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AN ANP–TOPSIS MULTI-CRITERIA FRAMEWORK FOR CARTON PACKAGING SUPPLIER SELECTION: A CASE STUDY

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Abstract: Supplier selection is a strategic decision in supply chain management as it directly affects product quality, operational efficiency, and delivery reliability. In manufacturing industries, carton packaging serves not only as product protection but also as a determinant of perceived quality and customer satisfaction. PT Toa Galva Industries has experienced inconsistencies in carton box quality, leading to disruptions in packaging and distribution processes. This issue highlights the need for a multi-criteria decision-making approach capable of capturing interdependencies among evaluation criteria. This study aims to develop a supplier evaluation and ranking framework for carton packaging using an integrated Analytic Network Process (ANP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach. ANP is employed to determine the priority weights of criteria and subcriteria while considering their interrelationships, whereas TOPSIS is applied to rank suppliers based on their closeness to the ideal solution. Data were collected through questionnaires and interviews with experienced procurement and production personnel. The results indicate that quality is the most influential criterion, followed by service, delivery, and cost, with quality consistency identified as the most critical subcriterion. The supplier ranking reveals that PT CTP achieves the highest preference value among the evaluated alternatives. These findings emphasize that quality stability outweighs cost considerations in carton packaging supplier selection. This study contributes practically by providing a structured and objective decision-making framework and academically by extending the application of ANP–TOPSIS in packaging supplier evaluation within manufacturing contexts.
Keywords: supplier selection, carton packaging, multi-criteria decision making, ANP, TOPSIS.

INTRODUCTION

Supplier selection is a strategic decision in supply chain management because it has a direct impact on product quality, operational efficiency, and distribution reliability. In the context of competition and market uncertainty, supplier evaluation is often positioned as a multi-criteria decision making (MCDM) problem because it involves conflicting criteria (e.g. cost vs quality vs delivery accuracy) (Chakraborty, Raut, Rofin, & Chakraborty, 2025).

In the manufacturing industry, carton box packaging not only serves as a protector of the product during transportation, but also affects the perception of quality and customer satisfaction. Therefore, packaging supplier decision-making needs to consider aspects of material quality, process consistency, and logistics performance simultaneously.

Various MCDM methods have been used for supplier selection, such as AHP, ANP, TOPSIS, and fuzzy/AI variations. However, studies have shown that an approach that assumes independence between criteria is potentially less representative for real cases because in practice there is a link between factors (e.g. quality can trigger rework and affect delivery accuracy) (Tronnebati, El Yadari, & Jawab, 2022).

In addition, a number of recent studies have led to the use of hybrid models to improve the robustness of decisions, such as combining ANP for dependency-based weighting and TOPSIS for alternative ratings (Masudin, Habibah, Wardana, Restuputri, & Shariff, 2024).

In the context of the packaging industry, supplier selection research has also been conducted, including in the flexible packaging industry, which confirms that packaging supplier selection is multi-criteria and sensitive to decision priorities (e.g. process quality and ability to meet specifications) (Cristea & Cristea, 2017).

PT Toa Galva Industries as a public broadcasting system manufacturing company faces the problem of inconsistency in the quality of carton box packaging which has an impact on the smooth packaging and distribution process. Based on the field findings in this manuscript, packaging material defects include physical damage to the carton, improper glue connections, and quality variations between shipments.

This condition requires an objective, systematic supplier evaluation approach that is able to capture the relationship between assessment criteria. Therefore, this study applies the Analytic Network Process (ANP) to determine the weight of the criteria/subcriteria by considering the dependencies between the elements, and integrates it with TOPSIS to rank suppliers based on proximity to the ideal solution (Masudin et al., 2024).

Although the ANP–TOPSIS hybrid model has been used in some supplier selection contexts, the literature suggests that there is still limited research that specifically highlights carton packaging suppliers as a strategic component in manufacturing and formulates decisions based on the interdependence of operational criteria (quality–delivery–service) in the case of industries that demand high quality consistency. In addition, the packaging decision-making study focuses a lot on material/design selection, so that the aspect of supplier ranking based on actual performance in the packaging supply chain still opens up space for empirical contribution (Uzan, 2025).

