A Hybrid AHP-TOPSIS Framework for Strategic Supplier Evaluation in the Textile Industry Supply Chain

[1] Dr.Vadivel S.M ,[2]Blessy Maria Mathew, [3]Abdulla Swalih NM ,[4]Saahith
[1]VIT Business School, Vellore Institute of Technology, Chennai, India
School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, India
vadivel.sm@vit.ac.in ,blessymaria.mathew2021@vitstudent.ac.in ,abdullaswalih.nm2021@vitstudent.ac.in, saahith.2021@vitstudent.ac.in

Abstract

The process of supplier selection is an essential function aimed at increasing the operational efficiency and competitiveness of supply chains. This paper introduces a hybrid framework integrating the Analytical Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to evaluate and select suppliers in the textile industry. We use AHP to determine accurate, normalized weights for the important criteria of the problem: cost, quality, delivery time, reliability, flexibility, and sustainability. Utilizing these weights, TOPSIS calculates the rankings for the suppliers based on how close they are to ideal and anti-ideal solutions. The framework cuts the trade-offs between quantitative and qualitative efficiencies, such as cost efficiency versus sustainability. Real-world application of the model demonstrates its efficacy in supplier selection that pays attention to strategic goals in order to improve the accuracy of decision and lead to resilient and sustainable supply chains. Bridging conventional methodologies and providing a scalable adaptable solution for complex supplier evaluation challenges, this hybrid approach copes with gaps.

Keywords-Supplier Selection, AHP, TOPSIS, Textile Supply Chain, Decision-Making Model, Sustainability, Operational Efficiency, Multi-Criteria Analysis

1. Introduction

The textile industry is one of the most dynamic and competitive sectors in the fast-changing global marketplace, requiring a supply chain to simultaneously achieve the balance between efficiency, cost-effectiveness, sustainability, and quality in response to the changing demands of consumers and businesses. As the backbone of this industry, supplier evaluation and selection are pivotal activities which allow a supply chain to be strong and endure. In this process, the procedure to choose suppliers comes out as a labyrinth of criteria and is often judgment-tinged, involved with conflicting priorities and interdependencies between cost, quality, delivery time, reliability, flexibility, and sustainability.

Addressing the problems enumerated above, this research advances a holistic, innovative hybrid framework that integrated the strength of Analytical Hierarchy Process with the Technique for Order Preference by Similarity to Ideal Solution so that an assessment of suppliers can be made with a robust, systematic, and strategic approach. AHP methodology thus helps in establishing weights for criteria under evaluation in a structured process of pairwise comparison which accommodates the subjective preferences of the stakeholders while thereby reducing inconsistencies.

On the other hand, TOPSIS will rank the suppliers by how close they are to the ideal solution, hence giving the decision-makers an option about choosing the most appropriate supplier using their respective weighted normalized performance values relative to the best and worst possible options. In the combined application of these two methods, the assessment becomes precise and comprehensive, covering interdependencies and trade-offs between these different criteria. This hybrid approach was applied to real-world data from nine stakeholders in the textile supply chain by the use of qualitative and quantitative assessments to prove applicability and

effectiveness. The different preferences of the stakeholders on the various dimensions have therefore enabled the building of a weighted normalized matrix that was the basis for further TOPSIS analysis. Criteria were categorized into either benefit or non-benefit types, which appropriately reflects their impacts on making decisions. For instance, with benefit criteria, the higher values are more desirable. In the case of non-benefit criteria, its value has to be minimized. Our study results thus show that the hybrid AHP-TOPSIS model is able to rank suppliers objectively and uncover available high-performance candidates that respond to strategic objectives, such as increasing sustainability and improving efficiencies in operations with an effective control of costs. This project is highly significant for the textile industry, which has been increasing pressure with global disruptions in supply chains, environmental regulations, and shifting expectations of consumers. Using advanced decision-support tools, the hybrid framework offers textile companies a data-driven and transparent decision-making process for choosing suppliers that supports supply chain resilience and long-term competitiveness. It also highlights the requirement of multistakeholder participation and involvement to make the process more refined which would diminish some of the disadvantages of conventional approaches used in the process of selection of suppliers, which, traditionally, pay little attention to the various dimensions of a decision. This framework can be easily implemented within modern supply chain management systems for scalability and adaptability into many contexts and sectors beyond textiles, as more industries embark on a journey of digital transformation.

A balanced approach that accommodates both kinds of data-quantitative and qualitative-will fill critical gaps in existing methodologies represented by the hybrid AHP-TOPSIS model, placing this model as an important step forward within the multi-criteria decision-making area. The structured methodology of this project thus also bridges the gap between theoretical models and practical applications and at the same time will be a guide for future research and innovations concerning frameworks of the evaluation of suppliers. In this project, it can be seen that the marriage of AHP and TOPSIS has evolved to revolutionize the evaluation of a supplier by change from subjective, complicated decision-making processes to ones that are transparent, reliable, and actionable. Driven from such evaluation procedures, the primary goal is to run operations with excellence and strategic alignment in the textile supply chain.

2.Related Works

SL. NO.	TITLE, AUTHOR & YEAR	OBJECTIVE	METHODOLOGY	DESCRIPTION /REMARKS
1.	**Sustainable supplier selection in the textile dyeing industry: A multi-criteria decision-making approach** Md Mahfujur Rahman, A. B. M. Mainul Bari, Syed Mithun Ali, Amirhossein Taghipour Year: 2022	to structure the framework of sustainable supplier selection in the textile dyeing industry, to identify and assess relevant economic, environmental, and social criteria in order to select suppliers in the textile industry .	SWARA (Step-wise Weight Assessment Ratio Analysis) WASPAS (Weighted Aggregated Sum Product Assessment)	• The study proposes a conceptual model for sustainable supplier conception for textile dyeing industry in Bangladesh which adopts multiple criteria decision making. • This paper defines 15 factors within the economic, environmental, and socio-parameters; the SWARA technique is then used to decide the weights of the criteria while the WASPAS technique is used in ranking the suppliers based on the criteria. • It will help the decision-makers while selecting sustainable suppliers; however, some of the limitations exist like a fewer number of experts.
2.	**Assessing sustainability risks in the supply chain of the textile industry under uncertainty** Shahriar Raian, Syed Mithun Ali, Md. Rayhan Sarker, Bathrinath Sankaranarayanan, Golam Kabir, Sanjoy Kumar Paul, Ripon Kumar Chakrabortty **Year:** 2021	Identifying and quantifying sustainability risks within the textile value chain. It is designed to support industry practitioners in evaluating and proactively managing these risks by providing practical directions	Fuzzy Synthetic Evaluation Probability Assessment (for likelihood, impact, and criticality)	• This study examines sustainability risks in the textile industry's supply chain using the fuzzy synthetic evaluation (FSE) method. It identifies five key risk groups—supplier, financial, social, transportation, and environmental—and highlights critical factors like poor transportation, pollution, and factory fires. • The research emphasizes the importance of managing these risks to ensure the industry's long-term sustainability.

3.	**Risk analysis in textile industries using AHP-TOPSIS** Authors: S. Bathrinath, R.K.A. Bhalaji, S. Saravanasankar Year: 2020	To identify the key risks of textile industry, understand their impact and establish essential alternatives for risk management .Analytic Hierarchy Process(AHP) along with Technique For Order Of Preference By Similarity To Ideal Solution(TOPSIS).	Analytic Hierarchy Process (AHP) Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	• The paper employs a two-phase Ainfiltrated Multiple Criteria Decision Making technique of AHP and TOPSIS to evaluate and rank the risks in the textile sector. • From this twelve accident risk factors involved in accident are recognized, weighted with AHP and ranked with TOPSIS.
4.	**Supply Chain Management Process of Textile Industry: A Case Study on Bangladesh** Md. Jahid Hasan Akash Year: 2023	Ahmet Aytekin, Ömer Faruk Görçün, Fatih Ecer, Dragan Pamucar, Çağlar Karamaşa 2023	Hybrid MCDM Analytic Hierarchy Process (AHP) Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)	• The fact that stock levels of medicines are negatively related with the quality of logistics services pharmaceutical supply chains makes the issue of selecting the right logistics service providers as imperative in the cases like this, as indicated in this paper. • In view of these matters as a context for the strategic decision-making processes, it underlines the methodological perspective as useful in approaching these complicated and at the same time ambiguous criteria.
5.	**Using AHP-TOPSIS methodologies in the selection of sustainable suppliers in an electronics supply chain** R.R. Menon and V. Ravi Year: 2022	To construct a model for green supplier selection in electronics industry where various criteria are considered that belongs economic, environmental, social and ethical dimensions.	Analytic Hierarchy Process (AHP) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	• The paper proposes a model for selecting sustainable suppliers in the electronics industry using AHP and TOPSIS. It identifies four main criteria—economic, environmental, social, and ethical—and ranks suppliers based on these criteria. • The model emphasizes the integration of sustainability into supplier selection, highlighting the importance of ethical and social factors.
6	***Sustainable supplier selection in the apparel industry: an integrated AHP-TOPSIS model for multi-criteria decision analysis***	This paper proposes a multi-criteria supplier selection model to enable organizations to evaluate and choose sustainable suppliers in an apparel supply chain by virtue of competing sustainable development criteria	AHP (uzzy Analytic Hierarchy Process) TOPSIS(Technique for Order of Preference by Similarity to Ideal Solution)	• This study proposes a framework for the sustainable supplier selection in the apparel industry adopting the methods of AHP and TOP-SIS. • Criteria weights are determined by AHP while the ranking of suppliers based on AHP determined weights is done by TOPSIS.

