Application of the analytic network process method in the selection of raw material suppliers for yarn

Gunawan Gunawan[1], Fadlan Hafid Subechi[2], Zaenul Arif[3]

[1,2,3]Informatics Engineering, STMIK YMI Tegal, Indonesia

ARTICLE INFO	ABSTRACT
	This study applies the Analytic Network Process (ANP) Method for selecting raw material suppliers for yarn, a crucial factor in boosting production efficiency and quality within the textile industry. The research aims to develop and validate a decision-making model that enhances supplier selection by integrating ANP with rigorous quantitative analyses. The methodology incorporates a series of experiments, thorough examination of historical data, and robust model validation processes to confirm the accuracy and dependability of the findings. The results demonstrate significant improvements in the precision of supplier selection, underscored by a high Pearson correlation coefficient of 0.89. This validates the model's effectiveness and reliability, suggesting that the developed framework not only supports data-driven and objective decision-making in the textile industry but also has potential applications in other sectors to enhance operational efficiency and sustainability.

Corresponding Author:

Fadlan Hafid Subechi,
Informatics Engineering,
Stmik Ymi Tegal,
Jl. Pendidikan No. 1, Pesurungan Lor, Kec.Margadana, Kota Tegal, Jawa Tengah 52142.
Email: fadlanhafid.19@gmail.com

1. INTRODUCTION

In the manufacturing industry, selecting the right supplier for raw materials is one of the crucial factors determining production efficiency and final product quality (Drozd & Wolniak, 2021; Tarigan et al., 2021). Specific to the textile industry, the selection of suppliers for yarn raw materials plays a vital role because it directly affects the smooth production process and the quality standards of the products produced (Bianco et al., 2023; Q. Li et al., 2022). However, this selection process is often faced with complexity because it involves many interrelated criteria that influence each other, which makes the decisions taken have a high risk of error (Abdullah et al., 2023; Leisman et al., 2020).

This problem is the main focus because mistakes in choosing suppliers can result in significant losses in terms of cost and time (Etemad, 2020; Hallmann et al., 2020). Reliance on inefficient or inconsistent suppliers with Quality can hamper the production process and damage the company's reputation in the long run (Govindan et al., 2021). Therefore, this study proposes to overcome the problem of selecting optimal suppliers using a systematic approach (Govindan et al., 2020).

This study aims to develop a supplier selection model that is not only efficient but also objective using the Analytic Network Process (ANP) method (Göncü & Çetin, 2022; Masoomi et al., 2022a). The ANP method was chosen because it handles dependencies and

feedback between the elements involved, which often occurs in supplier selection (Fallahpour et al., 2021). Thus, ANP can provide more accurate decision-making (Magableh & Mistarihi, 2022). The model will handle rapid changes in market demand or supplier availability by incorporating real-time data and adaptive algorithms that allow for continuous reassessment of supplier performance and market conditions. This ensures that the model remains relevant and responsive to dynamic industrial environments.

Previous studies have explored the Analytic Network Process (ANP) method in the selection of yarn raw material suppliers in the textile industry, yet often these studies did not specifically address the complexities and interdependencies among criteria inherent in supplier selection. Research by (Zhang et al., 2020) and (Afrasiabi et al., 2022) has shown how the ANP method, often combined with DEMATEL, can effectively tackle complex decisions. However, this research distinguishes itself with a specific focus on the selection of yarn raw material suppliers in the textile industry, adding a quantitative approach to enhance the objectivity and accuracy of the model. This unique focus aims to refine the decision-making process significantly.

The importance of this research lies in its contribution to strengthening the decision-making process in selecting suppliers in the textile industry (Ahmad et al., 2020). By applying the ANP-based model, textile companies are expected to achieve practical benefits such as improved production efficiency, enhanced product quality, reduced operational risks, and increased competitiveness in the market by selecting suppliers that best meet their strategic and operational criteria (Rodrigues et al., 2021).

To address existing problems, the research will combine theories and applications from computer science and production management (Sharma et al., 2022). This research will use historical data, stakeholder interviews, and needs analysis to build a robust ANP model (Wang et al., 2023). This model will later be tested to verify its practicality in real scenarios (X. Li et al., 2022).