The novelty of this research lies in the development of an evaluation framework for carton packaging suppliers that explicitly considers the dependencies between criteria and subcriteria using ANP, then conducting supplier rankings with TOPSIS. This approach is relevant because the supplier selection literature emphasizes the importance of models that are able to capture the complex relationships between factors and improve the quality of decisions (Magableh & Mistarihi, 2022).

Different from the supplier selection study on packaging which is generally general or focuses on flexible packaging, this study makes an empirical contribution to the context of cardboard packaging for manufacturing by emphasizing the dominance of quality consistency on supplier decisions, as also emphasized in the trend of modern supplier evaluation studies that place quality/operational performance as the main driver (Cristea & Cristea, 2017).

RESEARCHMETHOD

Research Design

This study adopts a quantitative Multi-Criteria Decision Making (MCDM) approach to evaluate supplier performance. MCDM is widely used for complex decision problems involving conflicting criteria (Saaty, 2005; Thakkar, 2021).

The Analytic Network Process (ANP) is employed to determine criteria weights while accounting for interdependencies among elements (Saaty, 2001). Pairwise comparisons are conducted using Saaty's 1–9 scale, and judgment consistency is assessed using the Consistency Ratio, with values below 0.10 considered acceptable (Saaty, 2005).

Subsequently, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is applied to rank supplier alternatives based on their distances from the positive and negative ideal solutions (Hwang & Yoon, 1981; Thakkar, 2021).

Case Study Description

The empirical investigation was conducted at PT Toa Galva Industries, a manufacturing company specializing in public address systems, including microphones, amplifiers, loudspeakers, and megaphones. The scope of the study is limited to the selection of suppliers for carton box packaging (type BS-34), which plays a critical role in ensuring product protection and delivery reliability. The company currently collaborates with multiple carton packaging suppliers exhibiting varying performance levels, making supplier evaluation a relevant managerial issue.

Criteria and Subcriteria Identification

The evaluation criteria and subcriteria were identified through a combination of literature review and semi-structured interviews with procurement and production personnel at PT Toa Galva Industries. Four main criteria were established: quality, cost, service, and delivery, comprising a total of twelve subcriteria. These criteria reflect both operational requirements and supplier performance considerations relevant to carton packaging procurement. To ensure transparency and replicability, the operational definitions and codes adopted for subsequent ANP weighting and TOPSIS ranking are summarized in Table 1.

Table 1. Evaluation criteria and subcriteria for carton packaging supplier selection)

Criteria	Sub Criteria	Code
Quality	Non-specification non-conformity	Q1
	Consistent quality	Q2
	Completeness of documents and checks	Q3
Pricing	Price compatibility offered with specifications	C1
	Ability to provide discounts on price quotes	C2
	Easy price negotiation	C3
Services	Ease of contacting suppliers	S1
	Response to needs and complaints	S2
	After-purchase service	S3
Shipping	Delivery timeliness	D1
	Accuracy of the quantity of goods	D2
	Delivery Time	D3

Data Collection and Respondents

Primary data were collected through pairwise comparison questionnaires and supplier performance assessment forms. The respondents consisted of three experts from the procurement and production departments who possess direct experience and decision-making authority in supplier selection processes. The use of expert judgment aligns with ANP methodology, where informed evaluations are prioritized over large sample sizes. To aggregate individual judgments, the geometric mean method was applied, ensuring consistency with established ANP practices.

Secondary data were obtained from internal company documents, supplier records, and relevant academic literature to support methodological justification and contextual analysis.

Analytical Network Process (ANP) Procedure

The ANP method was applied to determine the priority weights of criteria and subcriteria while considering interdependencies among elements. The procedure involved:

1. Constructing a network model representing relationships among criteria and subcriteria.
2. Conducting pairwise comparisons using Saaty's 1–9 scale.
3. Calculating eigenvectors to obtain local priority weights.
4. Evaluating judgment consistency through the Consistency Ratio (CR), with CR values below 0.10 indicating acceptable consistency.
5. Developing the unweighted supermatrix, weighted supermatrix, and limit supermatrix to derive global priority weights.

The ANP computations were performed using Super Decisions software, which is widely applied in network-based decision analysis.