	Nhu Ngoc Phan Ha, Duc Duy Nguyen, Song Thanh Quynh Le **Year**: 2024			
7.	***Integration of RFID strategic value attributes mechanism decision in apparel supply chain: fuzzy AHP-TOPSIS approach*** Mukesh Kumar **Year**: 2023	To find and rank Radio Frequency Identification (RFID) strategic value attributes (SVAs), by bridging them with technology coordination tools in the form of RFID tags, used for providing better supply chain visibility in apparel sector as a whole	FAHP (Fuzzy Analytic Hierarchy Process) FTOPSIS (Fuzzy Technique for Order of Preference by Similarity to Ideal Solution)	• The ranking and evaluation in this paper are done using FAHP and FAHP-FTOPSIS for RFID strategic value attributes and integration options in apparel SCs. • The methods enhance the supply chain transparency and flexibility. The following are some of the findings; the strategic implementation plan for RFID mechanisms and integration options that would improve inventory management and such issues as multiple tags ownership. • The study is confined to five RFID mechanisms and three integration options.
8.	**Prioritizing Resilient Capability Factors of Dealing with Supply Chain Disruptions: An Analytical Hierarchy Process (AHP) Application in the Textile Industry** Arsalan Zahid Piprani, Noor Ismawati Jaafar, Suhana Mohezar Ali Year:2020	To identify and categorize the resilient capability factors at various stages of supply chain disruptions in the Pakistan textile industry.	Analytical Hierarchy Process (AHP): Used to rank the factors of resilient capability that was identified above.	• The research also delineates and categorizes resilient capability attributes which are paramount in managing disruption risks in Pakistan's textile supply chain. • They underscore the need for constructing a coherent supply chain network and stress that the readiness phase is one of the most critical for creating a robust structure.
9.	**Analysing barriers of sustainable supply chain in apparel & textile sector: A hybrid ISM-MICMAC and DEMATEL approach.**	The purpose of the paper is also to determine and discuss the main challenges associated with the integration of sustainable supply chains in the apparel and textile sector.	ISM Technique. MICMAC Technique. DEMATEL Technique	• The specific concern of the paper is to ascertain and assess the antecedents of green innovation in the apparel and textile industry. ISM and DEMATEL will be employed to determine the interactions and relative impact of these drivers in the context of an SC. • Some of the critical drivers highlighted in the study are regulatory requirements, customers and

	Amit Vishwakarma, G.S. Dangayach,M.L. Meena,Sumit Gupta Year:2022			corporate top management commitment.
10.	**Applying Integrated Blockchain and Big Data Technologies to Improve Supply Chain Traceability and Information Sharing in the Textile Sector** Manal Hader, David Tchoffa, Abderrahman El Mhamedi, Parisa Ghodous, Alexandre Dolgui, Abdellah Abouabdellah Year:2022	The aim of this work is to suggest the application of the Blockchain and Big Data that enhances the-process of supply chain tracking and informed communication in the textile industry.	literature review of previous studies textile supply chain systems The study of the current textile supply chain systems A proposed blockchain integrated Big Data framework	• The paper also highlights the problems which textile supply chain encounter; these include opacity, falsification, and weak accountability. • To address the problem, the authors put forward an integrated solution based on the Blockchain and Big Data technologies for the textile sector to build a transparency, tractability, and scalability for information exchange.
11.	**Impact of COVID-19 on the Textile, Apparel and Fashion Manufacturing Industry Supply Chain: Case Study on a Ready-Made Garment Manufacturing Industry** Samit Chakraborty, Manik Chandra Biswas **Year:2020**	the aim of this paper is to examine how the COVID-19 pandemic affected the supply chain of the textile, apparel, and fashion manufacturing (TAFM) industries; discover the causes of interruption; pray consumer behaviour; and evaluate how it influenced a ready-made garment (RMG) industry.	analyzing a textual review of the effects of COVID 19 on TAFM academic journals and all other industry	• This paper discusses the severe impacts of the COVID-19 pandemic to the TAFM industry's supply chain interconnectivity. This one explains how globalization, international travel bans, and limited access to materials aggravated the effect. • The understanding gathered is derived from a textual analysis of documents of published information on disruption factors of the industry supply chains and a case of an RMG industry.
12.	**Investigating Barriers to Circular Supply Chain in the Textile Industry from Stakeholders' Perspective**	The objective of the research is to reveal key challenges that prevent the practical use of circular supply chain in the context of the textile industry with reference to the main stakeholders.	Fuzzy-Decision Making Trial and Evaluation Laboratory (DEMATEL) method	• The research focus of this paper is on the factors that hinder textile firms from migrating to circular supply chain management consistent with circular economy system. • Some of the barriers of interest are: no national network of collection, sorting and recycling; the refusal of adoption

	Ipek Kazancoglu, Yigit Kazancoglu, Aysun Kahraman, Emel Yarimoglu, Gunjan Soni Year:2020			of the circular economy model; the problems associated with standardization and homogenization
13.	**An Interactive Fuzzy Programming Approach for a Sustainable Supplier Selection under Textile Supply Chain Management** Muhammad Tayyab, Biswajit Sarkar Year:2021	The study aims to develop a comprehensive model for evaluating textile dyestuff suppliers and allocating quantities, addressing the multi-period and multi-objective nature of cost, quality, and time within textile supply chain management.	weighted fuzzy goal programming model management MPMOTSCM approach.	• This research presents an advanced model for evaluating and selecting dyestuff suppliers in the textile industry, focusing on optimizing cost, quality, and time objectives. • The model employs an interactive fuzzy programming approach to handle the uncertainty and multi-objective nature of the problem.
14.	**Social Sustainable Supply Chain Management in the Textile and Apparel Industry—A Literature Review** Deniz Köksal, Jochen Strähle, Martin Müller, Matthias Freise **Year:2019**	The research objectives of the study are: i) To propose a model for quantitative analysis of textile dyestuff suppliers and quantitative proportioning that will capture the multi-period analysis of cost, quality, and time in textile SCM.	45 peer-reviewed literature	To validate the SSCM indicators most relevant for the textile sector with the help of a quantitative approach, especially due to the existing industrial disruption and the requirement of ambidexterity.
15.	**Assessing data-driven sustainable supply chain management indicators for the textile industry under industrial disruption and ambidexterity.** Ming-Lang Tseng a b ,Tat-Dat Bui a f, Ming K. Lim c, Minoru Fujii , Umakanta Mishra e **Year: 2022**	To validate the SSCM indicators most relevant for the textile sector with the help of a quantitative approach, especially due to the existing industrial disruption and the requirement of ambidexterity.	Analytical Hierarchy Process (AHP) and Fuzzy AHP	• This paper aims at developing a systematic approach for technology and supplier selection criteria in the high functionality of textile industry with an implication of supply chain factors rather than the conventional technical values. • It reveals that upon the evaluation of competitive technologies for investment, the biggest struggle is identifiably when the technologies appear to offer similar performance benchmarks. • The proposed methodology containing AHP and Fuzzy AHP provides the framework which can be used and modified by other industries • In general, the study offers useful recommendations about decision-making in manufacturing environment.