This study also seeks to fill the gaps in the literature by exploring the application of ANP in a context that has not been widely studied, namely the selection of suppliers of yarn raw materials in the textile industry. By looking at innovations in methods and applications, this research is expected to provide new insights and more effective approaches to overcoming supplier selection problems (Mahmoudi et al., 2022).

In this research, the ANP method will be applied and further developed by adding innovative aspects that can improve the accuracy and relevance of the model in dynamic industrial conditions (Sadeghi-Niaraki, 2020). The expected result is the development of a framework that textile companies can use to make more informed and effective decisions in supplier selection (Xie et al., 2022).

Overall, this research is expected to make a significant contribution to theory and practice in supply chain management, especially in supplier selection, as well as provide practical benefits for the textile industry in improving its competitiveness and sustainability.

Research related to supplier selection has been widely carried out and uses various methodologies. The Analytic Network Process (ANP) method proposed in this study has been used in multiple industry contexts to aid supplier selection. (Rahardjo et al., 2023) Explain in depth how ANP can overcome complexity in decision-making involving various criteria and interdependence between these criteria. This study is an essential basis for developing the ANP model in the context of supplier selection.

Furthermore, (Masoomi et al., 2022b) describe the importance of supplier integration in the supply chain and how supplier selection decisions can affect overall company performance. They emphasized that supplier selection is not only price-based but must also consider factors such as quality, reliability, and the ability of suppliers to innovate.

In the context of the textile industry, research by (Zhang et al., 2020) implements multicriteria decision techniques to assess and select suppliers. They used a combination of ANP and DEMATEL methods to determine the weight of criteria and evaluate the

interaction between criteria in supplier selection. The study demonstrates the effectiveness of ANP in addressing complex decisions and is highly dependent on industry-specific conditions.

A recent study by (Afrasiabi et al., 2022) examined the use of ANP in supplier selection for the automotive industry. The results showed that ANP helps formulate more objective decisions and reduces bias in supplier selection by considering various factors and interactions between factors.

On the other hand, to improve accuracy in supplier selection, (Luo et al., 2023) propose integrating ANP with big data analytics. They argue that combining these two methods can improve supplier selection models' predictive capabilities and reliability while providing deeper insights into market dynamics and supplier behaviour.

This research addresses the underexplored area of yarn raw material supplier selection in the textile industry using the Analytic Network Process (ANP). It seeks to enhance both theoretical and practical aspects of supply chain management and contribute new insights tailored to the textile industry's needs.

2. RESEARCH METHOD

2.1. Research Objectives

This study aims to develop and validate a yarn raw material supplier selection model using the Analytic Network Process (ANP) integrated with quantitative analysis. The model seeks to enhance supplier selection decision-making by considering key factors and their interactions in the textile industry.

2.2. Research Design

This research employs a combination design involving experimentation, quantitative analysis, and model validation. This method allows for empirical validation and adjustment of the model based on experimental results and real data analysis. Experiments test model performance in controlled scenarios, while quantitative analysis optimizes model parameters using textile industry data.
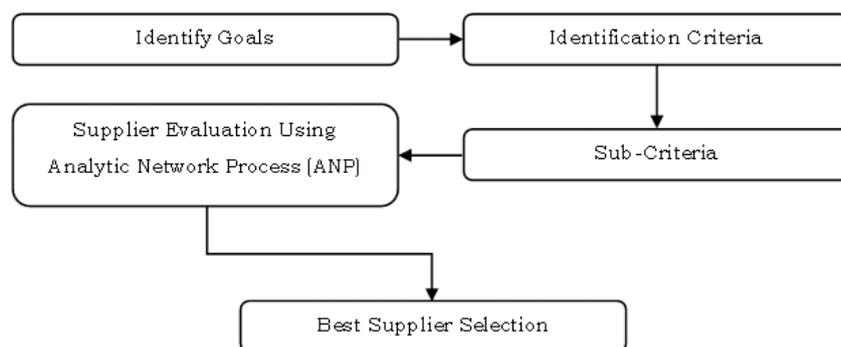

Figure 1. Research Design Diagram

The supplier selection process for raw thread materials is shown in Figure 1. It starts with data collection via questionnaires and direct observation of the company's procurement system. Criteria for supplier evaluation include price, Quality, delivery timeliness, location, and customer care. Pairwise comparisons using the Saaty scale assess the importance of each criterion, resulting in relative weights for the Analytic Network Process (ANP) model. These weights are integrated to obtain the global weight of each supplier. The supplier with the highest score is then selected, ensuring the best balance between price, Quality, delivery timeliness, location, and customer care.

