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APLICAÇÃO DO MÉTODO AHP NA SELEÇÃO ESTRATÉGICA DE FORNECEDORES: INTEGRAÇÃO COM A GESTÃO DE RISCOS EM UMA EMPRESA DO AGRONEGÓCIO

APPLICATION OF THE AHP METHOD IN STRATEGIC SUPPLIER SELECTION: INTEGRATION WITH RISK MANAGEMENT IN AN AGRIBUSINESS COMPANY

APLICACIÓN DEL MÉTODO AHP EN LA SELECCIÓN ESTRATÉGICA DE PROVEEDORES: INTEGRACIÓN CON LA GESTIÓN DE RIESGOS EN UNA EMPRESA DEL AGRONEGOCIO

Liliana Gomes Holanda
Pós-graduada, Brasil
E-mail: liliana_holanda@hotmail.com

Isabela Neto Piccirillo
Doutora, Universidade Federal de Lavras, Brasil
E-mail: isabela.piccirillo@ufla.br

Marina Gomes Murta Moreno
Doutora, Universidade Federal de Alfenas (UNIFAL-MG), Instituto de Ciência e Tecnologia (ICT), Poços de Caldas (MG), Brasil
E-mail: marina.moreno@unifal-mg.edu.br

Luís Fernando Magnanini de Almeida
Doutor, Universidade Federal de Uberlândia, Brasil
E-mail: magnanini.lf@gmail.com

Resumo

A seleção de fornecedores consolidou-se como uma competência estratégica crítica diante da crescente complexidade das cadeias de suprimentos e da maior exigência por resiliência e continuidade operacional. Este estudo propõe um modelo de apoio à decisão multicritério para avaliar e selecionar fornecedores de componentes plásticos para uma empresa do agronegócio, integrando o Analytic Hierarchy Process (AHP) à gestão de riscos da cadeia de suprimentos, com o objetivo de aumentar a eficiência das compras e a segurança do abastecimento. A metodologia proposta oferece uma avaliação estruturada de critérios qualitativos e quantitativos, derivados da literatura e calibrados ao contexto organizacional. Ao incorporar fatores de mitigação de riscos às dimensões tradicionais de desempenho (custo, qualidade e confiabilidade de entrega), o modelo permite uma avaliação

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equilibrada das alternativas concorrentes. Os resultados empíricos demonstram que a associação do AHP à análise de riscos favorece decisões de suprimento mais robustas e resilientes, alinhadas aos objetivos estratégicos da empresa e à continuidade de suas operações logísticas. Por fim, o estudo evidencia a eficácia do AHP como ferramenta de apoio à decisão na avaliação de fornecedores em ambientes marcados por incerteza persistente.

Palavras-chave: Seleção de Fornecedores; AHP; Gestão de Riscos; Tomada de Decisão Multicritério; Cadeia de Suprimentos.

Abstract

Supplier selection has emerged as a critical strategic capability in response to growing supply chain complexity and the heightened demand for operational resilience and continuity. This study proposes a multi-criteria decision-making framework to evaluate and select suppliers of plastic components for an agribusiness enterprise, integrating the Analytic Hierarchy Process (AHP) with supply chain risk management to enhance procurement efficiency and supply security. The proposed methodology provides a structured evaluation of qualitative and quantitative criteria derived from the literature and calibrated to the organizational context. By incorporating risk-mitigation factors alongside traditional performance dimensions (namely cost, quality, and delivery reliability) the model enables a balanced assessment of competing alternatives. The empirical results demonstrate that coupling AHP with risk analysis fosters more robust, resilient sourcing decisions aligned with the firm's strategic objectives and the continuity of its logistics operations. Ultimately, this study underscores the effectiveness of AHP as a decision-support tool for supplier evaluation in environments characterized by persistent uncertainty.

Keywords: Supplier Selection; AHP; Risk Management; Multicriteria Decision-Making; Supply Chain.

Resumen

La selección de proveedores se ha consolidado como una capacidad estratégica crítica ante la creciente complejidad de las cadenas de suministro y la mayor exigencia de resiliencia y continuidad operativa. Este estudio propone un modelo de apoyo a la decisión multicriterio para evaluar y seleccionar proveedores de componentes plásticos para una empresa del agronegocio, integrando el Proceso de Análisis Jerárquico (AHP) con la gestión de riesgos de la cadena de suministro, con el fin de mejorar la eficiencia de las compras y la seguridad del abastecimiento. La metodología propuesta ofrece una evaluación estructurada de criterios cualitativos y cuantitativos, derivados de la literatura y ajustados al contexto organizacional. Al incorporar factores de mitigación de riesgos junto con las dimensiones tradicionales de desempeño (costo, calidad y confiabilidad de la entrega), el modelo permite una evaluación equilibrada de las alternativas en competencia. Los resultados empíricos demuestran que la combinación del AHP con el análisis de riesgos favorece decisiones de abastecimiento más robustas y resilientes, alineadas con los objetivos estratégicos de la empresa y

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con la continuidad de sus operaciones logísticas. Finalmente, el estudio pone de relieve la eficacia del AHP como herramienta de apoyo a la decisión en la evaluación de proveedores en entornos caracterizados por una incertidumbre persistente.

Palabras clave: Selección de Proveedores; AHP; Gestión de Riesgos; Toma de Decisiones Multicriterio; Cadena de Suministro.

1. Introduction

The growing complexity of global markets and the deepening dependence on external partners have positioned supplier selection as a vital determinant of organizational competitiveness, quality performance, and operational sustainability (Carr & Pearson, 1999). A structured and methodologically rigorous evaluation process enables decision-makers to systematically identify critical decision criteria, assess associated operational vulnerabilities, and make procurement choices fully aligned with the organization's overarching strategic objectives (Van Weele, 2010).

For a supply chain to maintain high performance, it must balance cost efficiencies, meet dynamic market demands, and proactively mitigate systemic risks (Christopher & Peck, 2004; Wagner & Bode, 2006). Integrating risk management directly into supplier evaluation is therefore imperative in environments susceptible to logistics disruptions, demand volatility, and supplier defaults. As Christopher & Peck (2004) demonstrate, sound risk mitigation mechanisms can substantially attenuate disruptions, safeguarding organizational performance and long-term viability.

For PMBOK (2021), it is necessary a systematic deployment of risk management across all project phases to mitigate threats and capture strategic opportunities. Similarly, ISO 31000:2018 establishes standardized guidelines for risk management, reinforcing the strategic necessity of a structured, proactive architecture for risk identification, assessment, and treatment (ABNT, 2018).

In the agricultural and agribusiness sectors specifically, supply chain sustainability has emerged as an urgent priority in response to mounting global pressures, including natural resource scarcity and environmental degradation (Mangla et al., 2022). Securing sustainable growth within this sector demands robust, well-informed decision-making at every node of the value chain (Putra et al., 2025),

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where structured decision-support methodologies play an indispensable role in hedging against uncertainty and managing systemic supply risks.

Achieving these outcomes requires that supplier evaluation is aligned with broader corporate strategy, balancing both quantitative and qualitative criteria (Carr & Pearson, 1999). Selecting optimal suppliers not only enhances product and service quality, but also drives substantial cost rationalization, bolsters operational efficiency, and strengthens the organization's resilience against unforeseen supply network disruptions.

Consequently, multicriteria decision-making (MCDM) methodologies have gained widespread traction in operations research (Vaidya & Kumar, 2006; Pacheco et al., 2022). The AHP is particularly well-suited to complex decision landscapes such as supplier selection, as it provides a structured framework for decomposing multidimensional problems and synthesizing both qualitative judgments and quantitative performance metrics through pairwise comparisons.

By offering a rigorous analytical framework, AHP enables managers to evaluate suppliers under concurrent exposure to supply risks (Saputro et al., 2024). Coupling AHP with risk management practices further fortifies the supplier evaluation process and enhances overarching supply chain resilience (Manik, 2023). These approaches facilitate a multidimensional assessment of competing alternatives, encompassing critical parameters such as supplier reliability, responsiveness, flexibility, and adaptive capacity to evolving organizational demands.

This study proposes an AHP decision-support framework integrated with supply risk management to evaluate and select suppliers of plastic components for an agribusiness firm, thereby enhancing procurement efficiency and safeguarding supply continuity.

2. Theoretical Framework

This section outlines the theoretical underpinnings of the study, synthesizing supply chain management, supplier selection criteria, and supply risk management before formalizing the Analytic Hierarchy Process (AHP) as the operational decision-support tool.

