitable supplier based on the defined criteria. Additionally, it aims to analyse how the specific features of these models enable more informed decisions in an industrial context.

It is important to mention that the case data previously collected and validated in our previous research presented in Ramos et al. in [21], concerns the criteria and pairwise judgements, where only AHP was applied to study. Here they are used as a fixed information base; the AHP results are reproduced as the comparison baseline, while the conversion procedure, ELECTRE I application, sensitivity analysis and dashboards are original to this work.

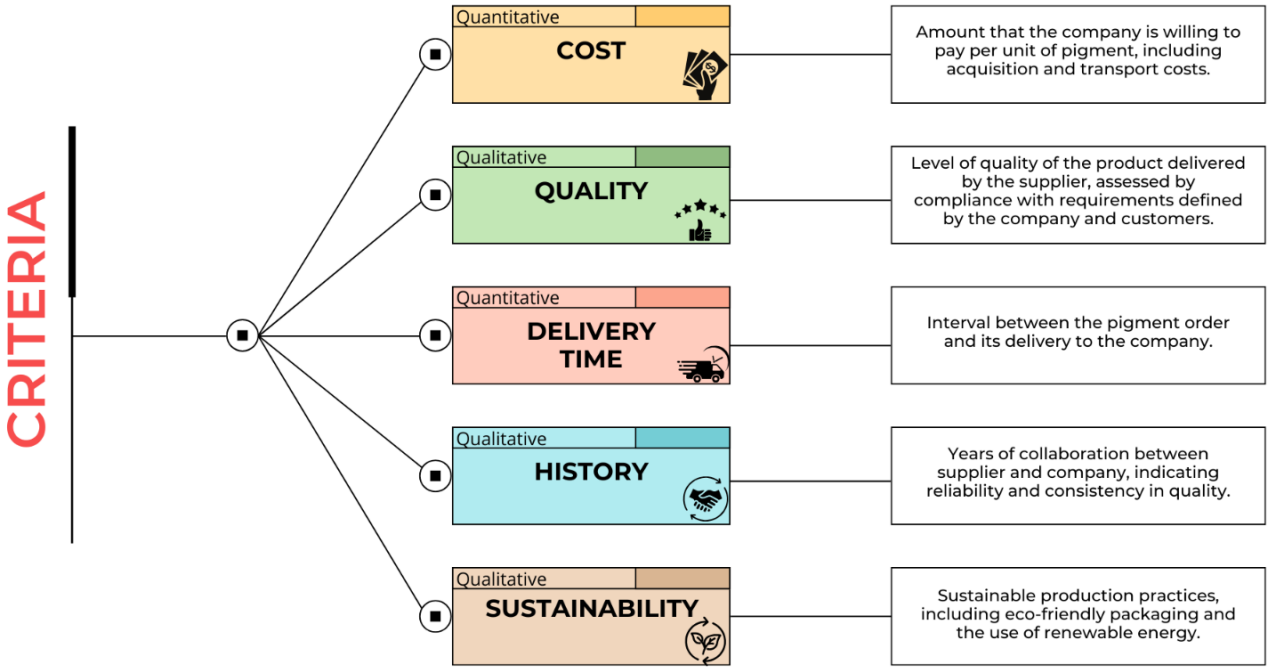

Figure 3. Pigment selection criteria

3.2. Parametrization and calculations

To allow for a fair comparison between the two MCDM addressed in this study, the initial data obtained by the study of Ramos et al. [21] for the AHP method were converted to the format required for the application of ELECTRE I, ensuring that both methods start from the same information base. To ensure a neutral evaluation of both methods, an independent strategy was applied to convert the criteria comparison matrix given by the decision make. Indeed, this ensured that both methods only share the same initial data and are not correlated. Table 2 presents the comparison matrix between the different criteria, based on Saaty's fundamental scale.

In the AHP method, weights are assigned through pairwise comparisons between criteria on a 1–9 scale (1 = equal importance, 3 = moderate, 5 = strong, 7 = very strong, 9 = extreme, with 2, 4, 6 and 8 as intermediate values). Reciprocal values (1/3, 1/5) fill the comparison matrix, whose normalized eigenvector gives the relative weight of each criterion, and the coherence of the judgments is checked with the consistency ratio (CR < 0.10).