16.	**A Fuzzy Multi-Criteria Model with Pareto Analysis for Prioritizing Sustainable Supply Chain Barriers in the Textile Industry: Evidence from an Emerging Economy.** M.R. Rashid,S.K.Ghosh, Md.F.B. Alam,Mohammad Faizur Rahman **Year:** 2023	To propose a fuzzy multi-criteria decision making model with Pareto analysis to unearth and rank as well as analyse the barriers associated with sustainable supply chain management: in the context of the textile industry, specifically in an emerging economy.	hybrid methodology that combines: Pareto Analysis - SSCM. The Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL).	There are many challenges and fluctuations occurring in the textile industry specifically in the emerging nations because of the high level of demand and low levels of resources. The influence of certain circumstances such as epidemics or regional conflicts increases the difficulties for companies to operate at a global level. The study thus calls for the enhancement of SSCM as a strategy in an attempt to attain the objective of cost reduction, increased productivity and thereby profits. It pinpoint and explicate the drivers that hinder the implementation of SSCM in the textile industry where the study reveals that the main ones are; top management uncomposure, inadequate financial motivation, and non-existent government policy support. The results generated are meant to guide the governments and policymakers confronted with these challenges in emerging economies to fashion out how they can overcome these barriers while enhancing the sustainability of the textile sector in the long run.
17.	**Industry 4.0 Technology-Supported Framework for Sustainable Supply Chain Management in the Textile Industry.** Ding, Chen., Umar, Muhammad, Gummi., Jia, Lei., Hua-Xin, Gao. Year:2023	To suggest the outline of the rather novel and rapidly developing concept of Industry 4. Enhance the sustainable supply chain management of textile through digital transformation through adoption of 0 technologies especially data analytics in supply chain management and supply chain transparency through	circular supply chain model • blockchain application in tracking • Big Data across the life cycle stages for	• There is a recognition of the effect on the environment hence development of sustainable development paper on textile industry. • It puts forward an intervention model that integrates S-SCM with Industry 4. No technologies for sustainability were practiced among the firms cited in the study. • The blockchain technology as an enabler of tracking and traceability is discussed as a feature of and in the context of the supply chain. • Big Data technologies are also used to improve the data management in the whole life cycle of the supply chain. • Altogether, the work signifies that Industry 4. 0 technologies will greatly help

		block chain technology.		the sustainability of the textile industry when it comes to the gathering of information, evaluation of this information, and relaying of such information.
18.	**Fermatean fuzzy framework based on preference selection index and combined compromise solution methods for green supplier selection in textile industry.** Dragan, Pamučar., Alptekin, Ulutaş., Ayşe, Topal., Çağlar, Karamaşa., Fatih, Ecer. Year:2024	In order to construct a new decision support tool for green supplier selection in the textile industry through the application of a Fermatean fuzzy framework with considering both of the PSI and CoCoSo approaches.	new decision support tool fuzzy group multi-criteria decision-making approach fuzzy group multi-criteria Preference Selection Index (PSI) Combined Compromise Solution (CoCoSo): The framework is called FF-PSI-CoCoSo	Therefore, the study intends to improve the green supplier selection procedure by establishing a decision making tool. Key contributions include: Integral to this, the FF-PSI model for priority weight extraction is presented. FF-CoCoSo originally is an innovative method for calculating CoSo; the development of the enhanced FF-CoCoSo methodology is an improvement of this method.
19.	**An AHP and Fuzzy AHP Multifactor Decision Making Approach for Technology and Supplier Selection in the High-Functionality Textile Industry** Adrian E. Coronado Mondragon ,	To utilize Analytical Hierarchy Process (AHP) and Fuzzy AHP under an integrated model to implement a multifactor decision making to measures and choose the suitable technology and supplier for the high functionality textile industries which will consider the supply chain	Analytical Hierarchy Process (AHP) and Fuzzy AHP are used.	The present paper outlines a framework for technology and supplier selection focusing the high functionality of textiles industry where the factors of supply chain were found more strategic than the technical criteria. • In the research, the difficulties that proponents meet while choosing between technologies are illustrated, especially when the potential technologies are at a similar performance level. fabrics.

	Ernesto Mastrocinque , Jung-Fa Tsai, and Paul J. Hogg Year:2021	factors and technological factors as the criterion in an equally in balance manner.		
20	**Supplier-customer relationships for sustainability-led innovation in the textile industry** Matteo, Dominidiato., Simone, Guercini., Matilde, Milanesi., Annalisa, Tunisini. Year:2023	To learn the nature of supplier-customer relationships and their impact towards the sustainability led innovation of the textile industry, putting much importance to identify how the mentioned relationship impact product and process innovation for sustainability	exploratory research method customer business relationship	• The paper focuses the relationships of product and process innovation to sustainability of products and services in the textile sector by focusing on supplier customer interface. • In particular, studies show that under the strategy of sustainability-led product innovation, companies pay particular attention to attributes like product life, reprocessing readiness, and utilization of the waste into new product formation. However, process innovation relates to such challenges as closed-loop systems, identification of the supply chain, and the reduction of water and chemical consumption .
21	**Hybrid Supplier Evaluation Framework Using AHP and TOPSIS for Textile Industry** Author:Blessy Maria, Abdullah Swali, Saahith Year:2024	To develop and implement a robust hybrid decision-making model that integrates AHP and TOPSIS to optimize supplier evaluation and selection in the textile supply chain.	Analytical Hierarchy Process (AHP) to determine criteria weights Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank suppliers	• In this study, a hybrid framework was applied to a real-world textile supply chain dataset collected from nine stakeholders. AHP was utilized for pairwise comparisons to derive normalized weights for criteria such as cost, quality, delivery time, reliability, flexibility, and sustainability. • These derived weights were then input into the TOPSIS method to rank suppliers. This approach effectively balanced both qualitative and quantitative data, providing actionable insights for supplier selection that align with business objectives.

3.METHODOLOGY

The methodology for this project integrates two powerful MCDM techniques: AHP and TOPSIS. This hybrid approach addresses the multi-level and often conflicting criteria involved in this type of supplier selection in the textile industry. This project guarantees an overall evaluation and balanced decision-making that is in line with strategic objectives, as stated below for each phase of the methodology.

Problem Statement and Objectives

Supplier selection is one of the principal steps of managing supply chains in the textile industry. Evaluation of suppliers requires numerous criteria affecting the operational productivity, sustainability, and cost-effectiveness. Unfortunately, many of these criteria work against each other. Thus, there is a need for an effective framework that can prioritize them appropriately.

The objectives of this project are:

- To define a clear and structured process of supplier evaluation.
- To identify the most suitable suppliers based on six critical criteria:
- Cost: Ensuring competitive pricing to maintain profitability.
- Quality: Meeting or exceeding industry standards to ensure customer satisfaction.
- Delivery Time: Minimizing delays to enhance operational efficiency.
- Reliability: Guaranteeing consistent performance and adherence to commitments.
- Flexibility: Adapting to changes in order requirements or production needs.
- Sustainability: Aligning with environmental and social responsibility goals.
- This research project will combine AHP and TOPSIS in order to achieve this balance in objectives for developing a practical and repeatable supplier selection framework.

Data Collection

Data collection is an integral part of the evaluation process. For this research, data were collected from nine key decision-makers and stakeholders in the textile supply chain. The stakeholders included procurement managers, quality control experts, and logistics coordinators. The information collected includes:

- Pairwise comparisons for criteria:
  Stakeholders were required to rate each criterion versus the other criteria based on relevance.

- Supplier performance scores:
  Each supplier was scored between 1 and 9 for each of the six criteria. These scores represent the aggregated view of stakeholders, thereby ensuring that they are aligned with practical application in reality.

The input data guarantees that the framework is indeed based on experience and sector-specific experience.

AHP

AHP is then used to derive the relative importance of each criterion. The following steps were carried out:

Construction of the Pairwise Comparison Matrix:
A pairwise comparison matrix was constructed for the relative importance of each criterion. Each cell in the matrix gives the relative importance that one criterion has over another with a scale of 1–9:

- 1 - Equal importance
- 3 - Moderate importance of one over the other
- 5 - Strong importance
- 7 -Very strong importance

- 9 - Extreme importance

For example, if cost is considerably less important than quality, then the entry in the matrix for (Cost, Quality) would be 1/5, whereas the reciprocal value (Quality, Cost) would be 5.

- Matrix Normalization:

Divide every element of the matrix by the sum of its column. This way, all criteria are comparable .

- Criteria Weights Computation:

The average value of each row of the normalized matrix was calculated, and the weights were determined for each criterion-the relative importance of the criteria.

- Consistency Check:

To validate the reliability of stakeholder judgments, the consistency ratio (CR) was calculated using the following formula:

CR=CI/RI

where CI is the consistency index, and RI is the random index for the matrix size. A CR less than 0.1 indicates acceptable consistency.

For this project, the consistency ratio was well within acceptable limits, confirming the reliability of the pairwise comparisons.

The AHP process provided the normalized weights of the criteria, which were used as inputs for the TOPSIS method.

Constructing the Decision Matrix

The decision matrix organizes supplier performance ratings across all criteria. Each row represents a supplier, and each column corresponds to a criterion.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS ranks suppliers based on their proximity to an ideal solution. The following steps were followed:

- **Normalization of the Decision Matrix:**
  Each value in the decision matrix was normalized using the formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

This ensures that all criteria are dimensionless and comparable.