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Pages: 1-41

2.1 The Supplier Selection Process

Strategic supplier selection is an inherently complex, multidimensional decision-making process that extends well beyond transactional cost minimization, encompassing interdependent qualitative and quantitative criteria across operational and strategic dimensions (Chen & Paulraj, 2004). Within modern SCM, supplier selection must be approached as a critical strategic imperative, given its direct influence on market competitiveness, operational efficiency, and overall organizational resilience (Wagner & Bode, 2006).

Effective supply chain governance necessitates the systematic integration of strategic and operational risk parameters, particularly in operating environments characterized by persistent volatility and systemic uncertainty (Christopher & Peck, 2004; Tang, 2006). In this context, supplier selection serves as a core managerial mechanism for attenuating structural supply vulnerabilities. Inappropriate sourcing decisions can disrupt operational continuity, precipitating delivery lead-time delays, cost overruns, quality non-conformances, and the progressive erosion of inter-organizational trust (Jüttner et al., 2003).

Historically, classical procurement models were dominated by deterministic criteria, most notably purchase price, product quality, and delivery performance (Weber et al., 1991). However, the acceleration of globalization and the increasing structural complexity of supply networks have expanded the decision space to encompass supplier reliability, operational flexibility, technological innovation capability, and risk management maturity. Contemporary literature demonstrates that vendor evaluation frameworks must transcend traditional deterministic paradigms by incorporating robust decision-support mechanisms capable of handling uncertainty and managerial cognitive hesitation in volatile environments (Beleski & Lima Junior, 2023).

Supplier selection must be operationalized as a cross-functional collaborative process, engaging stakeholders from operations, procurement, finance, and quality assurance to ensure that both technical specifications and overarching strategic requirements are comprehensively captured (Monczka et al., 2016). This evaluation

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Pages: 1-41

typically unfolds across well-defined sequential stages: strategic requirements definition, supplier prospecting and pre-qualification, rigorous multi-criteria evaluation, and final sourcing selection culminating in contract formalization (De Boer et al., 1998).

Institutionalizing this structured multi-criteria approach mitigates operational exposure and ensures that chosen partners align with the firm's long-term strategic posture. For instance, the systemic vulnerability of single-sourcing dependencies and vendor lock-in can be proactively identified, evaluated, and mitigated through structured multi-criteria decision tools such as AHP (Wagner & Bode, 2006; Nydick & Hill, 1992).

2.2 Risk Management in the Supply Chain

The expanding complexity and topological dispersion of modern supply networks have elevated supply chain risk management (SCRM) to an essential strategic mandate. According to Khan et al. (2008), risk represents an inherent, persistent condition of dynamic business ecosystems, necessitating robust risk-governance architectures underpinned by rigorous analytical methodologies and tools.

Waters (2007) conceptualizes risk management as a systematic process comprising the identification, assessment, and mitigation of operational vulnerabilities, with the explicit aim of preventing financial losses and safeguarding uninterrupted operational continuity. From a complementary standpoint, Cassidy (2005) frames risk management as the cross-functional coordination, planning, and control of enterprise activities designed to limit capital exposure and shield corporate revenue streams from volatility.

Although risk has always accompanied commercial and industrial activities, its institutionalization as a formal management discipline accelerated significantly during the 1990s, driven primarily by systemic interdependencies arising from global economic integration (Dickinson, 2001). Under ISO 9001:2015, risk is formally codified as the "effect of uncertainty on objectives," explicitly establishing that risk encompasses both adverse disruptions and positive deviations—the latter

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representing upside opportunities to be captured. Aven (2007) advances this theoretical conceptualization by framing risk as an ontological triad: the dynamic interaction among triggering events, their operational consequences, and the systemic uncertainties governing their likelihood.

From a quantitative modeling standpoint, Verma and Verter (2007) define risk analytically as expected loss, whereas Lowrance (1976) characterizes it as "a measure of the probability of occurrence and the magnitude of the resulting harm." Within this quantitative framework, deploying structured decision-support models becomes imperative. The systematic identification and hierarchical prioritization of operational vulnerabilities through multicriteria techniques serve as a vital proactive strategy to anticipate systemic disruptions, rank mitigation strategies, and preserve organizational assets (Lowrance, 1976; Verma & Verter, 2007; Silva et al., 2023).

2.3 Analytic Hierarchy Process

The AHP is a structured multi-criteria decision-making (MCDM) methodology that enables the relative measurement of heterogeneous criteria grounded in systematic evaluations elicited from domain experts or knowledgeable practitioners (Saaty, 2005). Developed by Saaty in the 1970s, this approach supports multi-attribute alternative prioritization through a hierarchical analytical architecture (Saaty, 2003). Its core mathematical principle relies on decomposing a complex decision problem into a structured hierarchy of criteria and sub-criteria, assuming preferential independence among elements within the same level (Jharkharia & Shankar, 2007). Recent empirical and methodological studies confirm AHP's mathematical robustness and reliability in structuring decision priorities within complex supplier selection problems, demonstrating high procedural consistency relative to other multicriteria methods (Neves et al., 2022).

In strategic sourcing and vendor evaluation, AHP is typically deployed at the terminal synthesis stage of the procurement process, where decision-makers must rigorously compare competing strategic alternatives while capturing the cognitive dimensions and subjective trade-offs inherent in managerial judgment (Bhushan, 2004). According to Nydick & Hill (1992), the method provides exceptional decision

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support in contexts characterized by conflicting objectives that require simultaneous reconciliation of qualitative and quantitative metrics.

The methodology is anchored in three foundational pillars: hierarchical structuring of the decision problem, systematic pairwise comparisons of criteria, and numerical prioritization via a fundamental ratio scale that captures the relative dominance among elements (Saaty, 1990). Once the hierarchical model is established, competing alternatives are evaluated pairwise against each operational criterion, transforming subjective qualitative preferences into calibrated numerical priority weights (Saaty, 2008).

In practice, executing the AHP begins by disaggregating the overarching goal into a functional hierarchy of criteria and sub-criteria, providing analytical transparency for each discrete dimension. Following this structuring phase, available alternatives are evaluated through pairwise comparison matrices. Utilizing Saaty's fundamental measurement scale, subjective expert judgments are converted into ratio-scale priorities that quantify the decision-makers' preferences and strategic trade-offs (Saaty, 2008).

A critical mathematical prerequisite for model validity is criterion homogeneity within each hierarchical tier; elements must share a comparable order of magnitude to prevent distortion in the preference ratios. Furthermore, evaluation criteria must remain mutually exclusive and non-redundant to avoid systemic bias and structural inconsistency (Saaty, 1990). Pairwise comparisons are conducted using Saaty's 1–9 fundamental scale (Saaty, 1980): a value of 1 denotes equal importance between two elements, whereas 9 signifies absolute dominance or extreme preference of one criterion over another.

Saaty (1980) recommends using odd integer values along the fundamental scale to establish sharp discrimination between priority levels and enhance evaluation consistency, reserving intermediate even integers for adjacent compromise judgments or instances of evaluator hesitation. The resulting pairwise judgments are arranged into an $n \times n$ reciprocal square matrix $A = [a_{ij}]$, satisfying the property of directional reciprocity:

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Pages: 1-41

$$a_{ij} = \frac{1}{a_{ji}} \quad and \quad a_{ii} = 1 \quad \forall\, i, j = 1, \dots, n$$

where if criterion A_i is judged three times more important than criterion A_j ($a_{ij} = 3$), then by mathematical necessity $a_{ji} = 1/3$ (Saaty, 1980).

Once all pairwise comparison matrices are completed, local priority vectors $w = [w_1, w_2, \dots, w_n]^T$ are derived using the standard eigenvector method or its normalized column-sum approximation:

$$w_i = \frac{1}{n}\sum_{j=1}^{n} \quad \frac{a_{ij}}{\sum_{k=1}^{n} \quad a_{kj}}$$

The resulting vector represents the relative priority weight of each criterion within the overall decision model (Saaty, 1980). To assess the cardinal and ordinal transitivity of expert evaluations, a consistency test is performed. This diagnostic computes the Consistency Index (CI) and the Consistency Ratio (CR) based on the maximum principal eigenvalue (λ_{max}) comparison matrix A. The principal eigenvalue λ_{max} estimated using the standard AHP weighted-sum formulation: the judgment matrix A is multiplied by the derived priority vector w to yield the weighted-sum vector Aw; each entry of Aw is divided by its corresponding priority weight w_i, and λ_{max} calculated as the arithmetic mean of these individual ratios:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \quad \frac{(Aw)_i}{w_i}$$

Based on $\lambda_{max}$the Consistency Index (CI) is formulated as:

$$CI = \frac{\lambda_{max} - n}{n-1}$$

where n denotes the matrix dimension (the number of evaluated criteria). The Consistency Ratio (CR) is subsequently determined by:

$$CR = \frac{CI}{RI}$$

where RI represents the Random Index derived from empirical simulations of randomly generated reciprocal matrices of size n (Appendix Table A3). A Consistency Ratio of $CR < 0.10$ establishes that the comparison matrix maintains acceptable mathematical consistency, validating the derived priority weights for subsequent decision synthesis. Conversely, values of $CR \geq 0.10$ denote inconsistent judgments, necessitating a structured re-evaluation of the pairwise comparisons (Saaty, 1990).

