Supply Chain Insider

Supply Chain Insider

Volume 17, Issue 01, 93-119. 10-10-25
Article Received: 25-08-2025
Accepted: 15-09-2025
Available Online: 10-10-2025
ISSN: 2617-7420 (Print), 2617-7420 (Online)
DOI: **10.5281/zenodo.17285031**
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Strategic Inventory Management in Plastic Manufacturing: A Delphi-AHP Sustainability Approach

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Abstract: Teams in the modern supply chain environment face important challenges, including increasingly intense competition at the global level and the growing environmental issues. The urgency to manage inventory in a way that is both sustainable to the planet and business-competitive has become absolute, especially to companies operating in emerging economies. The paper is an applied and scholarly research on the development of supply chain inventory management. The method used combines the testimonies of experts with powerful decision-making tools and therefore, focuses on the variables, which have the most significant implications. At the beginning of our program, we gain the experiences of the experienced practitioners to define the most significant factors underlying the wise administration of the inventory. We, therefore, maintain a simplified prioritization model to rank these key determinants. We have found that the so-called environmentally sustainable practices: waste minimization and optimal use of resources have a significant impact on the development of intelligent inventory strategies. Such an approach will help supply-chain teams better find ways to address complicated issues even when there is uncertainty or a difference of opinions. The essence of this is that the follow-up composite approach allows to have a smoother course of operation and has both resource conservation and sustainability goal. Therefore, organizations achieve the double payoff of improved business and conservation of the environment, thus strengthened as competitive players in the market. In synthesis, the presented practical framework empowers supply-chain professionals to implement more thoughtful ecologically friendly decisions- thus pushing efficiency to a new level, reducing environmental strictness and promoting a strong, sustainable competitive advantage. Keywords: Sustainable inventory management; supply chain management; plastic industry; economic viability; environmental impact; social responsibility; technological integration; operational efficiency.

Keywords: Sustainable inventory management, supply chain management, plastic industry, Economic Viability Environmental Impact, Social Responsibility, Technological Integration, Operational Efficiency.

1. Introduction

The supply-chain management has emerged as the central pillar on which modern business can be built successfully. At a time when market pressures have become more competitive and the world has become environmentally focused, sustainability is no longer a luxury goal but a mandatory engine of business sustainability over the long term. It is the imperative of minimizing emissions and waste and increasing operational efficiency that requires an integrative process whereby sustainable practices are put at each point throughout the supply-chain continuum. Inventory management is a key part of this continuum. This art goes beyond quantitative adequacy, it is the rational management of limited resources. Proper inventory management encompasses careful planning, organization, and control, in which the products are delivered only when they are demanded by customers at the same time, they are not spending unnecessary resources of energy, space, or capital optimization (Khan, Alam, Tabassum, and Khan, 2022).

Compared to the past, in the current globalized economy, the scope of the supply chain and its complexity has increased not only in crossing geographical borders but also in terms of the types of stakeholders that are involved. This increased interconnectivity adds further significance to the need to become sustainable in inventory practices. Companies are progressively adopting green supply-chains initiatives such as environmentally friendly sourcing, efficient storage guidelines, efficient transportation pathways, and effective waste management, into their business models as a way to reduce environmental influence and meet the mounting pressures of the consumer and regulator. The pressure on the environment in the form of the rapid urbanization and high intensity of industrial activity is acute. The development of large infrastructures and the running of large transport systems cause a massive waste and pollution. Therefore, the supply chains and factories themselves have to implement options that minimize waste, save on energy and minimize greenhouse-gas emissions. Many national governments and major corporations have adopted green-supply-chain agenda and have established stricter environmental regulations in a bid to encourage cleaner production procedures and a more sustainable industrial environment. The development of technologies, in particular, the advent of Industry 4.0 is also driving this change. Real-time data analytics availability that spans multiple supply-chain networks provides decision-makers with evidence-based insights fast enough to respond to these strategies and to manage networks in a smarter way. As an example, improved lighting control systems may lower the energy loads used in warehouse buildings significantly, and efficient routing systems can identify the best delivery routes (minimize fuel use and relyant emissions) with a corresponding rate of cost reductions (Sales, Guimarães, Neto, El Aouar, 2020).