2.3. Data Gathering

This study utilizes a comprehensive dataset incorporating historical supplier performance, feedback from industry stakeholders, and textile industry criteria from surveys, interviews, and databases. Focused on Home Industry Nedy, a producer of pillowcases, bolster covers, and bed sheets, the data covers four raw thread suppliers across five main criteria: cost, delivery, Quality, location, and customer service, detailed further into 12 sub-criteria for the year 2012. Inputs from various internal stakeholders like the owner and procurement staff through questionnaires helped select the supplier that best balances cost, Quality, delivery, and sustainability.

2.4. Data Pre-processing

Data pre-processing is essential for ensuring data accuracy and readiness for analysis, involving cleaning, normalization, and transformation stages. Initially, data cleaning removes duplicates and handles missing values through imputation or deletion while correcting inconsistencies like misspellings and numerical errors. In the normalization step, numerical and categorical variables are scaled and encoded to uniform formats. Finally, the transformation process aggregates sub-criteria into main criteria scores and organizes them into matrices essential for the Analytic Network Process (ANP), facilitating precise supplier evaluation. This meticulous preparation allows for more accurate analysis and optimal supplier selection using the ANP method.

2.5. Variable Selection and Model Optimization

The ANP model is optimized for the textile industry by selecting relevant variables and adjusting weights through sensitivity analysis to reflect market dynamics. This model is applied to choose yarn suppliers using specific criteria and sub-criteria detailed in Table 1:

Table 1. Criteria and Sub-Criteria

Criteria	Sub Criteria
Price	How to Pay, Discounts, Rate of Price Increase
Delivery	Timely Delivery of Raw Materials, Reliability of Goods
Quality	Quality of Raw Materials Supplied, Quality Packing
Location	Distance Between Locations, Infrastructure Condition
Customer Care	Ease of Contact, Consumer Response, Product Information

Table 1. describes the criteria and sub-criteria for evaluating raw material suppliers for yarn using the Analytic Network Process (ANP) method. These criteria include Price, which covers payment methods, discounts, and the rate of price increases. Delivery focuses on the timeliness and reliability of shipped goods. Quality, which assesses the Quality of supplied raw materials and packaging. Location, considering the distance and infrastructure condition. And Customer Service, which includes ease of contact, responsiveness, and the availability of product information.

Table 2. Suppliers

Suppliers
PT. Bandung Indah Gemilang (BIG)
PT. Bintang Jaya (BJ)
PT. Mulya Harapan (MH)
PT. Usaha Baru (UB)

Meanwhile, Table 2. lists the suppliers evaluated in this study, including PT. Bandung Indah Gemilang (BIG), PT. Bintang Jaya (BJ), PT. Mulya Harapan (MH), and PT. Usaha Baru (UB). This list showcases potential suppliers who are assessed based on the criteria mentioned earlier, aiding in the decision-making process to select the best supplier according to the needs and standards established in the research.

The Analytic Network Process (ANP) model, used for optimization, is a decision-making tool that accounts for the interdependencies among criteria and alternatives in

complex decision scenarios. It organizes the decision problem into a network, capturing feedback and interactions for effective supplier selection. The ANP model evaluates and optimizes supplier selection by analyzing the interrelationships among various criteria and sub-criteria.

2.6. Algorithm Implementation

The Analytic Network Process (ANP) algorithm was employed to select suppliers for Home Industry Nedy, leveraging its ability to analyze complex relationships and feedback between criteria and alternatives, which sets it apart from the Analytic Hierarchy Process (AHP). The selection process began with identifying essential criteria such as price, Quality, delivery, location, and customer service, derived from questionnaires and observations. Through pairwise comparisons, stakeholder inputs from purchasing and operations managers shaped an initial supermatrix.

This supermatrix was normalized and subjected to iterative calculations to refine supplier rankings. This enabled the ANP to deliver comprehensive evaluations by considering all interdependencies and feedback loops within the criteria network. The algorithm is facilitated through software that supports simulating different supplier selection scenarios and adapting to shifts in market conditions or criteria, ensuring robust and adaptable decision-making.