Table 2. Comparison matrix between criteria

Criteria	Q	S	Ct	H	DT
Quality (Q)	1	4	1/3	2	1/3
Sustainability (S)	1/4	1	1/7	1/2	1/6
Cost (Ct)	3	7	1	5	2
History (H)	1/2	2	1/5	1	1/4
Delivery Time (DT)	3	6	1/2	4	1

The average of each row of the comparison matrix is calculated and then normalized using Equation (1) to match the same numerical scale used by AHP method.

$$Norm\ (x) = \left(\frac{x-min}{max-min} \times (9-1)\right) + 1 \qquad (1)$$

The rounded values of the normalization of the average of each criterion correspond to the weights of the criteria used in the ELECTRE I method, after normalization between 0 and 1. Table 3 presents a structured overview of the objective associated with each criterion (maximize or minimize). Thus, criteria such as cost and delivery time should be minimized, while quality, history, and sustainability should be maximized in accordance with the company's objectives. This clarification is essential for the correct application of the ELECTRE I method, as it directly influences the process of normalization to obtain the weights of the criteria and the alternatives.

Table 3. Comparison matrix between criteria

Objective	Criteria	Weight (W)
Minimize	Cost	0.3913
Minimize	Delivery Time	0.3043
Maximize	Quality	0.1739
Maximize	History	0.0870
Maximize	Sustainability	0.0435

To ensure a fair comparison between the qualitative criteria for each supplier, it was necessary to create a scale that would allow this data to be treated in a manner comparable to the quantitative data. To determine the weights associated with each supplier for the qualitative criteria (quality and sustainability), a procedure like that presented for the comparison matrix between the different criteria was applied, but this time for each supplier A, B, C, and D. After applying the procedure to all suppliers and qualitative alternatives and using the quantitative data associated with the criteria of cost, history, and delivery time, the decision matrix can be obtained.

After completing the decision matrix, it was normalized to allow comparison between criteria with different objectives. This normalization allows all values to be between 0 and 1, so differences between the alternatives can be analysed in a balanced way. Thus, Equation (2) was used for the criteria to be maximized, while Equation (3) was used for minimization.

$$Maximization(x) = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (2)$$

$$Minimization(x) = \frac{x_{max} - x}{x_{max} - x_{min}} \quad (3)$$

Normalization is essential so that the weighting of criteria is applied correctly and the differences between the various alternatives can be analysed in a fair and balanced manner. Without this step, the analysis would be distorted by differences in scale between the data.

Thus, Table 4 presents the normalized matrix multiplied by the respective weights. This step aims to reflect the relative importance of each criterion in the overall evaluation of alternatives, with the criteria with greater weight having a greater impact on the evaluation of alternatives. Without this step, all criteria would have the same weight in decision-making, which would not correspond to reality. Through this parameterization, the first four steps of the ELECTRE I method were completed.

Table 4. Weighted normalized decision matrix

Supplier	Ct	Q	DT	H	S
A	0.0978	0.1739	0.3043	0.0000	0.0326
B	0.3913	0.0217	0.1014	0.0870	0.0000
C	0.0000	0.1087	0.2029	0.0000	0.0435
D	0.2935	0.0000	0.0000	0.0544	0.0054
Weight	0.3913	0.1739	0.3043	0.0870	0.0435

Based on the weighted normalized matrix, the agreement matrix (Table 5) was created through a pair-by-pair comparison between suppliers. Thus, for each pair of alternatives, the agreement index was calculated using Equation (4).

$$C_{ij} = \sum_{if\ x_{norm\,i} > x_{norm\,j}}^{n} W_j + \sum_{if\ x_{norm\,i} = x_{norm\,j}}^{n} \frac{1}{2} W_J \quad (4)$$

Equation involves the sum of the weights of the criteria, in which a given supplier alternative performs better than the alternative to which it is being compared, that is, when the value of a given alternative in the weighted normalized matrix is greater than the value corresponding to the alternative being compared. If the performances are equal, half the weight of the criterion being evaluated is added.

Table 5. Agreement matrix

Supplier	A	B	C	D
A		0.5217	0.9130	0.5217
B	0.4783		0.4783	0.9565
C	0.0870	0.5217		0.5217
D	0.4783	0.0435	0.4783	

Equation (5) represents the calculation of the disagreement index D_{ik}, used in the creation of the disagreement matrix in the ELECTRE I method.

$$D_{ik} = \frac{max_{C_j(A_i) < C_j(A_k)} |C_j(A_j) - C_j(A_k)|}{max_j |C_j(A_j) - C_j(A_k)|} \quad (5)$$

This index measures the degree of opposition of one alternative A_k in respect of another A_i, considering the criteria in which A_k surpasses A_i. In this equation, the numerator identifies the criterion where A_k most surpasses A_i, that is, the largest negative difference value. The denominator corresponds to the largest difference between the performances of two suppliers, considering all criteria. These calculations were performed for all suppliers' pairs.