Overall, sustainable supply-chain management extends beyond an environmental agenda and is inherently a strategy of corporate efficiency, corporate resilience, and corporate competitive advantage. Through improved inventory management operations and use of advanced decision, -/Needlework systems, businesses are able to minimize waste, limit expenditures and make a positive impact on Earth health at the same time strengthening market positions

1.1 Problem statements

Problem Statements Analytic Hierarchy Process (AHP) helps in the systematic ranking of a set of criteria and options thus helping organizations to identify trade-offs and make context-sensitive decisions that were consistent with their strategic goals. Such a methodological process will be especially relevant to the current thesis (i.e., A Delphi -AHP Framework of Strategic Inventory Management: Driving Sustainability and Competitiveness in Supply Chains of Emerging Economies in Plastic Manufacturing Industries) by enhancing the ability of decision-makers to incorporate various perspectives of stakeholders, make resource allocation more efficient, and operationalize sustainability. As a resultant effect, AHP provides companies active in emerging economies with analytical instruments that can be used to streamline inventory control, thus enhancing competitiveness and adding to the overall sustainability goals (Sbai, Benabbou, and Berrado, 2020).

RQ 1. How does the application of Delphi and Analytic Hierarchy Process (AHP) contribute to the strategic management of inventory in emerging economies, particularly in terms of fostering sustainability?

RQ 2. What are the most significant criteria and sub-criteria identified through the AHP process for enhancing sustainability in inventory management within the context of emerging economies?
RQ 3. How do the findings from AHP-driven strategic inventory management initiatives impact sustainability practices and competitive advantages for businesses operating in emerging economies?

Application of the Analytic Hierarchy Process in inventory plans benefits significantly the supply chain management, particularly in the emerging economies with limited resources and volatility. As it is with AHP, we can make numerous criteria count in an obvious way, we are able to rate the things which would matter the most as far as a sustainable way and a competitive advantage are concerned. At the time when we combine Delphi and AHP, we make use of the voice of the experts in order to identify the best factors influencing inventory. Such a partnership brings with it different opinions, which are very essential in proper stewardship throughout the supply chain. AHP emphasizes such areas as cost effectiveness, environmental consequences, supplier integrity, and social responsibility and helps us to enhance where the most appropriate. It enhances resilience, responsiveness, and innovation and focuses on sustainability in all the operations.

2. Related Studies

2.1 Current situation of Inventory Management in emerging economies

Present Inventory Management state of affairs in the frontier's economies. Inventory handling is extremely essential as far as the smooth running of business is concerned particularly in emerging economies where the handling of supply chain is somewhat cumbersome. This is the time when these nations have opportunities to develop and certain challenges to handle. As a case, some businesses have minimal infrastructures and technology in comparison to advanced countries (Han, Kalantari, and Rajabifard, 2023) Because of the lack of control over stocks, there are issues with exhaustion of goods or excess stock. As well, it may be difficult to deliver raw materials and finished products punctually due to a step in the supply chain hitches, such as delays in transportation, political related issues or even natural calamities. All this reflects upon how a business can efficiently respond to the needs of customers. But, there's good news too! With these challenges, innovation is opened up. As a larger number of businesses operate in a digital setting, managing supply chains beyond the physical realm, through cloud-based data management, analytics, and automation, they will be in a position to perform more effectively. These are the kinds of tools that enable businesses to get a clear view of what is going on in its supply chain, allowing a more swift and intelligent response. Emerging economies also have an increased level of interest in sustainability. This has seen an increasing number of companies consider settings that are friendly to the environment such as reducing waste and the packaging of products with green colors when improving inventory management. This helps the environment but also increases the efficiency, and may even reduce costs. (Han et al., 2023; Zhu, Zhou, Hu, Du, and Yuan, 2023) Businesses in emerging economies will be able to manage their inventory better by addressing the problem of infrastructure, disruptions, and the lack of technologies. Adoptions of new production technologies, greener business practices, and effective supply chain management will be the key to competing in the world market and developing a sustainable future.

2.2 Sustainability in Inventory Management

Sustainability in Inventory Management As much as there are benefits to introducing sustainability as part of inventory management, most businesses struggle to execute it. The lack of a clear plan that they can follow to prioritize eco-friendly practices and align them with their supply chain management goals are a big challenge. A company can find it difficult to make intelligent decisions without being aware of the aspects of sustainability that are most relevant to them. With customers being graphic conscious of environment and consumption of sustainable products, sustainable oriented businesses can be different and win the loyalty. Resources in most of the emerging regions are scarce and environmental regulations remain underdeveloped and thus a form of sustainable approach is necessary. The fundamental endeavors that help in the core operations such as production, delivery, and sale of goods are the supporting tasks as purchasing and communication systems. Concentrating better on sustainability through a clearly-defined approach to supply chain, business establishments are better placed to improve their sustainability and achieve a competitive advantage.