- **Weighted Normalization:**
  The normalized values were multiplied by the corresponding AHP-derived weights to create the weighted normalized matrix:

$$v_{ij} = w_j \cdot r_{ij}$$

- **Determine the Ideal and Anti-Ideal Solutions:**
  Ideal Solution (V^+): Maximum value for benefit criteria (e.g., Quality) and minimum value for cost criteria (e.g., Cost).
  Anti-Ideal Solution (V^-): Minimum value for benefit criteria and maximum value for cost criteria.

Calculate Euclidean Distances:

The distance of each supplier from the ideal (S+S^+S+) and anti-ideal (S−S^-S−) solutions was computed:

$$S_i^+ = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^+\right)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - v_j^-\right)^2}$$

Relative Closeness to Ideal Solution:

The closeness coefficient (CiC_iCi) for each supplier was calculated as:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

Supplier Ranking:

Suppliers were ranked based on their CiC_iCi values, with the highest CiC_iCi value indicating the top-performing supplier.

Interpretation of Results

The results from TOPSIS highlighted the suppliers that best met the criteria. Key observations included:

- Suppliers excelling in sustainability and flexibility ranked higher due to their alignment with strategic goals.
- Trade-offs between cost efficiency and quality were evident, enabling informed decision-making.

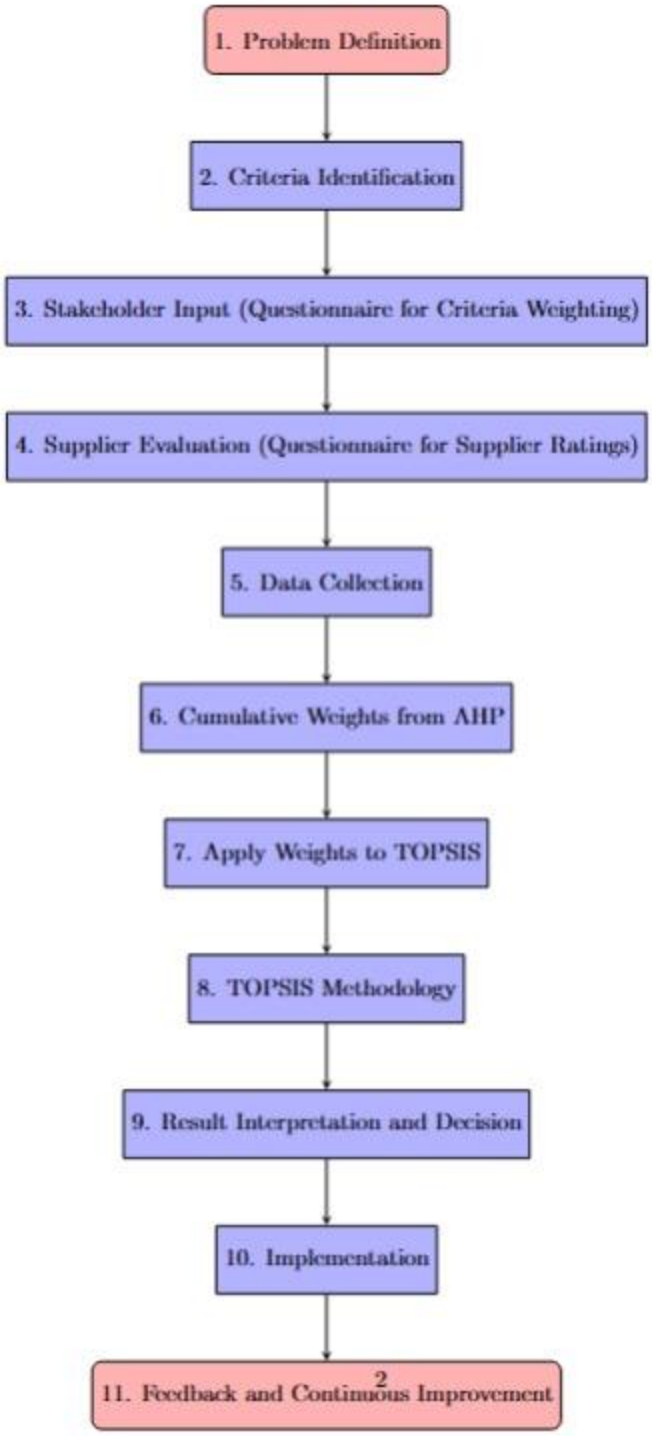

Fig:1 Methodology flowchart

4.Case Study: Issues with Supplier Evaluation and Selection in the Textile Industry

Introduction of the Problem

Today, the supply chain management has emerged as the critical differentiator factor that defines competitiveness and overall running success of a company in the textile industry. The increasing complexity of global markets emphasizes all the more the need for a well-structured and effective process in the evaluation of suppliers. The textile sector, more specifically, experiences challenges exclusively due to its dependence on various suppliers of raw materials, parts, and logistics support. Given the diversities available in multiple suppliers, companies continue facing considerable challenges in choosing the most suitable suppliers compatible with their operational objectives, sustainability expectations, and quality standards.

The basis of complexity lies in the fact that various, but generally competitive, criteria like cost, quality, delivery time, sustainability, and flexibility all need to be fulfilled together. Additionally, the textile industry is extremely vulnerable to supply chain glitches created by different temporal fluctuations in raw material prices, environmental policies, and the growing demand of customers from environmentally conscious segments. These complexities make it very difficult to create a combined framework for supplier evaluation.

The Textile Industry Landscape

The environment of the textile industry is fast-changing and is characterized by the following:

- **Mass Competition:** There are many firms in the industry. Therefore, to maintain low prices, firms will compromise either on quality or sustainability.
- **Sustainability Pressures:** The growing demands from the government and consumers on environmental-friendly products have raised sustainability as a critical selection criterion.
- **Global Supply Chains:** Increased dependence on international suppliers increases the risk of geopolitical events, transportation delay, and non-consistent quality.
- **Changing Customer Preferences:** Customers nowadays require not only cheap products but innovative and sustainable ones, which adds another dimension of complexity in choosing the suppliers.
- **Cost Pressures:** Although cost-effectiveness is core, it conflicts often with the other critical selection criteria, such as quality and sustainability.

These complexities therefore call for an effective decision-making framework that would be able to accommodate multiple criteria while considering the interdependencies between them.

Problem at Hand

Focusing on an SME textile company whose main resources and services depend on the network of its suppliers, the issue of supplier selection has emerged at the top of its strategic priorities driven by ambitious growth plans and its dedication to sustainability. However, the old methods in supplier evaluation that revolve around subjective judgment and scoring done manually were no longer enough. Key problems identified include:

- **Decision with subjectivity**: Selection of the supplier is subjective, and hence decision is inconsistent and biased. The unstructured approach may increase the chances of cost being considered for the buy rather than quality and sustainability.

- **Lack of Consistency in Criteria:** It is quite tough to balance cost, quality, delivery time, and sustainability. For example, suppliers who offer less cost compromise either on the quality or delivery time.

- **Lack of interdependency analysis**: The conventional assessment techniques consider criteria as independent without accounting for their complicated interrelationship with each other. Flexibility would directly impact the delivery time, and the same case for sustainability practice would affect the cost.

- **Lack of proper tools for multi-criteria decision-making:** Conventional tools that are designed are not capable enough to handle the multi-dimensional nature of supplier evaluation leading to inefficiency in choosing the optimum choice of suppliers.

- **Dynamic Challenges across Industries**: The pace of industry change means changing demands on selecting the suppliers, which the existing system cannot ensure. For example, it cannot readily adapt to alterations in the performance level of suppliers or the shift of customer demand.

Stakeholders Involved

The issue touches very extensively across all spectrum stakeholders such as:

- Supply Chain Managers These are the people who ensure suppliers are selected and evaluated, hence charged with the responsibility of making suppliers perform according to strategic business expectations.

- Procurement Team: This team is tasked with negotiating contracts and ensuring that the bought items are promptly delivered. They find it difficult to cope with unpredictable supplier performance.

- Sustainability Officers: They try to ensure that suppliers adhere to environmental requirements and follow sustainable measures. It is hard without proper evaluation criteria.

- End Customers: The ultimate beneficiaries, customers demand high-quality, sustainable products, putting additional pressure on the company to select the right suppliers.

Case Study Scenario

The company applied the grading system for the suppliers where grading was performed manually. The criteria used included cost, quality, delivery time, and flexibility. There was no differentiation in their weights given that their rankings were based on the aggregate scores provided. However, it did not account for interdependencies among criteria, how important those criteria are, or otherwise.

Problems Encountered

Supplier performance variability was such that while some suppliers were performing really well on cost-efficiency, they lacked in terms of sustainability or reliability

- Lack of Transparency: This manual scoring system provided little insight into why the score has been given so high and gave an element of mistrust towards different stakeholders
- Missed Opportunities: There were potential partnership opportunities with innovative suppliers that were developed for long-term value but were perceived short term costly.
- Reactive Decision Making: The company's supplier selection decisions were strictly reactive in nature, not taking into account future growth and other related issues that they would be faced with.