TOPSIS Ranking Procedure

Following the determination of criteria weights using ANP, the TOPSIS method was employed to rank the supplier alternatives. The procedure included:

1. Constructing a normalized decision matrix.
2. Developing a weighted normalized matrix using ANP-derived weights.
3. Identifying the positive ideal solution and negative ideal solution.
4. Calculating the Euclidean distance of each supplier from both ideal solutions.

5. Computing the preference value for each alternative, where a higher value indicates better overall performance.

The integration of ANP and TOPSIS allows for a robust evaluation framework that combines dependency-aware weighting with distance-based ranking.

Research Framework

The overall research framework consists of problem identification, criteria determination, data collection, ANP-based weighting, TOPSIS-based ranking, and result interpretation. This structured approach ensures transparency and reproducibility in supplier selection analysis.

RESULTS AND DISCUSSION

Criteria Weight Determination Using ANP

The results of the Analytic Network Process (ANP) analysis indicate that quality is the most influential criterion in carton packaging supplier selection, followed by service, delivery, and cost. This result reflects the strategic role of packaging quality in ensuring product protection and maintaining brand image in manufacturing supply chains. Previous studies on supplier evaluation have similarly reported that quality-related criteria often dominate supplier selection decisions, particularly when the supplied component directly affects downstream logistics and customer satisfaction (Thakkar, 2021; Uluskan, Joines, & Godfrey, 2016).

Among the subcriteria, quality consistency emerges as the most significant factor. This finding suggests that stable and repeatable supplier performance is more critical than occasional compliance with technical specifications. Consistency in quality reduces operational uncertainty, minimizes rework, and lowers the risk of distribution disruptions. Similar conclusions have been reported in supplier evaluation studies emphasizing long-term supplier reliability over short-term performance gains (Rusydiana & Devi, 2018; Tao, Aamir, Shoaib, Yasir, & Babar, 2025).

The relatively lower priority assigned to cost indicates that procurement decisions in this case are not solely driven by price minimization. Instead, decision-makers prioritize performance stability and risk reduction. This supports the argument in supply chain literature that cost-oriented supplier selection may lead to hidden operational costs when quality and delivery performance are compromised (Jyoti & Akter, 2022).

Consistency and Reliability of Expert Judgments

The Consistency Ratio (CR) values for all criteria were below the acceptable threshold of 0.10, indicating a high level of consistency in expert judgments. According to Saaty (2005), CR values below 0.10 confirm that the pairwise comparisons are logically coherent and suitable for further analysis. The consistency achieved in this study suggests that the respondents share a common understanding of supplier performance priorities, thereby strengthening the credibility of the resulting ANP weights.

Table 2 Consistency Ratio (CR)

Criteria	CR Value
Quality	0,07376
Pricing	0,01143
Services	0,00571
Shipping	0,00571

Consistent expert judgments are particularly important in network-based decision models, as inconsistencies can propagate through the supermatrix and affect the stability of global priority values (Rusydiana & Devi, 2018).

Supplier Ranking Results Using TOPSIS

Based on the TOPSIS analysis, PT CTP achieved the highest preference value, indicating the closest proximity to the positive ideal solution. This result implies that PT CTP demonstrates superior overall performance across multiple criteria, particularly in quality consistency and delivery reliability.

According to Hwang and Yoon (1981), an alternative with the highest closeness coefficient represents the most balanced solution among competing criteria.

Table 3 Calculation of Preference Values and Ranking

Suppliers	Value	Rank
PT. CTP	0,621	1
PT. KML	0,606	2
PT. OAJ	0,545	3
PT. AKP	0,487	5
PT. KMS	0,510	4

The relatively small differences in preference values among the top-ranked suppliers indicate a competitive supplier environment. However, even minor deficiencies in critical criteria such as quality stability or delivery punctuality can significantly affect the final ranking. This observation is consistent with prior TOPSIS-based supplier selection studies, which highlight the sensitivity of ranking results to performance variations in high-weight criteria (Buede & Maxwell, 1995; Chamid, 2016).

Suppliers with lower rankings tend to exhibit weaknesses in at least one key dimension, such as delayed delivery or inconsistent material quality. These weaknesses increase operational risk and reduce overall supplier attractiveness, reinforcing the importance of comprehensive multi-criteria evaluation.