2.3 Impact of implementing sustainable inventory management practices in emerging economies

Effect when sustainable inventory implementations are carried out in emerging economies. Inventory sustainability goes beyond waste reduction or cost outcome reduction. It encompasses an integrated solution, which takes into account environmental, social and economic effects of the inventory activities. Through ensuring sustainability in inventory management, businesses will be able to decrease their carbon footprint, save on resources and help to create a healthier future of the entire world. Using the AHP approach, the companies operating in the emerging economies will recognize the possibilities of the improvement in their practice in inventory management and apply the appropriate strategies aimed to improve their sustainability performance. It not only enables businesses to meet environmental requirements and reduce the harm but also makes them pioneers of sustainable business practices, shattered positive influence on the environment and the economy.(Moslem, 2024; Salehzadeh & Ziaeian, 2024)

2.4 Related Works and research gaps

Table 1: Analysis of Related Works

No	Author(s)	Research focus & objective	Key Research Findings	Applied Tools	Limitations
1	(Han et al., 2023)	Identifying & prioritizing sustainability indicators for demolition waste management in China via Delphi and AHP	a) Top indicators: GWP (32%) b) EE (~16%) c) LU (~13%) d) economic cost ranked low (~6.5%)	a) Semi-structured expert interviews b) Delphi rounds c) AHP weight calculation with reliability & CR checks	a) Small expert panel b) limited coverage of social indicators c) exclusion of lower-scored metrics d) No case application e) possible perception bias
2	(Truong & Le, 2024)	Prioritizing digital tools' importance for hospital performance using AHP and Delphi techniques	a) Seven performance indicators reached consensus b) digital tools ranked under those criteria with high consistency	a) Sequential rounds: expert clarification b) indicator consensus (Delphi) c) pairwise weighting (AHP) d) qualitative confirmation	a) Unclear expert sample size b) limited tool selection c) subjective bias d) no field validation e) static snapshot

3	(Kouskoura, Kalliontzi, Skalkos, & Bakouros, 2025)	Prioritizing factors that drive sustainable regional competitiveness via expert input and AHP	a) Economy, labor, and health were top-ranked b) Innovation at bottom	a) 93 experts across diverse EU regions b) AHP with statistical validation	a) No Delphi refinement missing weight values b) European-only sample c) static snapshot d) potential bias
4	(Yu, Jia, Zhang, Deng, & Herrera, 2020)	Constructing a dynamic, lifecycle-sensitive credit index system for Chinese TSMEs via Delphi and AHP	a) Built hierarchical credit framework (4→16→66 indicators) b) validated via case study of three firms	a) Delphi (2 rounds, ~150 experts) b) AHP weighting c) reliability & validity tests d) case application	a) Missing weight values & CR b) limited expert detail c) Narrow case validation d) operational complexity e) static lifecycle adaptation
5	(Jaleel, Abu, & Al-Hchaimi, 2025)	Prioritize barriers to BIM–sustainability integration using Delphi and AHP	a) Users: expert shortage, training costs, resistance to change b) Stakeholders: policy absence, legal gaps, low investment	a) Literature-derived barriers b) Delphi consensus c) AHP weighting	a) Expert sample details unspecified b) limited barrier scope c) no CR values d) potential categorization overlaps

3. Research Methodology:

This study uses the Delphi and AHP methods to determine the important criteria and sub- criteria for evaluating sustainable inventory management in plastic industry. Firstly, this study assesses inclusive literature to find out the important criteria and sub- criteria. Then, a Delphi method is employed to finalize the criteria in the context in plastic industry. Finally, the AHP method is used to determine the weights and ranking of criteria, sub-criteria, and two plastic manufacturing industry (alternatives) for successful adoption of sustainable inventory management in plastic industry. Fifteen experts participated during the Delphi and AHP method; the consulted experts were knowledgeable about sustainable inventory management in plastic industry.