Affected Outcomes The firm was affected in the following ways

- Tardy delivery resulted in disturbed production schedules.
- Frequent changes in suppliers increased costs.
- Lost targets on sustainability moved towards reputation damage.
- Loss competitive advantage in the market.

Solution Approach

Recognizing that there is an urgent need for an organized solution, the company decided to adopt a hybrid approach that will integrate the Analytic Hierarchy Process (AHP) with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). These are the reasons for such a decision**:**

AHP: For more objective weights to be assigned to the evaluation criteria so as to eliminate the issue of subjectivity. Since AHP allows criteria to be comparative pairwise for assurance that their relative importance is not lost.

TOPSIS: Ranking suppliers based on their distance from the ideal solution provides an easy-to-use and actionable ranking system. Whereby, the strength of TOPSIS is that it evaluates both the best and worst-case scenarios to give a balanced assessment .

Implementation

1. Setting Key Evaluation Criteria
The company then determined six key criteria upon which the suppliers will be evaluated:

Cost: The supplier's financial feasibility.
Quality: A case of always being able to meet product specifications.
Delivery Time: Delivery on or before time.
Reliability: Being consistent with respect to time and schedules.
Flexibility: The abilities to adapt to ever-changing demands.
Sustainability: Compliance with environmental standards.

2. Using AHP The weighting criteria were assigned using AHP.
Pairwise comparisons of the inputs made by the managers of the supply chain as well as the sustainability officers and the staff of procurement came into use. The weight yielded reflected more strategic priorities that define the company; thus, sustainability and quality were bestowed with greater importance.

3. Development of the Decision Matrix A decision matrix was designed where the potential suppliers were listed with their respective ranking against every criterion. All the data collection involved supplier audits, records of past performance, and market researches.

4. Normalizing the Matrix The decision matrix was normalized to make the comparisons comparable across different scales of criteria.

5. TOPSIS Implementation TOPSIS was used to prioritize the supplier. The relative closeness coefficient for each of the suppliers was determined and rankings were provided.

The hybrid AHP-TOPSIS methodology solved the company's problems:

- Improved Transparency: The structured approach justified rankings of the suppliers thus, building trust among stakeholders.
- Balanced choice-utility: The model struck a balance between cost-effectiveness and quality plus sustainability to ensure that supplier selection was in line with strategic objectives.
- Agility: The model allowed the company to alter its plans vis-à-vis changes in suppliers' performance and market dynamics.
  Strategic insights: There were important trade-offs like cost-quality relationship, which helped make decisions based on informed choices.

Affected Outcomes The firm was affected in the following ways:

- Tardy delivery resulted in disturbed production schedules.
- Frequent changes in suppliers increased costs.
- Lost targets on sustainability moved towards reputation damage
- Loss competitive advantage in the market

Solution:

Recognizing that there is an urgent need for an organized solution, the company decided to adopt a hybrid approach that will integrate the Analytic Hierarchy Process (AHP) with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). These are the reasons for such a decision:

- AHP: For more objective weights to be assigned to the evaluation criteria so as to eliminate the issue of subjectivity. Since AHP allows criteria to be comparative pairwise for assurance that their relative importance is not lost.
- TOPSIS: Ranking suppliers based on their distance from the ideal solution provides an easy-to-use and actionable ranking system. Whereby, the strength of TOPSIS is that it evaluates both the best and worst-case scenarios to give a balanced assessment.

Implementation:

1. Setting Key Evaluation Criteria

The company then determined six key criteria upon which the suppliers will be evaluated:

Cost: The supplier's financial feasibility.

Quality: A case of always being able to meet product specifications.

Delivery Time: Delivery on or before time.

Reliability: Being consistent with respect to time and schedules.

Flexibility: The abilities to adapt to ever-changing demands.

Sustainability: Compliance with environmental standards.

2. Using AHP The weighting criteria were assigned using AHP. Pairwise comparisons of the inputs made by the managers of the supply chain as well as the sustainability officers and the staff of procurement came into use. The weight yielded reflected more strategic priorities that define the company; thus, sustainability and quality were bestowed with greater importance.
3. Development of the Decision Matrix A decision matrix was designed where the potential suppliers were listed with their respective ranking against every criterion. All the data collection involved supplier audits, records of past performance, and market researches.
4. Normalizing the Matrix The decision matrix was normalized to make the comparisons comparable across different scales of criteria.
5. TOPSIS Implementation TOPSIS was used to prioritize the supplier. The relative closeness coefficient for each of the suppliers was determined and rankings were provided.

Key Findings/Implications

The hybrid AHP-TOPSIS methodology solved the company's problems:

- Improved Transparency: The structured approach justified rankings of the suppliers thus, building trust among stakeholders.
- Balanced choice-utility: The model struck a balance between cost-effectiveness and quality plus sustainability to ensure that supplier selection was in line with strategic objectives.
- Agility: The model allowed the company to alter its plans vis-à-vis changes in suppliers' performance and market dynamics.
- Strategic insights: There were important trade-offs like cost-quality relationship, which helped make decisions based on informed choices.

5.Results and Discussion

This chapter provides an overview and analysis of the results obtained from both the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods. The purpose of this investigation was to evaluate the supplier selection process based on six factors: Cost, Quality, Delivery Time, Reliability, Flexibility, and Sustainability. Eight participants each rendered input weights for each factor based on personal assessments, and those weights were subsequently processed to produce weighted values by the use of the AHP model. Subsequently to the provision of the cumulative weights mentioned above, the suppliers were ranked with the help of the TOPSIS technique utilizing these weights and performance of each criterion out of six.

Individual User Weights Overview

The next table illustrates the user's individual weights assigned to the six criteria and reflects the opinion differences among the users and the agreement level concerning the importance of the factors.

TABLE:1 Individual User Weights

User	**Cost**	**Quality**	**Delivery Time**	**Reliability**	**Flexibility**	**Sustainability**
1	0.1	0.5	0.2	0.1	0.1	0.1
2	0.2	0.4	0.2	0.1	0.05	0.05
3	0.05	0.4	0.25	0.2	0.05	0.05
4	0.1	0.3	0.3	0.1	0.1	0.1
5	0.15	0.45	0.25	0.1	0.05	0.05
6	0.1	0.5	0.2	0.1	0.1	0.1
7	0.1	0.4	0.2	0.1	0.1	0.1
8	0.05	0.5	0.2	0.1	0.05	0.05
Cumulative Weight	**0.113**	**0.421**	**0.205**	**0.121**	**0.079**	**0.06**

Upon examining the individual weights assigned to the criteria, it can be noticed that all users assigned the top weight to Quality and slightly varied on the ranking of the other criteria. The differences in the weights across users clearly show the different preferences and priorities that were taken into consideration while measuring, although Quality has always been and it still remains to be the most important factor. There was also slightly high emphasis for the Delivery Time factor among the users, however its significance varied more among the users.

The cumulative weight distribution, which summarizes these individual assessments, reinforces Quality and Delivery Time as dominant factors in the selection of the suppliers. On the other hand, the factors of Cost, Reliability, Flexibility and Sustainability however seem to have a lower dominance as evidenced by the relatively lower cumulative weights given to these factors.

AHP Cumulative Weights of All Users

Cumulative AHP weights were determined in accordance with the pairwise comparison matrix depicted by every user. These weights measure users' aggregate level of importance towards the given criteria. The final cumulative weights are as follows:

TABLE:2 Cummulative weights from AHP

Criterion	Cumulative Weight
Cost	0.113
Quality	0.421
Delivery Time	0.205
Reliability	0.121
Flexibility	0.079
Sustainability	0.060

AHP results demonstrate that Quality was at the top of the hierarchy, with a relative weight of 0.421. This indicates that suppliers who can produce goods and/or services of a high standard are preferred over others. With a cumulative score of 0.205 in weight, Delivery Time was identified as the third most important criterion of concern, which suggests the users' desire for being provided with goods and services within and at the right time. Reliability and Cost were rated as less than high-priority criteria with 0.121 and 0.113 weights respectively. This means in a way that both are equally important – secondary to Quality and Delivery Time. Otherwise, Flexibility (0.079) and Sustainability (0.060) earned the least weights, meaning that these attributes are considered, though not actively, in the process of making decisions.

All these weights add up to one and show the relative preferences of the users – thus we can evaluate which priorities should be adhered to when choosing suppliers. The reason why the weight associated with Quality is high is likely that users prefer suppliers who provide good quality and reliable products and services, then low cost or low delivery time suppliers. The reason why the weights for Flexibility and Sustainability are lower is that they are not considered as important aspects in the decision-making process however they might be

relevant in limited cases or in a case of differentiation of suppliers on these primary attributes in choosing between less primary attributes.