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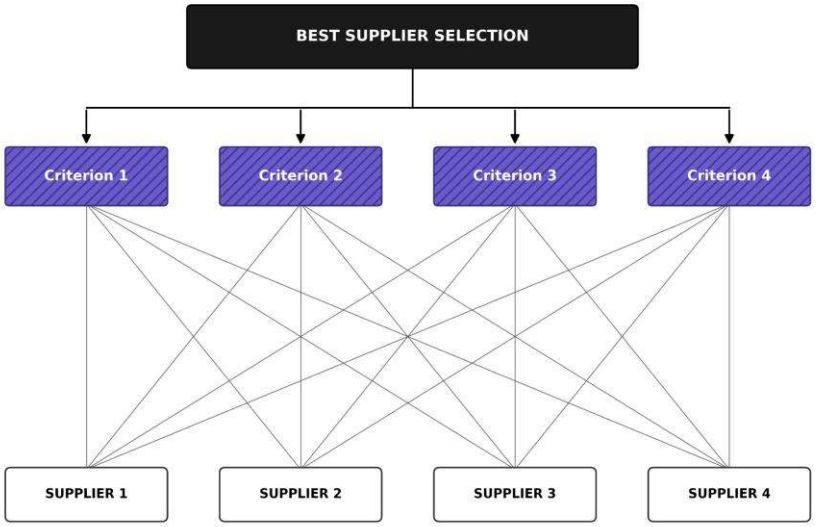
Figure 1. Criteria for supplier selection



Source: Adapted from Nydick & Hill (1992).

3. Research Method

This empirical investigation operationalizes a structured multi-criteria decision-support framework that couples the AHP with supply chain risk management practices. Grounded in the premise that strategic procurement decisions must balance operational performance with supply network resilience (Carr & Pearson, 1999; Christopher & Peck, 2004; Tang, 2006; Wagner & Bode, 2006), the proposed model evaluates competing alternatives across both conventional procurement metrics and a dedicated supply risk dimension.

This risk construct explicitly evaluates supplier-level vulnerabilities, including exposure to upstream disruptions, single-sourcing dependencies, manufacturing bottlenecks, and compliance with technical standards and certifications — capturing each vendor's capability to anticipate, mitigate, and absorb operational threats. To evaluate the framework empirically, a single case study design was selected as the overarching methodological strategy.

3.1 Case Study

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Pages: 1-41

The empirical application was conducted within a manufacturing facility of a multinational agricultural machinery corporation operating in Brazil. A single-case study strategy is particularly advantageous for investigating complex, decision-making phenomena within their real-world operational contexts, providing an empirical granularity that large-sample quantitative surveys cannot capture (Yin, 2015). In this research, this empirical design allowed for a contextualized analysis of how AHP, combined with risk management parameters, resolves the sourcing constraints of the focal enterprise.

The investigated plant operates under a high-volume, serial assembly regime dedicated to manufacturing compact, medium, and heavy-duty agricultural tractors. Under this operating structure, workstation balance depends on tight functional synchronization between internal operations and external suppliers to prevent line stoppages. Consequently, supplier reliability directly dictates the operational throughput and delivery lead times of finished equipment.

The empirical application focused on the vendor selection process for functional plastic components. This part family was selected due to its operational criticality and the acute structural constraints of its regional supply base, which features stringent technical tolerances and a limited pool of qualified manufacturers.

The components under study consist of exterior functional covering parts assembled directly onto the tractor chassis. While categorized as exterior components, their assembly is mandatory for final product release; any stockout, logistical delay, or technical non-conformance immediately halts the assembly line, undermining plant productivity and customer delivery schedules.

This operational vulnerability is compounded by complex manufacturing specifications: these parts involve specialized thermoforming and injection processes with tight geometric tolerances and have a documented history of quality non-conformances. In the South American supply base, only a small number of suppliers possess the necessary tooling capabilities, dimensional metrology equipment, and process expertise required to meet these specifications. This concentrated market configuration amplifies supply continuity risks, justifying a multi-criteria decision model that treats risk mitigation alongside conventional purchasing dimensions.

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Pages: 1-41

3.2 Definition of Criteria and Sub-criteria for AHP Application

Constructing a robust hierarchical structure requires identifying criteria and sub-criteria that reflect both the operational realities of the shop floor and established empirical literature. The initial candidate criteria pool was established from the seminal taxonomy of Weber et al. (1991).

To tailor this theoretical set to the operational specificities of tractor manufacturing, structured consensus-building sessions were conducted with seven cross-functional specialists representing the company's procurement, logistics, manufacturing engineering, and quality assurance departments. The screening protocol followed three sequential steps: (i) eliciting expert assessments regarding the operational relevance of candidate criteria within the regional agribusiness context; (ii) clustering the selected variables by thematic and functional affinity; and (iii) structuring the consolidated parameters into high-level decision criteria and measurable operational sub-criteria, reconciled with empirical literature and plant-level constraints.

Table 1 details the resulting hierarchical structure, outlining the operational definitions and origin of each criterion and sub-criterion — categorized as either directly derived from Weber et al. (1991) or adapted to the focal firm through the expert panel.

Table 1 – Criteria and sub-criteria with descriptions for AHP application in supplier selection

Main Criteria	Sub-criteria	Basis / Rationale	Description
Cost	Unit Price	Weber et al. (1991) – "Price" (rank 6)	Negotiated unit value per item supplied; directly impacts total acquisition cost.
	Transportation Cost	Split from "Price" into a separate logistics cost component during the brainstorming sessions	Expenses involved in shipping products to their destination; may or may not be included in the product price.

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Pages: 1-41

Main Criteria	Sub-criteria	Basis / Rationale	Description
Quality	Technical Compliance	Weber et al. (1991) – "Product quality" (rank 1) / "Compliance with procedures" (rank 9)	Assessment of adherence to the technical specifications required by the company.
	Claims History (PPM)	Weber et al. (1991) – "Warranty and claims policies" (rank 4)	Frequency of failures or issues reported in previous deliveries; indicates consistency in quality.
Delivery	Lead Time	Weber et al. (1991) – "Delivery capacity / on-time delivery" (rank 2)	Interval between order placement and receipt.
	Schedule and Quantity Compliance	Weber et al. (1991) – "Ability to meet requirements" (rank 18)	Degree to which the supplier delivers on agreed schedules and in correct quantities.
Location	Distance to Customer	Weber et al. (1991) – "Geographic location" (rank 20)	Geographic proximity between supplier and company, directly influencing delivery time and cost.
	Logistics Access Ease	Added to capture regional infrastructure constraints specific to the company's distribution network	Availability of infrastructure (highways, ports, etc.) that facilitates transportation.
Relationship	Communication	Weber et al. (1991) – "Communication system" (rank 10)	Clarity, objectivity and promptness in the exchange of information between parties.
	Technical Support	Weber et al. (1991) – "Repair service" (rank 15)	Support provided by the supplier for installation, operation, or problem resolution.
	Negotiation Flexibility	Added to capture supplier adaptability to contractual and volume changes, raised in the brainstorming sessions	Supplier's ability to adapt to contractual changes, order volumes, or deadlines.
Financial Situation	Economic Stability	Weber et al. (1991) – "Financial standing" (rank 8)	Financial condition of the supplier, indicating its ability to fulfill contracts.
	Supply Continuity Capacity	Added to reflect the company's specific concern with continuity of supply under adverse conditions	Aptitude to guarantee continuous supply even in adverse situations.
Risk Management	Single-Supplier Dependence	Entire criterion added from risk-management literature (Section 2.2) and company priorities; absent from Weber et al.'s (1991) original list	Degree of exclusivity in the commercial relationship, reflecting vulnerability to operational failures or discontinuity.