The disagreement matrix (Table 6) shows the indices calculated for each pair of suppliers. These vary between 0 and 1, so the closer to 1, the greater the opposition, i.e., the more a particular supplier is surpassed. Conversely, the closer to 0, the lower the disagreement, meaning that a given alternative is not meaningfully inferior in any criterion compared to the other.

Table 6. Disagreement matrix

Supplier	A	B	C	D
A		1.0000	0.1075	0.6431
B	0.6913		0.2594	0.0533
C	1.0000	1.0000		1.0000
D	1.0000	1.0000	0.6913	

After determining the agreement and disagreement matrices, a threshold is applied so that both matrices have dichotomous values. The value of this threshold is obtained by averaging the values determined in the respective matrices. The purpose of this intermediate process is to filter preferences so that preferences considered insufficient (low value) are disregarded and the remaining ones are overclassified, making them strong for the final classification. The aim is to obtain a binary classification that demonstrates the dominance between suppliers and not to create a ranking between them.

Thus, a threshold of 0.5 (average of all values in the matrix) is applied to the agreement matrix and a threshold value of 0.7038 is applied to the disagreement matrix.

4. Results and Discussion

This section presents the results demonstrated by Ramos et al. [21] for the case study under analysis and the application of the ELECTRE I method through the use of a dashboard developed in the Python programming language, using the parameterization described in the previous section. Finally, the methods are compared considering their qualitative assessment in terms of suitability for the industrial decision-making process.

4.1. AHP outcomes

According to Ramos et al. [21], the application of the AHP method for this case study for supplier selection indicated that supplier A is the most suitable, with a priority rank of 30.80%, the highest among the evaluated competitors. To present the AHP method results, an application and a dashboard for the case under study were developed using Python programming language (Figure 4).

This demonstrates that supplier A best meets the defined selection criteria. Suppliers C, B, and D presented priorities of 25.90%, 23.20%, and 20.10%, respectively, indicating less suitability compared to supplier A. Although they are valid options, their lower scores suggest that they are in secondary positions in the selection process. Therefore, based on the AHP results, it is recommended to prioritize supplier A for contracting, ensuring a well-founded decision aligned with the established criteria.

Regarding the relative priority of the supplier selection criteria, the results show a pronounced asymmetry in the relative priority weights assigned to the five supplier-selection criteria, with Cost Criterion accounting for approximately half of the total decision weight (≈0.50), followed distantly by Quality (≈0.22), History (≈0.14), Delivery Time (≈0.09), and Sustainability (≈0.05). The dominance of the cost criteria suggests a cost-driven decision context. The near-negligible weight attributed to sustainability is noteworthy given the increasing emphasis on environmental and social governance in the nowadays supply chains [22].

The stacked composition of each bar (A to D suppliers) depicts heterogeneity in judgment that is otherwise obscured by the aggregated totals. For instance, supplier B has a relatively weight regarding History criterion when compared to the other suppliers, whereas Cost priority is comparatively homogeneous across all suppliers, a pattern that signals differential consensus strength across criteria not conveyed by the final priority vector alone.

While the ranking of Cost > Quality > History > Delivery Time > Sustainability offers a plausible reflection of priorities in a cost-sensitive procurement environment, its adoption for operational decision-making should be contingent upon supplementary validation. This includes, specifically, disclosure of consistency ratios, justification of the aggregation procedure and sensitivity testing.

Thus, this method allows to ensure that the observed hierarchy reflects decision-maker preferences rather than an exercise of methodological choices or unrepresentative expert input.