TOPSIS Results: Supplier Ranking

After obtaining the qualitative and payoffs on all the criteria by the use of AHP, performance on rank order of supply of the suppliers was applied using TOPSIS. The suppliers were evaluated by checking their distance to the ideal solution, ai, and to the negative ideal solution, bi, where ai represented performance of all criteria at its best, and bi represented performance of all criteria at its worst.

Under the incorporated AHP analysis weight criteria, lists of suppliers were computed using TOPSY that matched with the performance of the suppliers as well as the weight assigned to each criterion. The final ranking outcomes aided in ensuring that the suppliers who best matched the ideal solution were selected, making sure

that the best supplier according to the preferences of the users is chosen.

TABLE:3 Weighted Normalized Matrix

Supplier	Cost	Quality	Delivery Time	Reliability	Flexibility	Sustainability
LTK	0.038	0.170	0.083	0.048	0.030	0.023
MADEIRA	0.042	0.168	0.080	0.046	0.031	0.024
WING HING	0.044	0.170	0.081	0.047	0.031	0.023
SAB	0.046	0.163	0.080	0.050	0.031	0.024
EPYLLION	0.046	0.157	0.078	0.046	0.030	0.022
JANAKSON	0.042	0.157	0.075	0.045	0.031	0.023
RUDHOLM INDIA	0.041	0.124	0.063	0.037	0.025	0.019

TABLE:4 Suppliers With Si+, Si- , Pi

Supplier	S+	S-	Pi
LTK	0.0028	0.0524	0.9501
MADEIRA	0.0064	0.0488	0.8840
WING HING	0.0070	0.0513	0.8805
SAB	0.0104	0.0457	0.8150
EPYLLION	0.0167	0.0377	0.6925
JANAKSON	0.0169	0.0367	0.6844
RUDHOLM INDIA	0.0526	0.0051	0.0879

Table:5 Suppliers with final rank from AHP-TOPSIS

Supplier	Rank
LTK	1
MADEIRA	2
WING HING	3
SAB	4
EPYLLION	5
JANAKSON	6
RUDHOLM INDIA	7

Evaluation of Results from TOPSIS Analysis

According to the results of TOPSIS, each supplier's proximity to the ideal solution has a corresponding value based on the criteria weights assigned by the user. This analysis enables an assessment of each supplier's association with the preferred dimensions as determined by the AHP weights. The more a supplier's performance approaches that of the ideal solution, the higher the supplier is ranked. In this section, we provide an extensive analysis of the rankings that are based on the TOPSIS results:

• As a result, LTK is placed at the top position, having a pi score of 0.9501, which means it satisfies the ideal supplier attributes to the greatest extent. LTK scored better than its rivals in all six factors especially in Quality and Delivery Time that were deemed most critical in the AHP analysis. This aspect of quality and on time delivery perfectly matches the users' need and Ts being the best supplier overall. This means that LTK provides the best quality product with timely delivery which is primarily the expectation of users.

• In second position, there is comparatively smaller value for pi score which is made up by MADEIRA at 0.8840. Like LTK, the performance of MADEIRA scored fairly well in all the perspectives meaning there is nothing wrong with it as a candidate. Where especially came out in index values of Sustainability and Quality which these were considered important but not above Delivery Time. Since MADEIRA performed well in this regard, it signifies that it can be used in scenarios where ecology and product quality are both critical factors.

However, LTK is superior when it comes to suitor selection in terms of matching parameters, it is still a potential candidate to be included in the supplier selection.

• To begin with, WING HING has placed third with a pi score of 0.8805. This particular vendor represents a good alternative especially while considering Flexibility and Cost more seriously. Quality and Delivery Time cut it; however, the level goes a notch higher with the Flexibility, which is favourable for those customers who want easily amendable suppliers. Again, in countries where cost of service is a key consideration, this supplier's services may as well be preferred due to the reasonable charges.

• After Janakson, Sab and Epylion come next. These suppliers have moderate strengths in the criteria but fail to compete in some key dimensions such as Delivery Time. Theoretically, those companies could be still viable players in the market or even strong candidates, but their performance does not provide them with enough allure compared to other players ranked higher than them.

• Last among the rated suppliers is RUDHOLM INDIA with a pi score of 0.0879, which means that it has the least configuration with the users' ideal typology. This finding reflects its low positioning performance, particularly in terms of Quality and Delivery Time, which are even rated as ranking interracial most aspects of suppliers. RUDOLHM INDIA'S overwhelming gap in pi scores with its better-placed suppliers shows that it is not a viable threat to the selection process. Finally, RUDHOLM INDIA does not come off as better quality provider cum timely deliverer to the users which concern standards under Quality and Delivery Time respectively, and so it will only be sought out in less pressing needs or where other elements override Quality and Delivery Time requirements.

The combination of AHP and TOPSIS methods provided a robust framework for supplier evaluation and ranking. The AHP analysis showed that Quality and Delivery Time were among the most important selection method aided matrices.

The findings reveal the need for supplier selection to conform to the most important strategic objectives of the company. In this study, the primary concern was to maintain the high levels of Quality and on-time delivery, which was why suppliers such as LTK and MADEIRA were considered potential suppliers. When Flexibility and Cost were the main focus, WING HING provided a suitable option whereas, SAB, EPYLLION and JANAKSON exhibited average performance but failed to compete in the most important areas. With the least fit to profile as emphasized by its low pi score, RUDHOLM INDIA was by far the most dissimilar to the ideal supplier type desired by the users stressing out the tacit significance of the two in the final decision making.

The analysis given here helps not only in evaluating such suppliers but also gives direction in making strategic choices in situations where quality products are needed and there is a need to deliver them on time. The double use of AHP and TOPSIS makes sure that the supplier selection process is extensive and fact-based as it helps to determine the right supplier who meets set parameters.

Through the structure of this framework, companies are able to reach more rational and politically impartial conclusions in the process of selecting the suppliers that fulfill best their operational and strategic goals. This is also true for other similar situations and industries where the selection criteria might be different but the approach is still the same.

6. Managerial Implications

The evaluation of the suppliers, incorporating AHP and TOPSIS, in fact offers a more robust and systematic framework for determining important decisions within supply chain management. All these critical elements - cost, quality, delivery time, reliability, flexibility, and sustainability -help conduct a thorough analysis of the supplier because it aligns with organizational goals. Some managerial implications from our study can, therefore, significantly enhance procurement efficiency, strategic alignment, and long-term supply chain performance.

1. More Suitable Decisions During Supply Chain Activities

The hybrid AHP-TOPSIS approach, thus, will be able to provide the needed basis for using a clear, structured evaluation and ranking of suppliers following qualitative and quantitative criteria that can ensure decisions are not only cost-driven but do consider important aspects like sustainability and flexibility, more and more nowadays, in competitive markets.

AHP allows the ranking of factors, hence the managers would focus their efforts on resource allocation around those factors which best align with the business goals. Then, TOPSIS measures these rankings into action rankings without ambiguity of any supplier's evaluation.

2. Consistency with Organizational Goals

Sustainability and corporate social responsibility (CSR) have increasingly become the concern for organizations. Having the sustainability criterion included in this study helps to reflect better on how procurement activities could be placed in line with even broader values by managers in organizations. For example, high rankings on sustainability may help suppliers meet ESG standards.

The weighing of cost efficiency with one or the other factor reduces the risk because of over-emphasis on a singular factor. It combines short-term operational requirements and long-term strategic needs.

3. Data-Driven Procurement Strategies

Procurement strategies via AHP and TOPSIS focus on the accumulation and analysis of data in supplier selection. Organizations turn towards data-driven procurement strategies. This pulls organizations towards more accurate and objective decision-making without bias and toward accountability.

Data-driven methods offer an opportunity for real-time appraisal and reevaluation of suppliers hence fostering consistency in performance and responsiveness to changing business needs or shifts in the market.

4. Good Supplier Relationships

The open and systematic approach adopted by the AHP-TOPSIS model fosters trust and responsibility between the organizations and the suppliers. The suppliers, in turn, understand fully what measures are used against them by which avenues of open communication and collaboration open up.

Identifying areas that need improvement from the suppliers, such as sustainability or reliability in delivery, creates more partnership-orientated approaches where suppliers need to attain the expected organizational performance.

5. Risk Reduction

AHP and TOPSIS are actually capable of accounting for trade-offs between the criteria, so that managers can identify suppliers that maximize both cost effectiveness and superior performance in key areas like reliability and flexibility. Those suppliers should reduce such major types of risks associated with supplier failure: delayed delivery or nonconforming quality.