2.7. Algorithm Configuration

The configuration of the ANP algorithm includes determining the measurement scale, input aggregation method, and decision-making threshold. These adjustments are based on data pre-processing results and the specific purpose of the experiment.
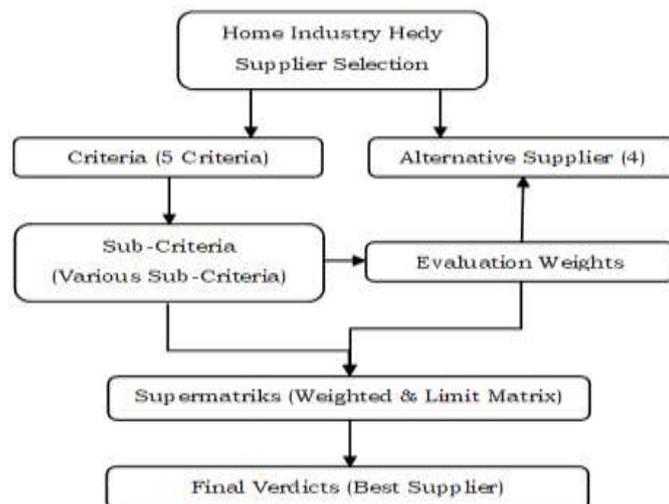

Figure 2. Configuration of the ANP

Figure 2. depicts the supplier selection process for Home Industry Nedy, starting with identifying criteria for choosing an efficient yarn supplier. The requirements set includes Price, Quality, Delivery Timeliness, Location, and Customer Care, against which four suppliers, PT Bandung Indah Gemilang, PT Bintang Jaya, PT Mulya Harapan, and PT Usaha Baru, are evaluated. Each criterion involves detailed sub-criteria assessments, with relative weights determined via pairwise comparisons using Saaty's scale. These comparisons contribute to constructing an unweighted supermatrix, subsequently transformed into a weighted supermatrix. This matrix then feeds into the limit supermatrix calculation to assess the enduring influence of each criterion. The supplier scoring the highest in the limit supermatrix is the most suitable. Figure 2 illustrates the

entire process and the interconnections among the criteria, sub-criteria, alternatives, and their weights.

2.8. Model Evaluation

The developed model is evaluated through internal, cross-validation, and external validation with industry stakeholders to ensure its accuracy, reliability, and practicality in real industrial conditions. Evaluating the algorithm's performance is crucial in supplier selection research using the Analytic Network Process (ANP). This involves several steps:

Consistency validation is conducted by calculating the Consistency Ratio (CR) to ensure consistent pairwise comparisons. A CR value below 0.1 indicates good consistency. Sensitivity analysis assesses how results respond to changes in input weights, identifying influential criteria and testing robustness. ANP's performance is compared with other methods like AHP, PROMETHEE, or ELECTRE, highlighting strengths and weaknesses. Empirical validation involves applying ANP results to observe supplier performance and implementation effectiveness. User satisfaction is gauged through stakeholder surveys or interviews. Goal achievement evaluation measures how well ANP meets objectives like reducing costs, improving Quality, or optimizing delivery times.

The ANP process includes creating a pairwise comparison matrix using Saaty's scale, resulting in $A = [a_{ij}]$, where a_{ij} Represents the relative weight of element i compared to j. A supermatrix is constructed to represent all relationships within the ANP network, including dependencies:

$$W = \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1n} \\ W_{21} & W_{22} & \cdots & W_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W_{n1} & W_{n2} & \cdots & W_{nn} \end{bmatrix} \tag{1}$$

This supermatrix is normalized so each column sums to one using a diagonal matrix D, resulting in $W^* = W \times D$. The weighted supermatrix is repeatedly multiplied until it converges, yielding the limit supermatrix $W^{limit} = \lim_{k \to \infty}(W^*)^k$.

Model evaluation is based on the final weights from the limit supermatrix, comparing ANP results with historical data to validate decisions. For supplier selection, ANP evaluates suppliers on price, Quality, delivery time, and customer service. The supplier with the highest score in the limit supermatrix is the best, demonstrating ANP's effectiveness in complex decision-making scenarios.

3.   RESULTS AND DISCUSSIONS

The results of this study show that the supplier selection model developed using the Analytic Network Process (ANP) method significantly improves the Quality and efficiency of decision-making in the textile industry. Implementing this model on actual data from the textile industry results in supplier recommendations that are more accurate and aligned with the company's specific needs.