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Main Criteria	Sub-criteria	Basis / Rationale	Description
	Inventory and Production Capacity	Entire criterion added from risk-management literature (Section 2.2) and company priorities; absent from Weber et al.'s (1991) original list	Inventory levels maintained and production flexibility in situations of sudden demand increase.
	External Risk Exposure	Entire criterion added from risk-management literature (Section 2.2) and company priorities; absent from Weber et al.'s (1991) original list	Susceptibility to uncontrollable events (environmental, social, political) that could disrupt operations.

3.3 Risk Management Criteria

This criterion evaluates the supplier's capacity to handle threats that may compromise supply continuity. It encompasses three dimensions:

- *Single-Supplier Dependence*: Degree of exclusivity in the commercial relationship, reflecting vulnerability to operational failures or discontinuity.
- *Inventory and Production Capacity*: Inventory levels maintained and production flexibility in situations of sudden demand increase.
- *External Risk Exposure* (environmental, social, political): Susceptibility to uncontrollable events that could disrupt operations.

The choice of exactly three sub-criteria was not arbitrary: it follows the canonical risk-source taxonomy proposed by Jüttner, Peck and Christopher (2003), who classify supply chain risk sources into three categories: organizational risk (internal to the firm), network-related risk (arising from the structure of inter-firm relationships), and environmental risk (external to the network). Single-Supplier Dependence corresponds to network-related risk, capturing the structural vulnerability created by an exclusive commercial relationship; Inventory and Production Capacity corresponds to organizational risk, reflecting the supplier's internal buffer and flexibility capabilities; and External Risk Exposure corresponds directly to environmental risk.

Mapping one sub-criterion to each category ensures comprehensive, non-redundant coverage of the recognized risk domains, while keeping the branch's size consistent with the other criteria in the hierarchy so as to preserve balance in the pairwise comparison structure.

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These three dimensions can be mapped onto the risk management process outlined by ISO 31000:2018 (ABNT, 2018). Single-Supplier Dependence and External Risk Exposure correspond primarily to the risk identification and analysis stages, as they characterize the nature and sources of the supplier's vulnerability. The pairwise comparison of suppliers on these dimensions constitutes the risk evaluation stage, translating expert judgment into a prioritized, quantified assessment. Inventory and Production Capacity reflects the supplier's own risk-treatment capacity. Finally, the selection of the highest-scoring supplier constitutes the organization's risk treatment decision: mitigating supply risk by choosing the alternative with the strongest aggregate risk profile.

3.4 Development of the Multicriteria Analysis

To operationalize the AHP evaluation, a structured pairwise comparison questionnaire was administered to a purposive panel of seven key professionals from the studied company. Informants were selected based on their technical and strategic domain expertise in agricultural machinery supply chains, procurement governance, and quality management. Table 2 summarizes the panel profile, outlining each respondent's functional role and years of industry experience.

Table 2 – Profile of questionnaire participants

Position	Years of Experience
Buyer	3
Supplier Business Manager	9
Strategic Quality Engineer for the Commodity	7
Supplier Quality Engineer	3
Materials Planner	6
Supplier Development Engineer	7
Materials Engineer	4

The composition of this expert panel was purposely designed to ensure cross-functional coverage across the core operational dimensions of the decision problem: (i) Procurement: Provided specialized knowledge regarding commercial conditions,

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cost structures, contractual negotiations, and historical supplier performance; (ii) Engineering: Contributed technical expertise regarding manufacturing tolerances, plastic-molding processes, geometric compliance, and supplier technological capabilities; (iii) Logistics and Materials Planning: Offered insights into material flow synchronization, lead times, geographical proximity, delivery reliability, and the operational ramifications of assembly-line disruptions.

The empirical protocol comprised two distinct procedural phases. In the initial qualitative structuring stage, participants collaborated to identify, refine, and validate the decision elements comprising the AHP hierarchy. In the subsequent quantitative evaluation stage, individual pairwise comparisons were elicited independently from each of the seven specialists using a questionnaire calibrated to Saaty's 1–9 fundamental scale. To mitigate groupthink, prevent cognitive anchoring, and preserve individual judgment diversity, no prior consensus was imposed during this comparative phase.

Given that the framework engages multiple decision-makers, individual preference matrices were synthesized into a collective group judgment using geometric-mean aggregation. In multi-expert AHP contexts, aggregating individual judgments via the geometric mean is mathematically required to preserve the reciprocal property ($a_{ji} = 1/a_{ij}$) in the resulting group matrix (Forman & Peniwati, 1998; Saaty, 2008).

Formally, for each entry a_{ij} of the aggregated pairwise comparison matrix, the collective group judgment is computed as:

$$a_{ij} = \left(\prod_{k=1}^{m} \quad a_{ij}^{(k)} \right)^{\frac{1}{m}}$$

where a_{ij} represents the consolidated group judgment between elements i and j, $a_{ij}^{(k)}$ denotes the pairwise judgment assigned by specialist k, and m represents the total number of decision-makers ($m = 7$). Geometric-mean aggregation is theoretically compatible with the multiplicative ratio scale of the AHP, ensuring that reciprocity holds across all evaluations:

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

$$a_{ji}^{(k)} = \frac{1}{a_{ij}^{(k)}} \; implies \; a_{ji} = \frac{1}{a_{ij}}$$

This aggregation procedure was systematically executed across all comparison matrices prior to prioritizing criteria and sub-criteria, generating the synthesized group matrices from which the global priority weights for criteria, sub-criteria, and supplier alternatives were subsequently derived.

4. Empirical Results: Criteria and Sub-criteria Development

The AHP was deployed through a top-down hierarchical architecture in which operational evaluations at lower tiers synthesize to determine overarching strategic sourcing outcomes. Following Saaty's (1980) pairwise comparison methodology, the seven primary criteria were evaluated against one another to derive a ratio-scale priority vector reflecting their relative importance in achieving supply resilience and operational efficiency.

The pairwise evaluations synthesized two complementary data streams: qualitative assessments elicited from the cross-functional expert panel and objective operational records obtained from the company's enterprise planning and supplier scorecard databases. This dual-source approach enabled subjective managerial priorities to be converted into mathematically calibrated weights aligned with corporate procurement objectives.

As detailed in Appendix Table A4, the aggregated pairwise comparison matrix exhibits a well-defined hierarchy of importance across the evaluation criteria. Cost and Quality emerged as jointly dominant — exhibiting equal relative weight ($a_{ij} = 1$) in their direct bilateral evaluation — while strictly dominating all other dimensions across every bilateral comparison. Cost was rated moderately more important than Delivery ($a_{ij} = 2$), strongly more important than Risk Management ($a_{ij} = 3$), substantially more important than Financial Health ($a_{ij} = 5$), and decisively dominant over Geographical Location ($a_{ij} = 6$) and Commercial Relationship ($a_{ij} = 7$). Quality followed an identical dominance trajectory, corroborating the central primacy of these two operational pillars within the panel's collective judgment.

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

Risk Management occupied an intermediate, structurally decisive tier: while subordinate to Cost, Quality, and Delivery, it consistently superseded Financial Health, Location, and Relationship, with pairwise dominance values ranging between 3 and 5. Delivery established a comparable intermediate standing, dominating Financial Health ($a_{ij} = 3$), Location ($a_{ij} = 4$), and Relationship ($a_{ij} = 5$), while yielding precedence to Cost and Quality. Conversely, Financial Health, Location, and Relationship registered the lowest priority ratings, with Commercial Relationship evaluated as the least influential criterion overall.

Appendix Table A5 presents the normalized pairwise comparison matrix, from which the local priority vector w was derived by computing the arithmetic mean across normalized row elements. As summarized in Table 3, Cost and Quality tied for the highest local weight ($w_i \approx 0.284$), confirming their pivotal role in the decision model. Delivery ranked third ($w_i = 0.167$), followed closely by Risk Management ($w_i = 0.127$). In aggregate, these four dimensions account for over 70% of the total decision weight, underscoring the organization's focus on operational throughput, logistical dependability, and disruption mitigation. In contrast, Financial Health ($w_i = 0.064$), Location ($w_i = 0.043$), and Relationship ($w_i = 0.030$) received marginal weights, indicating that within this manufacturing context, they operate as baseline qualifying prerequisites rather than order-winning strategic differentiators.