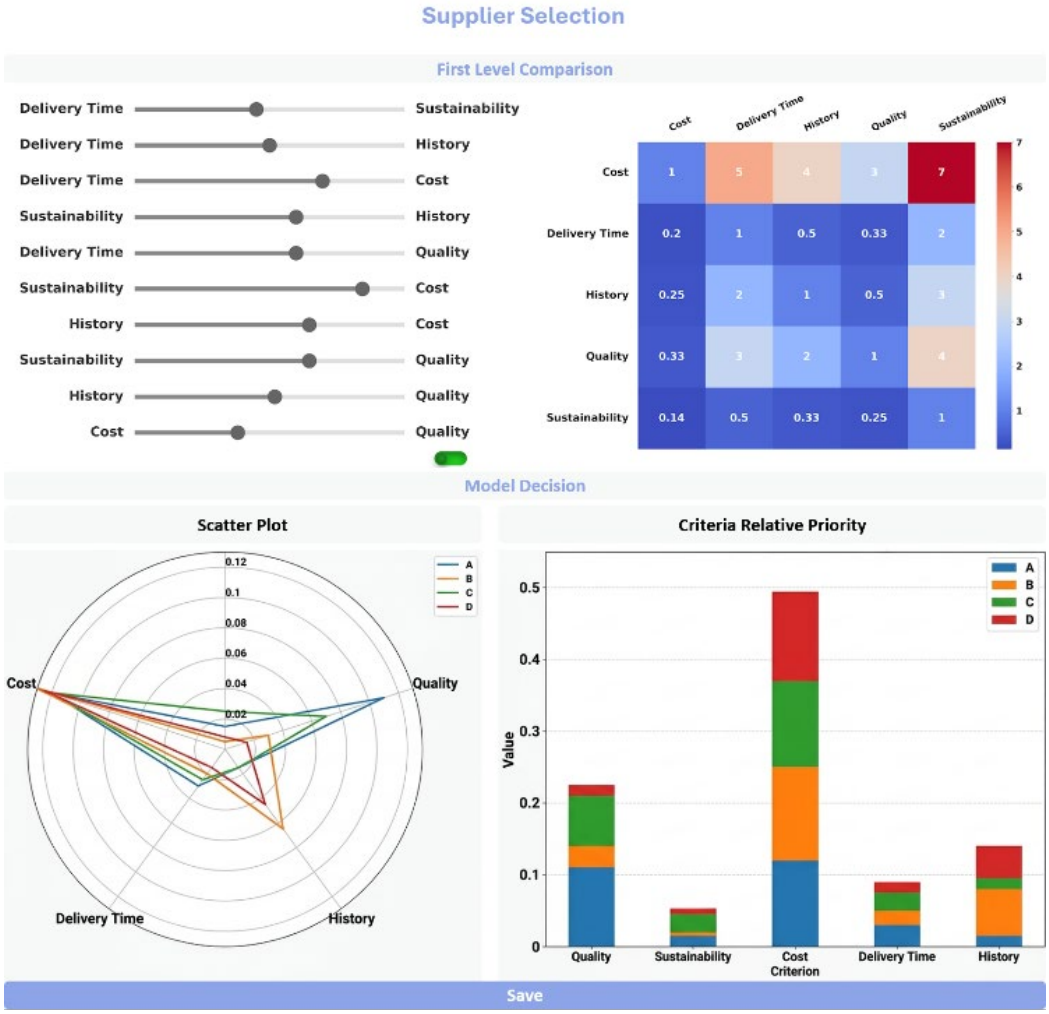

Figure 4. AHP method criteria priority results

4.2. ELECTRE I outcomes

The aggregate dominance matrix (Table 7) results from the combination of the agreement and disagreement matrix after performing its dichotomous transformation, allowing the identification of the alternatives that prevail over the others, as well as the alternatives that are surpassed. When both tables have the value 1 in the same cell, it is transferred to the aggregate matrix, otherwise the value 0 is entered.

The supplier A is the best alternative, followed by B. Supplier D is surpassed by suppliers A and B. The "Sum" column represents the number of suppliers that surpass each supplier, whereas the "Sum" row represents the number of suppliers that each supplier surpasses.

Therefore, supplier C is only surpassed by A, while D is surpassed by both suppliers A and B. Supplier A appears to be the best alternative, since it surpasses both C and D, while B only surpasses D.

To enable an easier application of the ELECTRE I to the case under study, a dashboard using Python programming language (v. 3.13) was developed. To create the plots, it was used Dash library (3.3.0) and dash-cityscape (1.0.2) for plotting the final alternatives' dominance relationship.

Table 7. Aggregate dominance matrix

Supplier	A	B	C	D	Sum
A		0	1	1	2
B	0		0	1	1
C	0	0		0	0
D	0	0	0		0
Sum	0	0	1	2	

The goal of the dashboard, presented in Figure 5, is to allow for a simple and easier data insertion regarding the number of alternatives and criteria, and their corresponding objective goal. Inserted values are validated to ensure data

validity (example, the criteria weight sum is 1) and to enable the model execution.