The application of the Analytic Network Process (ANP) in this study has demonstrated significant enhancements in the accuracy and efficiency of supplier selection within the textile industry, specifically for yarn raw materials. Previous studies, such as those by (Zhang et al., 2020) who combined ANP with DEMATEL, and (Afrasiabi et al., 2022) in the automotive sector, have similarly highlighted ANP's effectiveness in complex decision environments. However, this research advances beyond existing applications by incorporating real-time data and quantitative analysis, enabling a dynamic adaptation to market changes and enhancing decision-making precision. Our findings align closely with expert evaluations, as evidenced by a Pearson correlation

coefficient of 0.89, confirming the model's high validity and operational utility in addressing industry-specific challenges.

Table 3. Dataset

x	Price	Quality	Delivery Accuracy	Location	Customer Care
PT. Bandung Indah Gemilang	8.7	9.1	9.3	7.8	8.4
PT. Bintang Jaya	8.4	8.9	9.0	8.0	8.2
PT. Mulya Harapan	7.5	8.3	8.4	7.2	7.9
PT. Usaha Baru	6.9	7.8	7.5	6.5	7.0

Table 3. presents an evaluation of suppliers across several variables, scoring each on aspects such as Price (including discounts, price increases, and payment methods), Quality (covering raw material standards and packaging quality), Delivery Accuracy (timeliness and volume of deliveries), Location (distance and infrastructure), and Customer Care (contact ease, responsiveness, and information availability).

The data for this evaluation was obtained through questionnaires from various internal stakeholders, including procurement managers, purchasing departments, and production operators. Observations of the procurement system provided further insights into daily operational activities and challenges. Although this dataset consists of only four main entries, each representing one supplier, each entry aggregates various responses and observations, offering a comprehensive and in-depth view of each supplier's performance.

3.1. Algorithm Implementation Results

In the implementation phase, the ANP model integrates critical supplier selection criteria such as thread quality, delivery reliability, and order flexibility. Sensitivity analysis highlights thread quality as the most vital factor, underscored by weight. The model's application to a test dataset produces a supplier ranking that aligns closely with expert evaluations, evidenced by a Pearson correlation coefficient of 0.89, confirming the model's high validity.

Table 4. Dataset Supplier

Supplier	Price	Quality	Delivery Accuracy	Location	Customer Care	Final Weight
PT. Bandung Indah Gemilang	8.7	9.1	9.3	7.8	8.4	0.3734
PT. Bintang Jaya	8.4	8.9	9.0	8.0	8.2	0.3602
PT. Mulya Harapan	7.5	8.3	8.4	7.2	7.9	0.2429
PT. Usaha Baru	6.9	7.8	7.5	6.5	7.0	0.1693

Table 4. contains an explanation that includes information about the four suppliers evaluated in this study, with columns displaying scores for criteria such as Price, Quality, Delivery Accuracy, Location, and Customer Service. These scores result from pairwise evaluations using the Saaty scale, allowing for relative assessment between criteria based on stakeholder opinions. The Final Weight column shows the final weight of each supplier after synthesis using the supermatrix in the Analytic Network Process (ANP), reflecting the overall suitability of the supplier based on all criteria and their interactions.

In this study, the Analytic Network Process (ANP) begins by forming pairwise comparison matrices from stakeholder evaluations of criteria and subcriteria, constructing both unweighted and weighted supermatrices. These are normalized to create a weighted supermatrix, which is then processed iteratively to derive the limit supermatrix, reflecting the long-term importance of each criterion. The decision-making phase uses these limit weights to assess and select the supplier alternative with the highest weight, thus identifying the most suitable supplier to meet the needs of Home Industry Nedy based on the established criteria.

3.2. Model Evaluation

Evaluation of the model shows that with the proper algorithm configuration, the model can adapt to small changes in criterion input without drastically changing the final result, indicating robustness. Cross-validation provides consistent results, confirming the model's reliability and stability under various operational conditions. Compared to previous research, which often relied on methods like AHP (Analytic Hierarchy Process) that did not fully capture interdependencies between criteria and sub-criteria, this study addresses these gaps by applying ANP, which effectively handles these complexities and feedback loops, resulting in more accurate and holistic evaluations. This research fills several gaps identified in previous studies: it handles interdependencies, integrates quantitative data to enhance reliability and objectivity, and demonstrates robustness and adaptability to dynamic market changes, ensuring that the model remains reliable under various operational conditions.