The proposed step by step methodology for implementation of AHP and Delphi in inventory management:

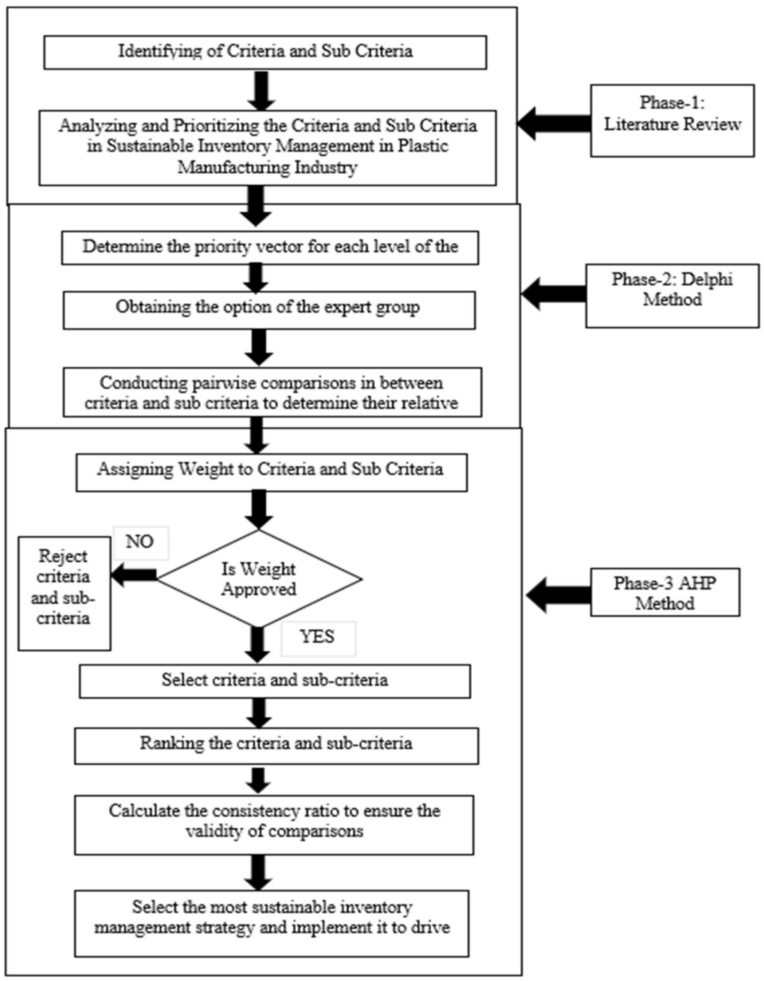

Figure 1: Methodological Flow Chart of the Study

3.1. Delphi Method

It is possible to combine the Analytic Hierarchy Process (AHP) and the Delphi method which can be an efficient way of deciding on inventory management. The organizations that adopt the Delphi technique in collecting the contributions of different stakeholders or experts with regard to inventory-related criteria and priorities can attain the overall understanding of the factors influencing inventory decisions. The information may then be added into the AHP model to determine a relative significance of the criteria and alternatives leading to more informed and objective decisions to make when managing inventory. The merge of Delphi technique and AHP allows organizations to adopt multiple perspectives, reduce bias and maximize the precision of assessments pertaining inventory. The combination enables companies to optimize stock and enhance supply chain performance and sustainable growth. In using the Delphi method and the Analytic Hierarchy Process (AHP) to analyze inventory management, one can take the following steps:

a) **Selecting of Experts**: It is the identification of a team of experts in inventory management, sustainability, and AHP methodology.
b) **Defining the Research Objective:** Clearing has stated the objective of the analysis, i.e., improvement of sustainability in inventory management with the use of AHP.
c) **Developing Criteria and Sub-Criteria:** Formulating appropriate criteria and sub-criteria of sustainable inventory management such as cost effectiveness, impact of environmental, social responsibility and operational efficiency.
d) **Implementation Planning:** Coming up with a plan of the prioritized criteria and sub-criteria to implement sustainable inventory management practices at the organization.

A Delphi method is used in this study to complete the sustainable inventory management criteria and sub-criteria of the adoption of initiatives in the plastic manufacturing industries, (Zytoon, 2020) and its key aim is to receive the opinions of experts concerning any decision issue by means of semi-structured interviews, group discussions, and questionnaires. In this approach, the professional and other field experience specialists give their opinion and thoughts as well as their knowledge and expertise to each other in order to agree on the issue. The Delphi process has a variety of steps, which include: selection of the expert, the initial round of questionnaire survey, the second and third round of questionnaire survey and this process is repeated or progressed until the expert has mutual agreement in his or her research. This approach is not limited in terms of experts to be consulted in order to give feedback to any decision problem. Deferent research has suggested deferent counts of specialists and guidelines to the validation of the data. Nevertheless, the Delphi method should engage at least 9 and 18 specialists in the process of decision-making. Thus, ten experts were called into the study and contributed in giving valuable information regarding the decision problem. The questionnaire survey was distributed to these experts via a webmail service, and each of the experts was requested to determine the weightings in the survey tool on a Likert point scale of 1 to 5 (not at all important to extremely important). (.(Zhou, Xu, & Shaikh, 2019)