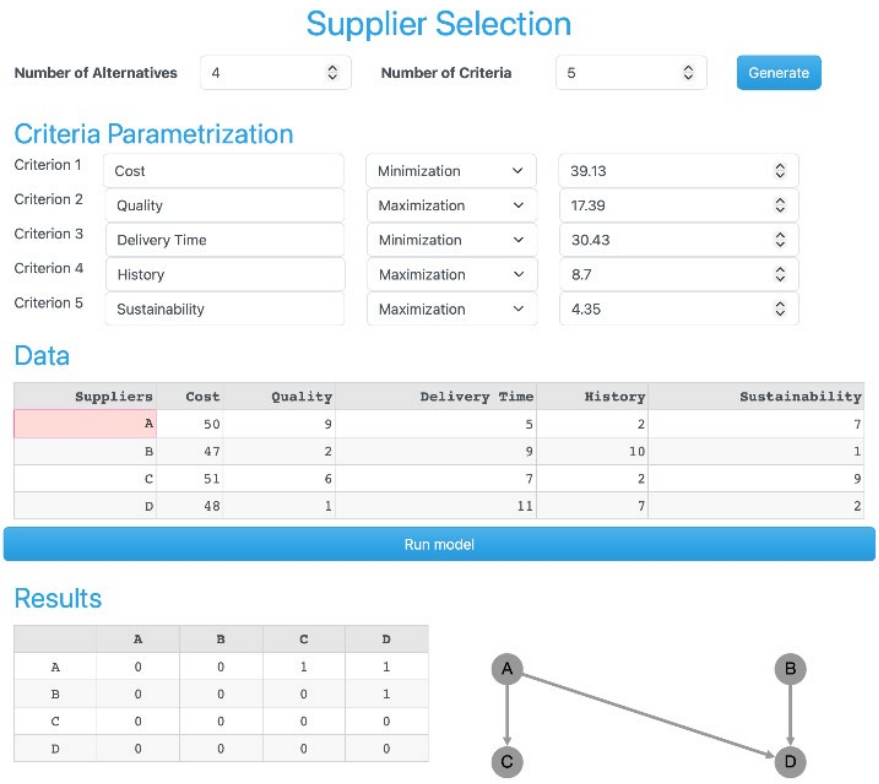

Figure 5. Developed dashboard for ELECTRE I supplier selection

Results are shown in a table format (the aggregated dominance matrix) and in a dominance graph. This diagram illustrates the process of comparing and selecting the most suitable supplier according to the valued criteria. Observing the graph generated for the case study under analysis, Supplier A dominates C and D, which is also dominated by B. Supplier C is only surpassed by A. Suppliers A and B are not surpassed by any other supplier.

4.3. Added-value of dashboards

The developed dashboards do not add analytical functions beyond those already available in existing MCDM software. Commercial packages such as Expert Choice and Super Decisions support AHP, and open-source libraries such as pyDecision implement both AHP and the ELECTRE family and now include a graphical interface [20], [23], [24]. Nevertheless, the dashboards serve as an enabling instrument and offer three advantages over these tools: i) they provide a practical, integrated, purpose-built workflow for supplier selection; ii) they ensure reproducibility, as they are released as open-source code and rely on an archived dataset; and iii) they offer a user-friendly interface.

Above all, the dashboards make each step of the method transparent. The ELECTRE I dashboard displays the weighted normalized matrix, the concordance and discordance matrices, the thresholds applied, and the resulting aggregate dominance matrix and outranking graph. The AHP dashboard reports the priority vectors and the consistency ratio. A procurement manager or auditor can therefore trace why one supplier outranks another, instead of receiving only a final ranking. This is particularly relevant in supplier selection, where decisions often must be justified internally or to the suppliers themselves.

Dashboards also contribute to the digitalization of procurement processes. In industrial companies, supplier selection is often carried out with spreadsheets or with judgement alone. The developed dashboards turn it into a structured, repeatable digital procedure in which the data, judgements and parameters are recorded, validated before execution and kept for later review. This supports the move from intuition-based purchasing decisions to traceable, data-supported ones, and it allows the analysis to be repeated quickly when supplier data or company priorities change. This is even more relevant for small and medium-sized enterprises which typically do not apply decision-support systems or have in-house MCDM expertise [9]. Because the dashboards are open source, require no programming, they offer such companies a low-cost and traceable supplier-selection procedure.