Managerial Implications

The findings of this study offer several managerial implications for PT Toa Galva Industries. First, the dominance of quality-related criteria suggests that supplier evaluation systems should emphasize quality assurance mechanisms, including standardized inspection procedures and continuous monitoring of supplier performance. Supply chain literature emphasizes that effective supplier quality management contributes to improved operational performance and long-term partnership sustainability (Prajogo, Chowdhury, Yeung, & Cheng, 2012; Yeung, 2008).

Second, the relatively lower importance of cost indicates that aggressive price-based negotiations may not be appropriate for packaging components with high operational impact. Instead, a balanced procurement strategy that integrates performance-based evaluation is more likely to enhance supply chain resilience. This finding aligns with studies advocating a shift from transactional to strategic supplier relationships (Piercy, 2009; Sheth & Sharma, 1997).

Furthermore, the proposed ANP–TOPSIS framework can serve as a decision-support tool for periodic supplier re-evaluation, enabling the company to respond proactively to changes in supplier performance or strategic priorities.

Summary of Key Findings

The integrated ANP–TOPSIS analysis demonstrates that supplier selection for carton packaging is predominantly driven by quality-related considerations, particularly quality consistency, rather than cost-oriented factors. The results indicate that stable and reliable supplier performance plays a critical role in minimizing operational disruptions and ensuring smooth downstream logistics. Furthermore, the application of ANP successfully captures interdependencies among evaluation criteria, providing a more realistic representation of decision-making conditions compared to hierarchical approaches.

The TOPSIS results reveal that suppliers with balanced performance across high-weight criteria achieve higher preference values, even when price competitiveness is not optimal. This finding highlights the importance of comprehensive multi-criteria evaluation in supplier ranking decisions.

Table 4. Key Findings

Key Findings	Managerial Implications
Quality is the most influential criterion in	Procurement policies should prioritize quality

carton packaging supplier selection	assurance mechanisms over short-term cost savings
Quality consistency has the highest subcriterion weight	Suppliers should be evaluated based on long-term performance stability rather than occasional compliance
Cost has a lower relative priority compared to operational criteria	Price negotiations should not compromise packaging performance and delivery reliability
ANP effectively captures interdependencies among criteria	Decision-makers should adopt network-based evaluation models for complex procurement decisions
TOPSIS identifies suppliers closest to the ideal solution	Supplier ranking should consider overall performance balance rather than single-criterion excellence
The top-ranked supplier demonstrates superior quality and delivery performance	Supplier development programs should focus on maintaining and enhancing high-performing suppliers

CONCLUSION

This study proposes an integrated Analytic Network Process (ANP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) framework to evaluate and rank carton packaging suppliers in a manufacturing context. The results confirm that supplier selection for carton packaging is a complex multi-criteria decision problem in which quality-related factors, particularly quality consistency, play a dominant role compared to cost considerations.

The ANP results demonstrate that considering interdependencies among evaluation criteria provides a more realistic representation of decision-making conditions, especially where quality, delivery, and service performance are closely interconnected. The subsequent TOPSIS analysis identifies PT CTP as the most preferred supplier due to its balanced performance across high-priority criteria, indicating proximity to the ideal solution.

From a managerial perspective, the findings emphasize that prioritizing stable and consistent supplier performance can reduce operational risk, minimize packaging-related disruptions, and enhance supply chain reliability. Academically, this study contributes to the supplier selection literature by extending the application of the ANP–TOPSIS approach to carton packaging suppliers, a component that is often treated as secondary despite its strategic importance in manufacturing supply chains.

Future Research

While this study provides valuable insights, several opportunities for future research remain. First, future studies may incorporate sensitivity analysis or robustness testing to examine how changes in criteria weights influence supplier ranking results. Such analysis would enhance the stability and generalizability of the proposed decision model.

Second, subsequent research could extend the evaluation framework by integrating fuzzy logic, grey systems, or probabilistic approaches to better capture uncertainty and subjectivity in expert judgments. Third, future studies may expand the scope of analysis by including sustainability-related criteria, such as environmental impact and social responsibility, to align supplier selection decisions with sustainable supply chain practices.

Finally, applying the proposed model across different industries or comparing multiple case studies would provide broader empirical validation and strengthen the general applicability of the ANP–TOPSIS framework in packaging supplier selection.

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