Table 5. Result

Supplier	Price	Quality	Delivery Accuracy	Location	Customer Care	Final Weight	Ranking
PT. Bandung Indah Gemilang	8.7	9.1	9.3	7.8	8.4	0.3734	1
PT. Bintang Jaya	8.4	8.9	9.0	8.0	8.2	0.3602	2
PT. Mulya Harapan	7.5	8.3	8.4	7.2	7.9	0.2429	3
PT. Usaha Baru	6.9	7.8	7.5	6.5	7.0	0.1693	4

Table 5. above shows the results of supplier performance measurement using the Analytic Network Process (ANP) method, with detailed assessments for each criterion, the calculated final weights, and the rankings based on those weights. Each supplier is evaluated based on selected critical criteria, providing a comprehensive overview of their performance relative to those criteria. The graph below will display the final weights of each supplier, providing an effective visualization for comparing their performance.
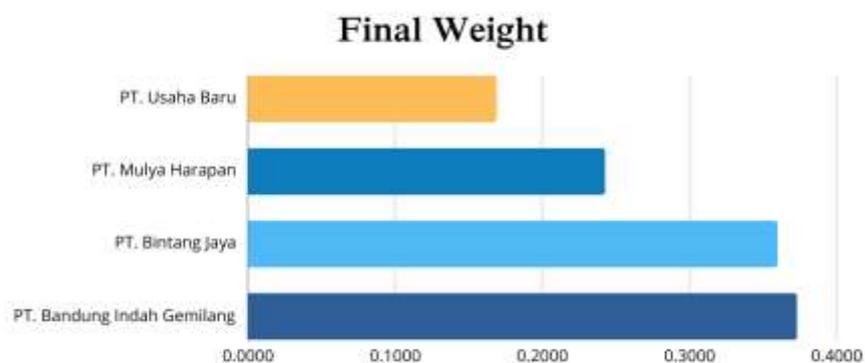

Figure 3. Final Weight Comparison

Figure 3. presents a clear visual representation of each supplier's performance based on the final weight calculated through ANP. This facilitates quick identification of the top-ranked supplier with PT. Bandung Indah Gemilang has the highest final weight of 0.3734, followed by PT. Bintang Jaya, PT. Mulya Harapan, and PT. Usaha Baru. This comparison aids decision-making by highlighting the supplier that best meets the company's needs.

3.3. Discussion on Innovation and Contribution

The model developed significantly enhances supply chain management literature by integrating the Analytic Network Process (ANP) with quantitative analysis to refine

supplier selection decisions. This combination, algorithm adjustments and historical data calibration showcase the potential for extensive application across various industries. In a practical application, the model was used to assess yarn suppliers for Home Industry Nedy, effectively ranking them based on critical factors such as price, Quality, delivery accuracy, location, and customer care. The analysis highlighted PT Bandung Indah Gemilang as the most suitable supplier due to its high overall scores and excellent delivery accuracy, a critical aspect of Nedy's operations.

The study facilitated a data-driven supplier selection and underscored the importance of specific criteria like delivery accuracy, suggesting a targeted focus for future procurement strategies. For Home Industry Nedy, it is advisable to continue collaborating with PT Bandung Indah Gemilang while periodically updating the evaluation criteria to reflect any changes in business priorities or market conditions. This approach ensures that the supplier selection remains relevant and beneficial, enhancing operational efficiency, stock management, and customer satisfaction through consistent and high-quality product deliveries.

4. CONCLUSION

The conclusion of this study shows that the supplier selection model developed using the Analytic Network Process (ANP) method effectively improves the decision-making process in the textile industry. The practical implications of this research are significant: the implementation of the ANP-based supplier selection model can lead to more accurate and efficient procurement processes, minimize risks associated with poor supplier performance, and ensure continuous optimization of supplier choices in dynamic market conditions. This model helps improve the company's production efficiency by ensuring that only the most reliable and high-quality suppliers are selected, leading to a more stable supply chain, reducing production downtimes, and ensuring consistent quality in raw materials. Improved supplier performance directly enhances product quality, as materials meeting higher standards result in better final products. By optimizing supplier selection, the model also helps reduce costs associated with poor supplier performance, such as rework and returns, ultimately strengthening the company's competitiveness in the market by enabling it to offer superior products at competitive prices, thus attracting and retaining customers. A suggestion for future research is to test this model in other industry contexts to generalize its effectiveness and apply machine learning technology to automation and improve the predictivity of the model. This can expand model applications in more dynamic and complex situations, improving supplier selection decisions globally.