4.4. Comparison of Methods Performance

This study was based on the adaptation of a supplier selection case in the textile industry, originally developed using the AHP method, for a comparative analysis with the ELECTRE I method. This approach allows to observe how different multi-criteria methods can lead to distinct interpretations, even when applied to the same set of data and criteria. Table 8 summarizes the main aspects that differentiate both methods, highlighting the influence they have directly on the process and the results of the decision in the context of supplier selection.

The AHP provides a complete and ordered ranking of alternatives, facilitating the direct choice of the best option, while ELECTRE I generates a dominance graph that allows the elimination of dominated alternatives and the identification of a viable subset, being used in a complementary way to reinforce confidence in the decision. AHP is more sensitive to variations in the weights of the criteria, while ELECTRE I proves to be more suitable in the face of these changes and more suitable for handling conflicts between criteria [25].

In terms of interpretation, AHP is more intuitive, while ELECTRE I requires greater graphical analysis skills. Regarding application, AHP is better suited to well-structured problems, while ELECTRE I is more appropriate for complex contexts. In fact, ELECTRE I uses true criteria, with no indifference or preference thresholds, so it does not model uncertainty explicitly [26], [27].

The application of the ELECTRE I method allowed for the comparison of suppliers considering multiple criteria. It was observed that supplier C is surpassed only by A, while D performs worse than A and B, highlighting supplier A as the best alternative. The analysis using the AHP method confirms this hierarchy, also indicating supplier A as the most suitable among the four evaluated. Thus, both methods converge on the same conclusion, highlighting the reliability of the decision based on a careful evaluation of suppliers according to the preferences demonstrated by the decision-maker.

In ELECTRE I, supplier A clearly emerges as the best alternative, but the choice of a second supplier may not be so immediate. Supplier C is overrated only by A, while D is overrated by A and C. Thus, depending on how the graph is interpreted, considering who is overrated by fewer suppliers or who overrates more, the second position can be attributed to supplier C or B, requiring a more careful analysis of the overclass relationships. In the AHP analysis, supplier C emerges as the second choice, although the percentages for B and C are very close, which indicates a margin for weighing these two alternatives as possible secondary choices. This analysis would have to be carried out by the company's decision maker, who has a system to support and validate their decisions within the company.

Thus, AHP and ELECTRE I answer different decision questions: AHP yields a complete, compensatory ranking suited to final selection, whereas ELECTRE I returns a non-outranked subset that supports shortlisting and prevents poor performance on a critical criterion from being offset. Their combined use offers a practical cross-check.

In the supplier-selection literature, AHP and ELECTRE are frequently used together. In Salvador et al. [24], AHP supplies the criteria weights and ELECTRE ranks the alternatives. Both methods are never compared as alternative decision models. Only one result is produced, so it is impossible to see how far the recommendation depends on the method chosen. The present study does the opposite. It keeps the data, criteria and decision-maker judgements fixed and changes only the aggregation logic.

This isolates the effect of the method, which hybrid studies cannot do. Earlier comparative work has shown that different MCDM methods can give different recommendations for the same problem [20], [29].

It is also important to mention that comparative evidence of this kind for supplier selection in manufacturing, using the choice-oriented ELECTRE I, is still scarce.

Table 8. Practical implications of applying AHP and ELECTRE I in the case study [24], [28]

Aspect	AHP	ELECTRE I
Type of result	Complete and ordered ranking of alternatives	Dominance graph with relationships between alternatives
Decision approach	Direct selection of the supplier with the highest score	Elimination of dominated alternatives and selection of a viable subset
Sensitivity to weights	High sensitivity – small changes affect the ranking	Lower sensitivity – is not affected by moderate variations
Handling of conflicting criteria	Weighted integration (weighted average of judgments)	Pairwise evaluation with thresholds – better conflict management
Clarity in communicating the decision	Easy to interpret by non-specialist decision-makers	Requires graphical analysis and interpretation of relationships

Context suitability	Structured decisions with well-defined objectives	Uncertain environments or cases with very close alternatives

4.5. Managerial Implications

The results offer procurement managers several practical lessons. First, the convergence of AHP and ELECTRE I on supplier A, obtained from the same information base, suggests that this choice is not an artefact of a single method. When both tested methods agree with different logics, i.e., compensatory aggregation versus outranking, the decision-maker can proceed to procurement negotiation with greater confidence. Applying both methods works as a cross-check at low marginal cost, mainly because the dashboards reduce the effort of data input, model implementation and performance analysis.