Table 3 – Final relative weights for main criteria

Criteria	Average Weight (≈)
Cost	0.284
Quality	0.284
Delivery	0.167
Risk Management	0.127
Financial Situation	0.064
Location	0.043
Relationship	0.030

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

To confirm the transitive and cardinal coherence of the pairwise judgments, the Consistency Index (CI) and Consistency Ratio (CR) were calculated using the maximum principal eigenvalue (λ_{max}) following the formulation defined in Section 2.3. For the 7×7 criteria comparison matrix, the analysis yielded $\lambda_{max} = 7.183$ resulting in the Consistency Index (CI):

$$CI = \frac{(7.183 - 7)}{6} \approx 0.0305$$

With Random Index RI = 1.32 for n = 7 criteria (Appendix Table A3), the Consistency Ratio (CR) is calculated as follows:

$$CR = \frac{0.0305}{1.32} \approx 0.0231$$

Because the resulting CR is strictly below the established 0.10 threshold (Saaty, 1980), the pairwise comparison matrix demonstrates acceptable mathematical consistency, validating the derived priority weights for subsequent alternative evaluation and decision synthesis.

4.1 AHP Development – Sub-criteria

Having established the global criteria weights, the same pairwise comparison and consistency testing procedure is applied iteratively to the sub-criteria within each main criterion. Because each main criterion's weight propagates directly to its sub-criteria, it is essential to conduct this analysis independently for each group. The Cost criterion is used here as an illustrative example.

As indicated at Appendix Table A6, the matrix indicates that Unit Price is considered substantially more important than Transportation Cost, with a comparison value of 3 implying that Unit Price exerts three times greater influence on procurement decisions, while Transportation Cost receives an inverse rating of 1/3.

4.1.1 Normalization of the Comparison Matrix for Cost

Following the normalization procedure established for the primary criteria, the pairwise comparison matrix for the Cost sub-criteria was normalized to compute their respective relative weights, as detailed in Appendix Table A7. This normalization

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

yields the local priority vector reported in Appendix Table A8, defining the relative importance of each sub-criterion within the Cost dimension.

To determine the final weight of each sub-criterion for the supplier evaluation stage, its local priority weight (Appendix Table A8) was multiplied by the global weight of the overarching Cost criterion ($w_i = 0.284$). This hierarchical composition generates the global sub-criteria weights presented in Table 4 (see Section 4.2).

4.1.2 Consistency Test (Sub-criteria)

As with the main criteria matrix, a consistency test is performed for the Cost sub-criteria. Since this is a 2×2 perfectly reciprocal matrix, the maximum eigenvalue is λmax = 2, yielding:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} = \frac{(2-2)}{1} = 0$$

In the AHP framework, matrices of order n ≤ 2 are inherently consistent, as the structure precludes circular inconsistencies. Because RI = 0 for n ≤ 2 (making CR undefined due to division by zero), perfect consistency is directly confirmed by CI = 0. The Cost sub-criteria weights are therefore valid and reliable for use in the global evaluation

4.2 AHP Development – Alternatives

The four suppliers evaluated in this study were identified from the qualified supply base for the plastic component family under analysis. The selection of these alternatives was non-arbitrary, being restricted to vendors already formally approved (homologated) and technically certified by the focal enterprise. This screening boundary was governed by the manufacturing complexity of the components, which demands specialized tooling infrastructure, mastery of functional plastic-molding techniques, and compliance with stringent geometric tolerances. Given these technical constraints, the pool of viable suppliers within the regional market is structurally limited. Suppliers A, B, C, and D therefore constitute the viable alternatives for the sourcing decision, ensuring that the AHP was applied strictly among pre-qualified vendors satisfying baseline technical capacity requirements.

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

To maintain corporate confidentiality, the four candidates are designated as Suppliers A, B, C, and D, omitting commercial names and proprietary identifiers. Supplier A is a medium-sized enterprise located in the state of Rio Grande do Sul. Supplier B is a small enterprise located in the state of São Paulo. Supplier C is a large corporation also situated in the state of São Paulo, whereas Supplier D is a medium-sized company based in the state of Santa Catarina. This selection captures a heterogeneous structural profile distributed across Brazil's South and Southeast industrial regions.

Notwithstanding variations in enterprise size and geographical location, all four suppliers fulfill the prerequisite conditions for the multi-criteria assessment: each belongs to the certified vendor base, operates manufacturing assets calibrated to this component family, and implements the polymer-processing routines necessary to comply with product engineering standards. This geographical and size characterization contextualizes the alternative set within the decision space without denoting prior managerial preference; operational disparities among candidates are captured systematically through the weighted criteria and sub-criteria of the model.

At the final synthesis tier, pairwise comparisons and consistency checks were applied to the four alternatives (A, B, C, and D) across each operational sub-criterion. Alternative performance was assessed using Saaty's (1980) 1–9 fundamental scale, triangulating historical enterprise procurement records with cross-functional evaluations from the supply chain team.

As an empirical demonstration, Appendix Table A9 presents the pairwise comparison matrix for the alternative set evaluated against the Unit Price sub-criterion.

Supplier A demonstrated marked superiority regarding Unit Price, whereas Supplier D registered the lowest performance priority along this dimension. Appendix Table A10 details the corresponding normalized matrix and the derived local priority vector.

The Weight (w) column reports the local priority vector computed via normalized row-wise arithmetic means, quantifying each supplier's relative performance under the Unit Price sub-criterion. Consistency verification yielded:

$$\lambda_{max} = 4.118$$

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Pages: 1-41

$$CI = \frac{(4.118 - 4)}{3} = 0.039$$

$$CR = \frac{0.039}{0.90} = 0.044$$

Since CR < 0.10, the matrix satisfies the consistency threshold, and the derived supplier weights can be reliably incorporated into the global score computation. This same procedure was applied across all sub-criteria and criteria levels. Table 4 synthesizes the complete weight structure for all four suppliers.

Table 4 – Summary of criteria, sub-criteria, and supplier (A, B, C, and D) weights

Criteria (Weight)	Sub-criteria (Weight)	Local A	Global A	Local B	Global B	Local C	Global C	Local D	Global D
Cost (0.284)	Unit Price (0.750)	0.558	0.119	0.263	0.056	0.122	0.026	0.057	0.012
	Transportation Cost (0.250)	0.214	0.015	0.070	0.005	0.550	0.039	0.165	0.012
Quality (0.284)	Technical Compliance (0.750)	0.371	0.079	0.250	0.053	0.232	0.049	0.147	0.031
	Claims History (PPM) (0.250)	0.450	0.032	0.050	0.004	0.450	0.032	0.050	0.004
Delivery (0.167)	Lead Time (0.712)*	0.291	0.035	0.063	0.008	0.342	0.041	0.304	0.036
	Schedule and Quantity Compliance (0.288)*	0.357	0.017	0.042	0.002	0.386	0.019	0.215	0.010
Location (0.043)	Distance to Customer (0.600)	0.472	0.012	0.090	0.002	0.236	0.006	0.202	0.005
	Logistics Access Ease (0.400)	0.372	0.006	0.212	0.004	0.265	0.005	0.150	0.003
Relationship (0.030)	Communication (0.250)	0.348	0.003	0.218	0.002	0.270	0.002	0.164	0.001
	Technical Support (0.250)	0.392	0.003	0.238	0.002	0.224	0.002	0.147	0.001
	Negotiation Flexibility (0.500)	0.451	0.007	0.283	0.004	0.175	0.003	0.092	0.001
Financial Situation (0.064)	Economic Stability (0.750)	0.259	0.012	0.359	0.017	0.229	0.011	0.153	0.007
	Supply Continuity Capacity (0.250)	0.245	0.004	0.273	0.004	0.276	0.004	0.205	0.003