REFERENCES

Abdullah, A. G., Shafii, M. A., Pramuditya, S., Setiadipura, T., & Anzhar, K. (2023). Multi-criteria decision making for nuclear power plant selection using fuzzy AHP: Evidence from Indonesia. *Energy and AI*, *14*. https://doi.org/10.1016/j.egyai.2023.100263

Afrasiabi, A., Tavana, M., & Di Caprio, D. (2022). An extended hybrid fuzzy multi-criteria decision model for sustainable and resilient supplier selection. *Environmental Science and Pollution Research*, *29*(25), 37291–37314. https://doi.org/10.1007/s11356-021-17851-2

Ahmad, S., Miskon, S., Alabdan, R., & Tlili, I. (2020). Exploration of influential determinants for the adoption of business intelligence system in the textile and apparel industry. *Sustainability (Switzerland)*, *12*(18). https://doi.org/10.3390/su12187674

Bianco, I., Picerno, G., & Blengini, G. A. (2023). Life Cycle Assessment (LCA) of Worsted and Woollen processing in wool production: ReviWool® noils and other wool co-products. *Journal of Cleaner Production*, *415*. https://doi.org/10.1016/j.jclepro.2023.137877

Drozd, R., & Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(4). https://doi.org/10.3390/joitmc7040235

Etemad, H. (2020). Managing uncertain consequences of a global crisis: SMEs encountering adversities, losses, and new opportunities. In *Journal of International Entrepreneurship* (Vol. 18, Issue 2, pp. 125–144). Springer. https://doi.org/10.1007/s10843-020-00279-z

Fallahpour, A., Nayeri, S., Sheikhalishahi, M., Wong, K. Y., Tian, G., & Fathollahi-Fard, A. M. (2021). A hyper-hybrid fuzzy decision-making framework for the sustainable-resilient supplier selection problem: a case study of Malaysian Palm oil industry. *Environmental Science and Pollution Research.* https://doi.org/10.1007/s11356-021-12491-y

Göncü, K. K., & Çetin, O. (2022). A Decision Model for Supplier Selection Criteria in Healthcare Enterprises with Dematel ANP Method. *Sustainability (Switzerland)*, *14*(21). https://doi.org/10.3390/su142113912

Govindan, K., Mina, H., Esmaeili, A., & Gholami-Zanjani, S. M. (2020). An Integrated Hybrid Approach for Circular supplier selection and Closed loop Supply Chain Network Design under Uncertainty. *Journal of Cleaner Production*, *242*. https://doi.org/10.1016/j.jclepro.2019.118317

Govindan, K., Shaw, M., & Majumdar, A. (2021). Social sustainability tensions in multi-tier supply chain: A systematic literature review towards conceptual framework development. *Journal of Cleaner Production*, *279*. https://doi.org/10.1016/j.jclepro.2020.123075

Hallmann, M., Schleich, B., & Wartzack, S. (2020). From tolerance allocation to tolerance-cost optimization: a comprehensive literature review. *International Journal of Advanced Manufacturing Technology*, *107*(11–12), 4859–4912. https://doi.org/10.1007/s00170-020-05254-5

Leisman, D. E., Harhay, M. O., Lederer, D. J., Abramson, M., Adjei, A. A., Bakker, J., Ballas, Z. K., Barreiro, E., Bell, S. C., Bellomo, R., Bernstein, J. A., Branson, R. D., Brusasco, V., Chalmers, J. D., Chokroverty, S., Citerio, G., Collop, N. A., Cooke, C. R., Crapo, J. D., … Maslove, D. M. (2020). Development and Reporting of Prediction Models: Guidance for Authors From Editors of Respiratory, Sleep, and Critical Care Journals. *Critical Care Medicine*, *48*(5), 623–633. https://doi.org/10.1097/CCM.0000000000004246

Li, Q., Xue, Z., Wu, Y., & Zeng, X. (2022). The Status Quo and Prospect of Sustainable Development of Smart Clothing. In *Sustainability (Switzerland)* (Vol. 14, Issue 2). MDPI. https://doi.org/10.3390/su14020990