The fact that it involves multicriteria will help in ensuring that there is no over-reliance on a single supplier and also increases the resilience of the supply chain.

6. Strategic Supplier Portfolio Management

The ranking developed from TOPSIS lets organisations classify suppliers based on tiers, and therefore helps them more efficiently manage the portfolio. For instance:

Tier 1 Suppliers: The top ranked suppliers can be suitably placed on long term contracts and strategic partnerships

Tier 2 Suppliers: Suppliers at a middle ranking can be encouraged and developed towards bettered performance in certain fields

Tier 3 Suppliers: Suppliers have a lower ranked and considered or replaced to achieve peak performance of the supply chain

This categorization ensures that this strategy of supplier management aligns with the organizational priorities in maximizing utilization of resources.

7. Sustainability Objectives Support

Inclusion of sustainability in selection criteria facilitates companies to spot and collaborate with responsible suppliers for the environment. This is helpful in preventing continuous increase of regulatory pressures, as well as continuous interest from consumers in safe products for the environment.

The managers can refer to the analysis of AHP-TOPSIS towards designing activities relating to sustainability in the supply chain, such as reduction in carbon footprint or support with responsible sourcing.

8. Flexibility and Adaptability

This methodology is quite applicative in nature to most of the industries and organizational requirements. The criteria and weights in AHP may be adjusted as per business needs by managers in order to prioritize specific needs like innovative research or technology management; cost efficiency in price-sensitive sectors, among others.

TOPSIS is, after all, a decision-making tool, so scalable, allowing the consideration of more and more suppliers, enabling organizations to become agile in dynamic market environments

9. Competitive Advantage

The supplier selection process is structured with a strategic advantage, which usually means capable and aligned suppliers with whom to partner. Quality products, cost reduction, and speeding up time-to-market are expected.

Criteria such as flexibility and reliability will help organizations act rapidly in the face of disruption, thus continuing to maintain the momentum, as far as customer satisfaction and market share are concerned.

10. Trade-Off Insights

This integration of AHP and TOPSIS identifies the trade-offs managers need to make in supplier selection decisions. For instance, a supplier that has the lowest price may be behind in sustainability or delivery reliability. This understanding allows the managers to have a chance of making informed decisions under their preferred risk posture and strategic objectives.

Managers can use this knowledge in negotiations with suppliers by identifying weak areas and encouraging continuous improvement.

11. Scenario Analysis and Sensitivity Testing

The AHP-TOPSIS framework allows for scenario analysis since managers' weights on criteria can be varied to model varying strategic emphasis. For instance, when in financial stress, cost can be emphasized more whereas at growth times, quality or sustainability may be emphasized more.

Sensitivity analysis would help managers understand how the changing weights or supplier performance impact rankings to ensure robust and confident decision making.

12. Operational Efficiency

Systematic supplier evaluation reduces the time and effort required for decision-making. With AHP and TOPSIS, the evaluation process can be more straightforward and fairer with clear or actionable conclusions without requiring lengthy deliberations.

Through this efficiency, procurement teams are liberated for strategic activities, such as the development of suppliers and innovation.

13. Performance Benchmarking

The ranks from TOPSIS ranks serve to indicate a benchmark level for supplier performance. Managers can use the benchmarks to track over time the changes in supplier performances, observe trends, and make data-driven improvements in supplier management practices.

Benchmarking equally promotes competition among suppliers that can motivate them to perform better to obtain higher ranks.

14. Global Supply Chain Optimization

The AHP-TOPSIS model would provide a standardized way of assessing region-wide suppliers for the firm to analyze as it operates in global markets. The business would thus integrate its operations in a global supply chain and achieve consistency in decisions taken.

Unique market challenges can be addressed by using criteria specific to regions, such as geopolitical stability or local regulations, in the model by managers.

7. Conclusion

This paper on the application of AHP and TOPSIS to rank suppliers has well proved the use of a systematic data-driven approach to selection. There can definitely be an easy collaboration and integration of both the approaches toward deciding so that qualitative and quantitative criteria are put together in an orderly fashion into the selection process. Therefore, selected suppliers would thus provide an assurance of best anchor fit with the strategic objectives of the organisation. Quality and delivery time factors, as project findings conclude, as proven very important criteria for assessing the supplier, demand critical attention and consideration.

With inputs from eight users, AHP analysis revealed that the cumulative weight of Quality was at 0.421, meaning it is most important in the supplier's selection procedure. Delivery Time ranked third with a weight of 0.205, which is again a significant factor, thereby underlining the urgency for timely delivery of goods and services. Where the second most important criterion is Cost (0.113), and the third is Reliability (0.121), Flexibility (0.079), and Sustainability (0.060) are relatively less important for the decision. This score of criteria depicts that in between Quality and Delivery Time, those criteria are much more important that are attached directly to customer satisfaction and operational efficiency.

Applying TOPSIS ranks the suppliers according to their distance from the ideal solution. For the data considered, LTK is at the top with proximity score: 0.9501, meaning powerful performance on both Quality and Delivery Time criteria. MADEIRA 0.8840, WING HING 0.8805, and many others show similarity and closeness but differ significantly in other key criteria. The immediate suppliers are SAB, EPYLLION, and JANAKSON, which displayed a mid-range performance but lack competitive edge in some of the critical criteria. The most ill-favored is RUDHOLM INDIA with a nearness score of 0.0879, which garnered low quality and delivery performance.

This research was informed by the following key insights at multiple levels:

- Strategic alignment: The results justify why the process of selecting a supplier should be aligned with the aims of an organization. Quality followed by timely delivery were the key drivers that portrayed the need for suppliers to meet quality standards so as to ensure smooth supply chain operations.

- Objective Decision-Making: AHP was used to find out the relative importance of criteria, while TOPSIS is applied for ranking suppliers. Thus, the whole project ensures objective unbiased decision-making. It reduces the influence of personal biases and gives clear rationale for selection.

- Framework Flexibility: The hybrid AHP-TOPSIS framework is applicable for different types of domains and scenarios as the selection criteria and weights might be changed according to the specific requirements of organisations. This flexibility helps make it versatile and beneficial for various applications.

- Increased transparency: This structured assessment process creates greater transparency and accountability in the selection of suppliers. That the criteria, weights, and rankings are documented evidences an audit trail over decision making.

The dual use of AHP and TOPSIS has proved to be an extremely effective and comprehensive approach toward the evaluation of suppliers. Results not only identify the most suitable suppliers but also give insights into areas where suppliers need to improve to meet organizational standards. This makes the present study especially valuable for decision-makers in making informed, strategic choices in selecting suppliers.

7.1 Limitations

Although the AHP-TOPSIS framework is robust, the study encountered crucial limitations that would go a long way in reducing the generalizability and applicability of the findings:

Subjectivity of Weight Assignment : The AHP method makes use of pairwise comparison to rank criteria by importance. It is a structured method but the outcome of such an approach is bound by the subjective preferences of respondents. In this case, with eight participants, the result may not be characteristic of the diversity of stakeholder views manifested in an organizational context. Increasing the size and diversity of the group of respondents would enhance the chances of gaining more representative results.

- Few Suppliers Example

Only a few suppliers were evaluated. This means that the representation of the performance may not be purely representative of the suppliers' performance in the industry. An extension of the suppliers within the analysis may be helpful in gaining a better understanding of the competitive landscape.

- Static Weights of Criteria

Criteria weights were assumed to be constant over the analysis. In real life, the importance of criteria can change due to several factors such as changes in market conditions, overall economic scenario, and a shift in organizational strategy. For instance, Sustainability might become more crucial to those sectors whose business undertakes stricter environmental regulations.

- Qualitative Factors Not Included

The study was solely quantitative; however, reputation of the suppliers, innovation capacity, and relationship management were not considered. All these factors play a crucial role in making supplier selection decisions; thus, they need to be included in future studies. Industry Used Single

The context in which it has been conducted is an industrial environment, which restricts the generalization of the results of the study towards industries other than the one involved. The scale of importance varies from industry to industry, which means innovation becomes a critical criterion for technology-driven sectors, whereas commodity-based industries value cost efficiency as a critical criterion.

- Historical Data Applicability

For the analysis, historical performance data are used - which cannot account for changes in the supplier's capabilities or in the market dynamics that may occur in the future. Therefore, this may result in suboptimal decisions if suppliers' performance improves or worsens over time.

The underlying assumption of the study was that all the criteria involved were independent. This may not necessarily hold true in real scenarios. For example, how quickly one can deliver depends on many occasions on the flexibility or reliability of a supplier. More realistic insights could be offered by including interdependencies between criteria.

7.2 Future Scope

Further research might be conducted towards above-identified limitations and other measurement scales which could extend the horizon and effectiveness of the AHP-TOPSIS framework:

- Dynamic Weights Incorporation:

Future models can be engineered such that dynamic weights will be allowed with changes in the organizational priorities or changes in market conditions. For example, Cost will be over Quality during economic turmoil.