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Vol: 13.20
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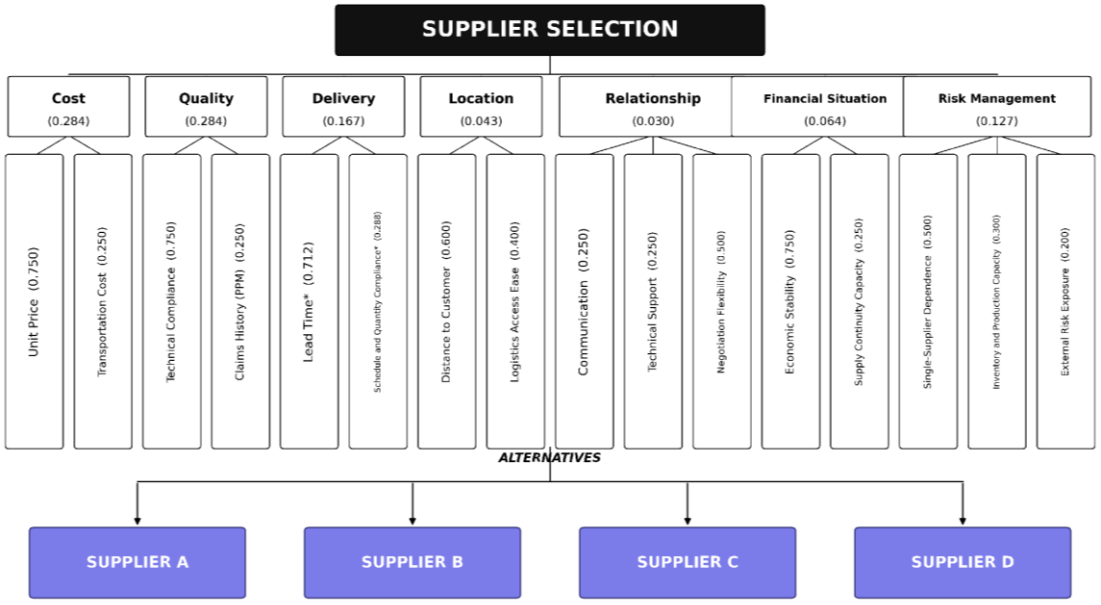
Pages: 1-41

Criteria (Weight)	Sub-criteria (Weight)	Local A	Global A	Local B	Global B	Local C	Global C	Local D	Global D
Risk Management (0.127)	Single-Supplier Dependence (0.500)	0.429	0.027	0.357	0.023	0.143	0.009	0.071	0.005
	Inventory and Production Capacity (0.300)	0.333	0.013	0.278	0.011	0.250	0.010	0.139	0.005
	External Risk Exposure (0.200)	0.344	0.009	0.236	0.006	0.183	0.005	0.236	0.006

*Delivery sub-criteria weights were normalized to satisfy the AHP requirement that sub-criteria weights within each criterion sum to 1.00.

Figure 2 - AHP decision hierarchy for supplier selection with local and global priority weights



4.3 Consistency Verification Summary

Consistency verification was conducted across all levels of the AHP framework, encompassing the primary criteria, sub-criteria, and alternative evaluation matrices. Appendix Table A11 reports the maximum principal eigenvalue (λ_{max}), Consistency Index (CI), and Consistency Ratio (CR) across all 24 pairwise comparison matrices underpinning the decision hierarchy: 1 primary criteria matrix, 7

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

sub-criteria matrices, and 16 alternative matrices (one for each operational sub-criterion).

The complete computational chain is compiled in the Technical Appendix, ensuring full mathematical transparency and replicability for the synthesized results in Table 4. Every pairwise comparison matrix satisfied the standard consistency threshold ($CR < 0.10$) formulated by Saaty (1980). Consequently, all expert evaluations exhibited acceptable transitive and cardinal coherence, requiring no revision, recalibration, or iterative re-administration of pairwise judgments.

5. Analysis and Discussion of Results

The application of the AHP established a structured multi-criteria decision framework grounded in criteria and sub-criteria derived from the specialized supply chain risk management and procurement literature. The model was deployed to select the most suitable supplier of functional plastic components for an agribusiness machinery manufacturer, with explicit emphasis on mitigating operational, financial, and strategic supply vulnerabilities. The computational execution encompassed pairwise comparison matrix formulation, normalization procedures, priority vector derivation, and consistency verification across all hierarchical tiers.

The seven evaluation criteria were established based on their empirical relevance to logistics performance and supply risk governance. The aggregated pairwise comparison matrix revealed that Cost (28.4%) and Quality (28.4%) shared primary dominance, followed by Delivery (16.7%), Risk Management (12.7%), Financial Health (6.4%), Location (4.3%), and Commercial Relationship (3.0%). These priority weights demonstrate the expert panel's strategic focus on operational continuity, economic viability, and supply dependability, validating the core tenets of supply chain risk resilience (Christopher & Peck, 2004; Wagner & Bode, 2006).

This balanced emphasis on Cost and Quality, coupled with the substantial weight assigned to Delivery performance, aligns with established principles of manufacturing operations and project risk governance (PMBOK, 2021). Notably, Risk Management achieved an intermediate priority weight (12.7%), surpassing both Financial Health and Geographical Location. This relative ranking confirms that the

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

organization has systematically embedded vulnerability attenuation and operational risk mitigation into its formal sourcing architecture, rather than treating them as secondary qualifying factors.

Table 5 summarizes each supplier's local priority score across the three risk sub-criteria, providing an analytical profile of each candidate's operational strengths and vulnerabilities. Within this ratio-scale framework, higher values represent superior relative performance — and, consequently, lower operational risk exposure.

Table 5 – Supplier risk profile across risk-management sub-criteria

Risk Sub-criterion	Supplier A	Supplier B	Supplier C	Supplier D
Single-Supplier Dependence	0.429	0.357	0.143	0.071
Inventory and Production Capacity	0.333	0.278	0.250	0.139
External Risk Exposure	0.344	0.236	0.183	0.236

Supplier A shows the strongest and most balanced risk profile, leading on Single-Supplier Dependence and External Risk Exposure and ranking second on Inventory and Production Capacity. Supplier B, despite its modest overall ranking, performs competitively on Single-Supplier Dependence and Inventory and Production Capacity, which explains why it overtakes Supplier C once Risk Management is given greater strategic weight (Table 9). Supplier D is the weakest across all three risk dimensions, reinforcing the earlier finding that it is the least suitable alternative from a risk management perspective.

While Financial Situation (6.4%), Location (4.3%), and Relationship (3.0%) ranked at the bottom of the hierarchy, their positioning warrants interpretive nuance. In the agricultural sector context, these factors appear to function primarily as qualifying conditions — prerequisites for supplier viability rather than active differentiators — given that operational priorities center firmly on the Cost–Quality–Delivery triad. Accordingly, even strong performance on these secondary criteria carries limited mathematical influence over the overall ranking.

This dynamic is clearly visible in the alternative-level results. Supplier B achieved the highest relative score on Financial Situation, particularly for its economic stability and capacity to sustain long-term contractual commitments, while Supplier A

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

led in Location (geographic proximity and logistical accessibility) and Relationship (flexibility and communication quality). Nevertheless, since these three criteria collectively account for only 13.7% of the total decision weight, strong performance in these areas proved insufficient to substantially alter the overall supplier ranking or challenge the dominance of criteria with higher strategic priority.

With the global weights established, the four supplier alternatives — A, B, C, and D — were evaluated against each sub-criterion through pairwise comparisons. The priority vector synthesis (presented in Table 4) aggregated these values into each supplier's overall score.

The overall score of each supplier k is obtained by summing, across all m sub-criteria, the product of each sub-criterion's global weight (reported in Table 4) and the supplier's corresponding local priority score:

$$Score_k = \sum_{j=1}^{m} w_j^{global} \times s_{j,k}^{local}$$

where wj (global) is the global weight of sub-criterion j (Table 4) and sj,k (local) is supplier k's local priority score for that sub-criterion. Applying this expression produced the following global scores:

Supplier A achieved the highest overall score of 0.393 (39.3%), driven by superior performance on the two highest-weighted criteria — Quality (particularly Technical Compliance and a strong claims record) and Cost (notably Unit Price competitiveness). This alignment between Supplier A's strengths and the model's priority structure positions it as the most strategically coherent choice for the organization.

Supplier C ranked second with a global score of 0.262 (26.2%), supported by strong Delivery performance and a competitive Transportation Cost. However, lower scores on Risk Management sub-criteria partially offset these advantages.

Supplier B attained a global score of 0.202 (20.2%), reflecting balanced but unremarkable performance across the majority of criteria. Despite its financial solidity, it did not achieve sufficient differentiation on the higher-weight dimensions to advance in the ranking.

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Vol: 13.20
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Pages: 1-41

Supplier D received the lowest global score of 0.143 (14.3%), penalized by the weakest evaluations on Cost (Unit Price) and Quality — the two most influential criteria in the model — making it the least suitable alternative from both an operational and risk management perspective. Table 6 presents the final normalized supplier ranking.