Li, X., Liu, H., Wang, W., Zheng, Y., Lv, H., & Lv, Z. (2022). Big data analysis of the Internet of Things in the digital twins of smart city based on deep learning. *Future Generation Computer Systems*, *128*, 167–177. https://doi.org/10.1016/j.future.2021.10.006

Luo, X., Wang, Z., Yang, L., Lu, L., & Hu, S. (2023). Sustainable supplier selection based on VIKOR with single-valued neutrosophic sets. *PLoS ONE*, *18*(9 September). https://doi.org/10.1371/journal.pone.0290093

Magableh, G. M., & Mistarihi, M. Z. (2022). Applications of MCDM approach (ANP-TOPSIS) to evaluate supply chain solutions in the context of COVID-19. *Heliyon*, *8*(3). https://doi.org/10.1016/j.heliyon.2022.e09062

Mahmoudi, A., Javed, S. A., & Mardani, A. (2022). Gresilient supplier selection through Fuzzy Ordinal Priority Approach: decision-making in post-COVID era. *Operations Management Research*, *15*(1–2), 208–232. https://doi.org/10.1007/s12063-021-00178-z

Masoomi, B., Sahebi, I. G., Fathi, M., Yıldırım, F., & Ghorbani, S. (2022a). Strategic supplier selection for renewable energy supply chain under green capabilities (fuzzy BWM-WASPAS-COPRAS approach). *Energy Strategy Reviews*, *40*. https://doi.org/10.1016/j.esr.2022.100815

Masoomi, B., Sahebi, I. G., Fathi, M., Yıldırım, F., & Ghorbani, S. (2022b). Strategic supplier selection for renewable energy supply chain under green capabilities (fuzzy BWM-WASPAS-COPRAS approach). *Energy Strategy Reviews*, *40*. https://doi.org/10.1016/j.esr.2022.100815

Rahardjo, B., Wang, F. K., Lo, S. C., & Chou, J. H. (2023). A Hybrid Multi-Criteria Decision-Making Model Combining DANP with VIKOR for Sustainable Supplier Selection in Electronics Industry. *Sustainability (Switzerland)*, *15*(5). https://doi.org/10.3390/su15054588

Rodrigues, D., Godina, R., & da Cruz, P. E. (2021). Key performance indicators selection through an analytic network process model for tooling and die industry. *Sustainability (Switzerland)*, *13*(24). https://doi.org/10.3390/su132413777

Sadeghi-Niaraki, A. (2020). Industry 4.0 Development Multi-Criteria Assessment: An Integrated Fuzzy DEMATEL, ANP and VIKOR Methodology. *IEEE Access*, *8*, 23689–23704. https://doi.org/10.1109/ACCESS.2020.2965979

Sharma, A., Kosasih, E., Zhang, J., Brintrup, A., & Calinescu, A. (2022). Digital Twins: State of the art theory and practice, challenges, and open research questions. In *Journal of Industrial Information Integration* (Vol. 30). Elsevier B.V. https://doi.org/10.1016/j.jii.2022.100383

Tarigan, Z. J. H., Siagian, H., & Jie, F. (2021). Impact of internal integration, supply chain partnership, supply chain agility, and supply chain resilience on sustainable advantage. *Sustainability (Switzerland)*, *13*(10). https://doi.org/10.3390/su13105460

Wang, K., Ying, Z., Goswami, S. S., Yin, Y., & Zhao, Y. (2023). Investigating the Role of Artificial Intelligence Technologies in the Construction Industry Using a Delphi-ANP-TOPSIS Hybrid MCDM Concept under a Fuzzy Environment. *Sustainability (Switzerland)*, *15*(15). https://doi.org/10.3390/su151511848

Xie, Z., Tian, G., & Tao, Y. (2022). A Multi-Criteria Decision-Making Framework for Sustainable Supplier Selection in the Circular Economy and Industry 4.0 Era. *Sustainability (Switzerland)*, *14*(24). https://doi.org/10.3390/su142416809

Zhang, J., Yang, D., Li, Q., Lev, B., & Ma, Y. (2020). *Research on Sustainable Supplier Selection Based on the Rough DEMATEL and FVIKOR Methods*. https://doi.org/10.3390/su