Secondly, the methods answer different managerial questions and should be matched to the decision under scope. The AHP method is suited to situations that require a single, easily communicated choice, since its priority values (30.8%, 25.9%, 23.2% and 20.1%) can be presented to non-specialist stakeholders without further explanation. On the other hand, the ELECTRE I method is better suited to shortlisting, since it removes dominated alternatives and returns a viable subset.

In this case, suppliers A and B are not surpassed by any other supplier, so the company could keep both as candidates for a diversified sourcing strategy. This matters because the final decision may involve a portfolio of suppliers rather than a single one, as previously discussed. Thus, both methods disagree about the second position, which is informative.

AHP places C second and B third, but only by a small margin, while method ELECTRE I leaves B unsurpassed and surpasses C once. Rather than being treated as inconsistency, this should alert managers that the choice between B and C depends on the preference model. Thus, the decision should be supported by additional information such as total cost of ownership, supply-risk exposure or the strategic value of keeping a backup supplier.

A further managerial contribution of this work is the development of the two dashboards, which turn both methods into tools that can be used without programming or MCDM expertise. The user only defines the number of alternatives and criteria, the objective of each criterion (minimize or maximize) and the corresponding data or pairwise judgments, so the model is simulated from the same interface. The dashboards implement the conversion procedure of explained at section 3.2, so both methods run from one input, show all intermediate matrices and validate inputs before execution. The dashboards can be used to different case studies and incorporate different supplier selection criteria through the interface which can be easily managed.

Built-in validation of the imputed values reduces the risk of errors, which are a common source of unreliable results in spreadsheet-based decision analyses as also documented in literature [30]. The outputs are presented visually, as priority charts in the AHP dashboard and as an aggregate dominance matrix and dominance graph in the ELECTRE I dashboard, which supports the discussion of results with stakeholders who are not familiar with the underlying calculations [31], [32].

5. Main Conclusions

The increase of data available to decision support systems allows decision makers to establish their choices on larger quantities of information, rather than relying on immediate data or intuitive judgment.

Within supply chain management, supplier choice represents a determining step in establishing contracts, contributing to a more competitive position for the company and to lasting relationships. This work examines two multi-criteria decision-making methods applied to supplier selection.

Both were tested in a real-world scenario and compared with one another, to assess their suitability and limitations given the specific characteristics of the problem. The AHP method is structured into seven stages and allows for the integration of quantitative and qualitative criteria, converting subjective judgments into a numerical scale for comparison purposes.

In turn, the ELECTRE I method relies on pairwise comparison between alternatives, building agreement and disagreement matrices that establish the degree of dominance.

Dashboards were also built using the Python programming language to support the implementation of methods. Through a straightforward interface, the aim was to allow input of the required data in a direct manner, generating, once the model is run, the aggregate dominance matrix and the corresponding dominance graph, giving the user a visual reading of the degree of predominance among suppliers.

The results obtained from both AHP and ELECTRE I converged on identifying supplier A as the most suitable option for the company in this case study. Although AHP is widely used to rank suppliers, its structure leads to a fixed ordering of alternatives, whereas the ELECTRE I method allows for a more adaptable analysis, considering the concordance and discordance relationships between criteria, making it appropriate for more complex industrial settings.

Despite the pertinence of the research, the present work has few limitations. The study relies on a single case from the textile dyeing industry, with four suppliers and five supplier selection criteria. This is, in fact, a small decision universe, in which agreement between methods is easier to obtain when compared with problems with many alternatives and conflicting criteria. Yet, the methods were

adapted to treat both quantitative and qualitative selection criteria, where qualitative parameters (quality and sustainability) were converted into a numerical scale, which is an important contribution. So, conclusions about suitability for "complex industrial contexts" are therefore analytical rather than empirically established.

As future work, it is proposed to study the application of AHP and ELECTRE I methods in other industrial contexts, comparing their combined application of both methods, with a view to supporting more complete and better-informed decisions.

Future work could also include a sensitivity analysis to examine how changes in the criteria weights and in the concordance and discordance thresholds affect the final ranking of suppliers. This would provide stronger evidence of the robustness of the proposed approach.

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