Table 6 – Supplier ranking according to normalized score

Rank	Supplier	Normalized Score	Percentage (%)
1st	Supplier A	0.393	39.3%
2nd	Supplier C	0.262	26.2%
3rd	Supplier B	0.202	20.2%
4th	Supplier D	0.143	14.3%

The results demonstrate that the AHP application delivered not merely a ranking, but a comprehensive, risk-integrated decision rationale. The transparent weighting of criteria and the systematic pairwise evaluation of alternatives allowed for the explicit mapping of each supplier's risk profile, contributing to a decision process that is both defensible and aligned with the organization's strategic planning horizon.

A further strength of the method is its capacity to integrate quantitative dimensions (cost metrics, financial indicators) with qualitative assessments (relationship quality, reputation), thereby providing a genuinely holistic view of each supplier's suitability. The consistency of expert judgments was confirmed at every analytical stage ensuring the reliability of the comparative assessments throughout the process.

Collectively, these findings align with the broader literature positioning AHP as a rigorous and versatile tool for multicriteria decision-making in uncertain, risk-prone environments. The model demonstrates clear potential for structuring complex procurement decisions with greater transparency and analytical discipline, particularly in supply chains that depend on the consistent and reliable availability of critical input materials.

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

Table 7 decomposes each supplier's final score by main criterion, obtained by summing the global weights of the corresponding sub-criteria in Table 4. This breakdown clarifies which criteria drove each supplier's ranking position.

Table 7 – Decomposition of suppliers' final score by main criterion

Main Criterion (Weight)	Supplier A	Supplier B	Supplier C	Supplier D
Cost (0.284)	0.134	0.061	0.065	0.024
Quality (0.284)	0.111	0.057	0.081	0.035
Delivery (0.167)	0.052	0.010	0.060	0.046
Location (0.043)	0.018	0.006	0.011	0.008
Relationship (0.030)	0.013	0.008	0.007	0.003
Financial Situation (0.064)	0.016	0.021	0.015	0.010
Risk Management (0.127)	0.049	0.040	0.024	0.016
Total (normalized score)	**0.393**	**0.202**	**0.262**	**0.143**

5.1 Sensitivity Analysis

To assess the robustness of the supplier ranking, a one-at-a-time sensitivity analysis was performed on the three criteria with the greatest influence on the final scores: Cost, Quality, and Risk Management. For each criterion, its weight was varied by ±10% and ±20%, while the weights of the remaining six criteria were rescaled proportionally so that the total continued to sum to 1.00. The resulting supplier scores were recomputed for each scenario using the criterion-level local scores underlying Table 7 (Table 8).

Table 8 – Sensitivity of the supplier ranking to variations in criteria weights

Criterion Varied	Weight Change	New Weight	Score A	Score B	Score C	Score D	Resulting Ranking
Cost	-20%	0.227	0.387	0.202	0.266	0.147	A > C > B > D
Cost	-10%	0.256	0.390	0.203	0.264	0.144	A > C > B > D
Cost	+10%	0.312	0.396	0.203	0.262	0.140	A > C > B > D
Cost	+20%	0.341	0.399	0.204	0.260	0.137	A > C > B > D

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Pages: 1-41

Criterion Varied	Weight Change	New Weight	Score A	Score B	Score C	Score D	Resulting Ranking
Quality	-20%	0.227	0.393	0.203	0.261	0.143	A > C > B > D
Quality	-10%	0.256	0.393	0.203	0.262	0.143	A > C > B > D
Quality	+10%	0.312	0.393	0.203	0.264	0.141	A > C > B > D
Quality	+20%	0.341	0.393	0.203	0.265	0.141	A > C > B > D
Risk Management	-20%	0.102	0.393	0.200	0.265	0.142	A > C > B > D
Risk Management	-10%	0.114	0.393	0.201	0.264	0.142	A > C > B > D
Risk Management	+10%	0.140	0.393	0.205	0.262	0.142	A > C > B > D
Risk Management	+20%	0.152	0.393	0.206	0.261	0.142	A > C > B > D

As shown in Table 8, the ranking order (A > C > B > D) remained unchanged across all twelve scenarios, even under a ±20% variation in the weights of Cost, Quality, and Risk Management — the three criteria that jointly account for 67.5% of the total decision weight. Supplier A retained the highest score in every scenario, with its margin over Supplier C narrowing only under a +20% increase in the Cost weight (0.399 vs. 0.260) and widening under a +20% increase in Risk Management weight (0.393 vs. 0.261). This stability indicates that the final recommendation is not an artifact of the specific weight elicitation and would hold under reasonably different prioritizations among the panel of experts.

Beyond the one-at-a-time test, a complementary scenario analysis was conducted to examine whether the ranking holds under markedly different strategic priorities (Table 9). Five alternative weighting profiles were defined: a Balanced profile with equal weights across all seven criteria, and four “focused” profiles in which a single criterion (Cost, Quality, Delivery, or Risk Management) is assigned 50% of the total weight, with the remaining weight distributed proportionally among the other six criteria, following the same procedure used in Table 8.

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Pages: 1-41

Table 9 – Scenario analysis of the supplier ranking under alternative weighting profiles

Scenario	Cost	Qual.	Deliv.	Loc.	Relat.	Fin.	Risk	Score A	Score B	Score C	Score D	Ranking
Base (panel weights)	**0.284**	**0.284**	**0.167**	**0.043**	**0.030**	**0.064**	**0.127**	**0.393**	**0.202**	**0.262**	**0.143**	**A > C > B > D**
Balanced (equal weights)	0.143	0.143	0.143	0.143	0.143	0.143	0.143	0.380	0.218	0.255	0.150	A > C > B > D
Cost-Focused	0.500	0.198	0.117	0.030	0.021	0.045	0.089	0.417	0.207	0.253	0.125	A > C > B > D
Quality-Focused	0.198	0.500	0.117	0.030	0.021	0.045	0.089	0.392	0.202	0.270	0.136	A > C > B > D
Delivery-Focused	0.170	0.170	0.500	0.026	0.018	0.038	0.076	0.360	0.146	0.301	0.195	A > C > D > B
Risk-Focused	0.163	0.163	0.096	0.025	0.017	0.037	0.500	0.390	0.251	0.231	0.135	A > B > C > D

The second-place position, however, proved less stable: Supplier C led the runner-up position in the Balanced, Cost-Focused, and Quality-Focused scenarios, but Supplier B overtook it under the Risk-Focused profile (0.251 vs. 0.231), reflecting Supplier B's comparatively strong risk-management performance. Conversely, under the Delivery-Focused profile, Supplier B fell to last place (0.146), behind even Supplier D, exposing its weak delivery performance as a critical vulnerability should the organization ever prioritize delivery reliability above other considerations. These findings suggest that while the choice of Supplier A is robust, the ranking of the remaining alternatives is sensitive to the organization's strategic emphasis and warrants periodic re-evaluation if priorities shift.

6. Conclusions

Supplier selection has undergone a profound strategic transformation alongside the increasing complexity of global supply networks and volatile market dynamics. Historically framed as an operational task driven by narrow transactional metrics, chiefly unit cost and contractual lead time, supplier evaluation has matured into a sophisticated multi-criteria decision problem requiring the simultaneous, balanced synthesis of heterogeneous qualitative and quantitative attributes. Persistent exposure to supply disruptions, demand fluctuations, and environmental

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Vol: 13.20
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Pages: 1-41

volatility underscores the strategic necessity for structured, mathematically robust, and transparent decision-support frameworks.

This study addressed that imperative by developing and implementing an AHP framework integrated with a supply chain risk management architecture, deployed to evaluate and select functional plastic component suppliers for an agribusiness machinery manufacturer. The empirical application demonstrated the operational efficacy of the proposed model: by constructing a validated multi-tier hierarchy and eliciting pairwise evaluations from a cross-functional panel of domain specialists, the framework reconciled conflicting performance dimensions into an internally consistent and reproducible alternative prioritization.

The empirical findings offer compelling insights into modern industrial procurement priorities. While operational fundamentals retained primary dominance within the weighting structure, the explicit formalization of the Risk Management dimension represented a critical strategic differentiator. By weighting disruption probabilities, single-sourcing vulnerabilities, and technical compliance, the framework moves sourcing decisions beyond short-term cost minimization toward systemic, preventive risk mitigation. AHP proved uniquely equipped to structure these trade-offs, converting subjective qualitative evaluations into calibrated ratio-scale priorities. Furthermore, the selection of Supplier A demonstrated exceptional stability across sensitivity analyses, retaining its leading position under priority weight perturbations of up to $\pm 20\%$ and across five contrasting strategic scenarios, thereby confirming the structural robustness of the final recommendation.