- Qualitative Factors Incorporation:

All these quantitative factors would, therefore, be supplemented by other qualitative factors, for example, the reputation of suppliers or innovation potential and strategic alignment. As for the methods applied could be the Delphi method, or interviews with experts, to be able to quantify these qualitative aspects.

- Exploring Industry-Specific Criteria

The AHP-TOPSIS framework can be designed for specific use in sectors based on specific criteria to be used and their selection and prioritization that can be applied to the sectors in question. For instance, regulation compliance is much more important in industries related to health care than in a technology firm, which will have focal points on innovation and scalability.

- Application of Machine Learning

The structure can assemble machine learning algorithms to analyze large datasets and predict the performance of suppliers. For example, supervised models can be trained on historical data for the identification of some patterns that will eventually predict future performance to help with better decision-making.

- Scenario-based analysis

Although, however, scenario-based analysis can be used to analyze supplier performance under various conditions. In such instances, they include an abrupt increase in demand, some form of disruption in the supply chain, or in an economic recession. Therefore, its usage may give an overview on the robustness and flexibility of suppliers.

- More Extensive Supplier Network

More suppliers can be analyzed in the pursuit of getting a better view of the competitive landscape. This can be done with the aid of industry databases or supplier directories and portals that exist on the Internet.

- Application of Fuzzy Logic

For the AHP-TOPSIS model, fuzzy logic can solve the problems caused by subjective weight assignment. Hence, the vagueness in inputs can be comprehensively offset, and the outputs from fuzzy AHP and TOPSIS can approach reality more closely.

- Presentation of New Sustainability Metrics

Further studies would have scope to add further more sustainable metrics into sustainability model, such as carbon footprint and energy efficiency, in addition to social responsibility to make this sustainability model easier to align their supplier selection process to the firms' sustainability goals.

- DSS Development

A decision support system can be designed to automatically process the AHP-TOPSIS, whereby all the criteria of the organisation will be inputted and ranked lists of suppliers will be received in real time, and thereby integrated with ERP softwares for complete seamless decision-making.

- Longitudinal studies:

Longitudinal research would assist in gaining insight into how the performance of suppliers changes over time and the factor by which the importance of criteria is changed in the wake of external influences. This has the result of improving organizations with greater adaptive and forward-looking frameworks for evaluating suppliers.

- Researching Multi-Objective Optimization:

This problem can be considered for performing future research using multi-objective optimization techniques that will handle multi-criteria decision making, handling conflicts between non-compatible criteria, for example, Cost and Quality. Goal programming or genetic algorithms could be used for finding optimal solutions.

- Researching the Integration of Blockchain Technology

The blockchain technology will provide transparency and traceability into data pertaining to the suppliers' assessment process. This makes the analysis done valid and will create confidence on the part of the organizations and their suppliers.

- Validations through Case Studies:

The framework so designed will have to be validated through case studies in various industries, which would give in-practice insight into the study and provide applicability to the study across the various contexts.

REFERENCES

[1] Rahman, M. M., Bari, A. B. M. M., Ali, S. M., & Taghipour, A. (2022). Sustainable supplier selection in the textile dyeing industry: A multi-criteria decision-making approach. Resources, Conservation & Recycling Advances, 15, 200117. doi:10.1016/j.rcradv.2022.20011

[2] Shahriar Raian , Syed Mithun Ali a, Md. Rayhan Sarker , Bathrinath Sankaranarayanan b, Golam Kabir c, Sanjoy Kumar Paul , Ripon Kumar Chakrabortty doi.org/10.1016/j.resconrec.2021.105975

[3] Bathrinath, S., Bhalaji, R.K.A., & Saravanasankar, S. (2020). Risk analysis in textile industries using AHP-TOPSIS. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2020.04.722

[4] Akash, M. J. H. (2023). Supply chain management process of textile industry: A case study on Bangladesh. International Journal for Multidisciplinary Research, 5(6), 1-14. doi.org/10.36948/ijfmr.2023.v05i06.8398

[5] Menon, R. R., & Ravi, V. (2022). Using AHP-TOPSIS methodologies in the selection of sustainable suppliers in an electronics supply chain. Cleaner Materials, 5, 100130. doi.org/10.1016/j.clema.2022.100130

[6] Phan Ha, N.N., Nguyen, D.D. and Le, S.T.Q. (2024), "Sustainable supplier selection in the apparel industry: an integrated AHP-TOPSIS model for multi-criteria decision analysis", *Research Journal of Textile and Apparel*, Vol. ahead-of-print No. ahead-of-print.doi.org/10.1108/RJTA-04-2024-0056

[7] Kumar, M. (2023), "Integration of RFID strategic value attributes mechanism decision in apparel supply chain: fuzzy AHP-TOPSIS approach", Journal of Modelling in Management, Vol. 18 No. 4, pp. 1022-1063. doi.org/10.1108/JM2-11-2021-0283

[8] Piprani, A. Z., Jaafar, N. I., & Mohezar Ali, S. (2020). Prioritizing resilient capability factors of dealing with supply chain disruptions: an analytical hierarchy process (AHP) application in the textile industry. Benchmarking: An International Journal, 27(9), 2537-2563.

[9] ishwakarma, A., Dangayach, G. S., Meena, M. L., & Gupta, S. (2022). Analysing barriers of sustainable supply chain in apparel & textile sector: A hybrid ISM-MICMAC and DEMATEL approach. Cleaner Logistics and Supply Chain, 5, 100073.

[10] Hader, M., Tchoffa, D., El Mhamedi, A., Ghodous, P., Dolgui, A., & Abouabdellah, A. (2022). Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector. Journal of Industrial Information Integration, 28, 100345.

[11] Chakraborty, S., & Biswas, M. C. (2020). Impact of COVID-19 on the textile, apparel and fashion manufacturing industry supply chain: Case study on a ready-made garment manufacturing industry. Journal of Supply Chain Management, Logistics and Procurement, 3(2), 181-199.

[12] Kazancoglu, I., Kazancoglu, Y., Kahraman, A., Yarimoglu, E., & Soni, G. (2022). Investigating barriers to circular supply chain in the textile industry from Stakeholders' perspective. International Journal of Logistics Research and Applications, 25(4-5), 521-548

[13] Tayyab, M., & Sarkar, B. (2021). An interactive fuzzy programming approach for a sustainable supplier selection under textile supply chain management. *Computers & Industrial Engineering*, *155*, 107164.

[14] Köksal, D., Strähle, J., Müller, M., & Freise, M. (2017). Social sustainable supply chain management in the textile and apparel industry—A literature review. *Sustainability*, *9*(1), 100.

[15] Schreiber,, Zvi. (2022). (1) Assessing data-driven sustainable supply chain management indicators for the textile industry under industrial disruption and ambidexterity. International Journal of Production Economics, doi: 10.1016/j.ijpe.2021.108401

[16] Mohammad, Rafiqur, Rashid., Sourav, Kumar, Ghosh., Md., Fahim, Bin, Alam., Mohammad, Faizur, Rahman. (2023). A Fuzzy Multi-Criteria Model with Pareto Analysis for Prioritizing Sustainable Supply

Chain Barriers in the Textile Industry: Evidence from an Emerging Economy. Sustainable operations and computers, doi: 10.1016/j.susoc.2023.11.002

[17] Ding, Chen., Umar, Muhammad, Gummi., Jia, Lei., Hua-Xin, Gao. (2023). Industry 4.0 Technology-Supported Framework for Sustainable Supply Chain Management in the Textile Industry. Communications in computer and information science, 350-361. doi: 10.1007/978-981-99-7587-7_30

[18] Dragan, Pamučar., Alptekin, Ulutaş., Ayşe, Topal., Çağlar, Karamaşa., Fatih, Ecer. (2024). Fermatean fuzzy framework based on preference selection index and combined compromise solution methods for green supplier selection in textile industry. International Journal of Systems Science: Operations & Logistics, 11(1) doi: 10.1080/23302674.2024.2319786

[19] Adrian, E., Coronado, Mondragon., Ernesto, Mastrocinque., Jung-Fa, Tsai., Paul, J., Hogg. (2021). (1) An AHP and Fuzzy AHP Multifactor Decision Making Approach for Technology and Supplier Selection in the High-Functionality Textile Industry. IEEE Transactions on Engineering Management, doi: 10.1109/TEM.2019.2923286

[20] Matteo, Dominidiato., Simone, Guercini., Matilde, Milanesi., Annalisa, Tunisini. (2023). Supplier-customer relationships for sustainability-led innovation in the textile industry. doi: 10.1108/jbim-01-2023-0060