From a managerial and applied perspective, the model equips procurement and operations executives with an evidence-based, scalable decision-support instrument that directly aligns component sourcing with organizational resilience mandates. By quantifying risk exposure at the pre-qualification and alternative evaluation stages, organizations can proactively preempt supply continuity failures rather than relying on reactive troubleshooting. Theoretically, this research contributes to the operational research and operations management literature by demonstrating the empirical viability of coupling classical AHP with supply risk governance within the agribusiness machinery sector.

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

This study has limitations. First, the empirical investigation was bounded to a single manufacturing facility and four pre-qualified alternatives, which limits cross-industry generalizability. Future work should replicate the framework across diverse sectors and broader supplier pools. Second, standard AHP assumes preferential independence among criteria. Approaches such as ANP or hybrid DEMATEL-AHP could help capture these feedback loops more explicitly. Third, all seven evaluators were internal organizational actors, which may have introduced cognitive anchoring rooted in shared routines and historical supplier relationships.

Addressing these limitations, future studies could incorporate external auditors, triangulate findings with complementary methods such as TOPSIS, VIKOR, or PROMETHEE, and track post-contractual supplier performance over time to validate decision efficacy empirically. Another limitation concerns the absence of a dedicated ESG criterion in the final hierarchy, reflecting the firm's immediate operational priorities; as regulatory and green supply chain pressures continue to intensify, future iterations of the framework should formally incorporate carbon footprint, recyclability, and ethical sourcing metrics.

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Appendix – Supporting Tables

This appendix presents supporting reference material and intermediate calculation steps referenced throughout the main text: the literature-derived criteria list, standard AHP reference tables, the raw and normalized main-criteria comparison matrices, the worked calculation examples for the Cost sub-criteria and the Unit Price alternative comparison, and the consolidated Consistency Ratio (CR) summary for all matrices in the model.

Table A1 – Most commonly used criteria for supplier selection

Rank	Evaluation Criteria	Rank	Evaluation Criteria
1	Product quality	13	Management and organization
2	Delivery capacity (on-time delivery)	14	Operational controls
3	Performance history	15	Repair service
4	Warranty and claims policies	16	Attitude toward the buyer organization
5	Production facilities and capacity	17	Impression made in personal contacts
6	Price	18	Ability to meet requirements

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

Rank	Evaluation Criteria	Rank	Evaluation Criteria
7	Technical capability	19	Labor relations history
8	Financial standing	20	Geographic location
9	Compliance with procedures	21	Volume of previous business with the supplier
10	Communication system	22	Availability of training materials and courses on product use
11	Reputation and industry position	23	Reciprocal arrangements
12	Desire to earn the business		

Source: Adapted from Weber et al. (1991).

Table A2 – Saaty's Fundamental Scale of Relative Importance

Relative Importance Scale	Verbal Definition
9	Extreme importance – Evidence absolutely favors one element over the other.
7	Very strong importance – One element is strongly favored; its importance is demonstrated in practice.
5	Strong importance – One element is strongly favored.
3	Moderate importance – Experience or judgment slightly favors one element over the other.
1	Equal importance – Both elements contribute equally to the objective.
2, 4, 6, 8	Intermediate values – Used for intermediate judgments between the main values.
Reciprocals	Inverse of the assigned value – If A is 3 times more important than B, then B is 1/3 relative to A.

Source: Adapted from Saaty (1980).

Table A3 – Random Index for Comparison Matrices

Number of Criteria	1	2	3	4	5	6	7	8
RI Value	0	0	0.58	0.90	1.12	1.24	1.32	1.41

Table A4 – Pairwise comparison matrix of main criteria

Criteria	Cost	Quality	Risk Mgmt.	Delivery	Fin. Situation	Location	Relat.
Cost	1	1	3	2	5	6	7
Quality	1	1	3	2	5	6	7

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

Criteria	Cost	Quality	Risk Mgmt.	Delivery	Fin. Situation	Location	Relat.
Risk Management	1/3	1/3	1	1/2	3	4	5
Delivery	½	1/2	2	1	3	4	5
Financial Situation	1/5	1/5	1/3	1/3	1	2	3
Location	1/6	1/6	1/4	1/4	½	1	2
Relationship	1/7	1/7	1/5	1/5	1/3	1/2	1

Table A5 – Normalized comparison matrix of main criteria

Criteria	Cost	Quality	Risk Mgmt.	Delivery	Fin. Situation	Location	Relat.
Cost	0.299	0.299	0.307	0.318	0.280	0.255	0.233
Quality	0.299	0.299	0.307	0.318	0.280	0.255	0.233
Risk Management	0.100	0.100	0.102	0.080	0.168	0.170	0.167
Delivery	0.150	0.150	0.204	0.159	0.168	0.170	0.167
Financial Situation	0.060	0.060	0.034	0.053	0.056	0.085	0.100
Location	0.050	0.050	0.026	0.040	0.028	0.043	0.067
Relationship	0.043	0.043	0.020	0.032	0.019	0.021	0.033

Table A6 – Pairwise Comparison Matrix of Cost Sub-criteria

Sub-criteria	Unit Price	Transportation Cost
Unit Price	1	3
Transportation Cost	1/3	1

Table A7 – Normalized Matrix of Cost Sub-criteria

Sub-criteria	Unit Price	Transportation Cost
Unit Price	0.75	0.75
Transportation Cost	0.25	0.25

Table A8 – Priority Vector of Cost Sub-criteria

Sub-criteria	Weight (w)
Unit Price	0.75
Transportation Cost	0.25

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

Source: Prepared by the authors (2025).

Table A9 – Supplier comparison matrix for the Unit Price sub-criterion

Supplier	A	B	C	D
A	1	3	5	7
B	1/3	1	3	5
C	1/5	1/3	1	3
D	1/7	1/5	1/3	1

Table A10 – Normalized supplier matrix (Unit Price sub-criterion)

Supplier	A	B	C	D	Weight (w)
A	0.597	0.662	0.536	0.438	0.558
B	0.199	0.221	0.321	0.313	0.263
C	0.119	0.074	0.107	0.188	0.122
D	0.085	0.044	0.036	0.063	0.057

Table A11 – Consistency Ratio (CR) summary for all matrices in the AHP model

Level	Criterion / Sub-criterion	Matrix basis	CR	CR < 0.10?
Criteria	Main criteria	Original consolidated matrix	0.023	Yes
Sub-criteria	Cost	Original consolidated matrix	0.000	Yes
Sub-criteria	Quality	Complementary consolidation matrix*	0.000	Yes
Sub-criteria	Delivery	Complementary consolidation matrix*	0.000	Yes
Sub-criteria	Location	Complementary consolidation matrix*	0.000	Yes
Sub-criteria	Relationship	Complementary consolidation matrix*	0.000	Yes
Sub-criteria	Financial Situation	Complementary consolidation matrix*	0.000	Yes
Sub-criteria	Risk Management	Complementary consolidation matrix*	0.000	Yes
Alternatives	Unit Price	Original consolidated matrix	0.044	Yes
Alternatives	Transportation Cost	Complementary consolidation matrix*	0.000	Yes
Alternatives	Technical Compliance	Complementary consolidation matrix*	0.000	Yes
Alternatives	Claims History (PPM)	Complementary consolidation matrix*	0.000	Yes
Alternatives	Lead Time	Complementary consolidation matrix*	0.000	Yes
Alternatives	Schedule and Quantity Compliance	Complementary consolidation matrix*	0.000	Yes

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Vol: 13.20
DOI: 10.66104/3qnc1k97
Pages: 1-41

Level	Criterion / Sub-criterion	Matrix basis	CR	CR < 0.10?
Alternatives	Distance to Customer	Complementary consolidation matrix*	0.000	Yes
Alternatives	Logistics Access Ease	Complementary consolidation matrix*	0.000	Yes
Alternatives	Communication	Complementary consolidation matrix*	0.000	Yes
Alternatives	Technical Support	Complementary consolidation matrix*	0.000	Yes
Alternatives	Negotiation Flexibility	Complementary consolidation matrix*	0.000	Yes
Alternatives	Economic Stability	Complementary consolidation matrix*	0.000	Yes
Alternatives	Supply Continuity Capacity	Complementary consolidation matrix*	0.000	Yes
Alternatives	Single-Supplier Dependence	Complementary consolidation matrix*	0.000	Yes
Alternatives	Inventory and Production Capacity	Complementary consolidation matrix*	0.000	Yes
Alternatives	External Risk Exposure	Complementary consolidation matrix*	0.000	Yes

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