3.2. Analytical Hierarchy Process (AHP) Method

Analytical Hierarchy Process (AHP) Method Several reasons why the Analytic Hierarchy Process is considered to be one of the most useful multi-criteria decision-analysis instruments in inventory management have been highlighted. First, AHP is extremely applicable in inventory management since it allows companies to prioritize and evaluate many criteria at the same time in an orderly, well-organized manner. The hierarchical structure of AHP enables the decision-makers to break down complicated inventory management decisions into small manageable segments which helps in the appreciation of the interdependence between different criteria and alternatives.

Secondly, AHP is a powerful decision-making model because it takes into consideration qualitative and quantitative aspects. This flexibility permits organizations to accommodate a lot of criteria including cost, lead time, reliability of the suppliers, and sustainability in taking inventory management decisions. Using individual comparisons to determine the relative importance of the criteria, AHP allows the relative preferences and judgments of participants of the decision-making process to be caught, and thus more informed and objective results are obtained.

Besides, AHP has been known to be transparent and consistent in its decision-making processes in managing inventory. The pair-wise comparison and computation methods that are systematically applied in AHP guarantee that decisions are executed on the basis of clear and rational thinking and make communication and justification of decisions to the stakeholders an easier process. This openness increases accountability and buy-in by all the stakeholders of the inventory management. Also, the AHP flexibility and adaptability enables the organizations to adjust the criteria weights and priorities where needed. This is particularly a helpful feature in the fluid and volatile environment of inventory management, order variables such as business climate, customer tastes, and supplier performance can change in a short amount of time. The ability to change criteria weights in reaction to evolving circumstances helps businesses adapt to make agile and data-driven decisions to fit their strategic goals.
The steps of AHP are given below:

a) **Create A Problem Structure and Hierarchy Process Model:** The initial step of the AHP process involves the structure of a logical hierarchy of the research problem into the AHP model that comprises the objective, criteria or factors, sub-criteria or sub-factors, and alternatives**.**

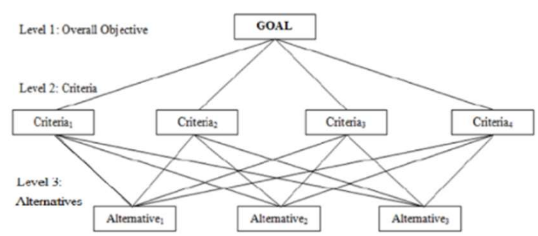

Figure 2: General Hierarchy Structure of AHP

b) **Establish the relative importance of various criteria in relation to the goal:** The establishment of the relative importance of various criteria in relation to a specific goal is a crucial process in the process of decision-making that aids in prioritizing actions.

c) **Construction of pair-wise comparison matrices of factors:** The pair-wise comparisons are an essential step that identifies relative significance of factors a process introduced by and further elucidated by.(Sneesl, Jusoh, Jabar, Abdullah, & Bukar, 2022) During these comparisons, judgments are derived and expressed as integers, signifying the preference of one factor over another**.** (Mundottukandi, Jusoh, Pa, Nor, & Bukar, 2024)**.**

Alternatives	Decision criteria				
	C_1	C_2	C_3	…	C_N
	(W_1)	(W_2)	(W_3)	…	(W_N)
A_1	a_{11}	a_{12}	a_{13}	…	a_{1N}
A_2	a_{21}	a_{22}	a_{23}	…	a_{2N}
A_3	a_{31}	a_{32}	a_{33}	…	a_{3N}
…	…	…	…	…	…
A_M	a_{M1}	a_{M2}	a_{M3}	…	a_{MN}

Figure 3: Pairwise Comparison Matrix

Pairwise comparison matrix is created with the help of scale of relative importance from table-

Table 2: Relative Important Scale of the AHP

Importance Level	Intensity of Importance
Equal Importance	1
Moderate Importance	3
Strong Importance	5
Very strong Importance	7
Extremely Strong Importance	9
Intermediate Values	2,4,6,8

d) **Constructing aggregate comparison matrices of the factor:** To zero out the judgments of each aspect of the comparison matrix, we use the geometric mean technique, which is to consolidate the response obtained between all the experts who had participated in the pair-wise comparisons of the different factors and sub-factors. (Mundottukandi et al., 2024).

e) **Relative weight of the factor:** To compute the priority of each category (main factor) and sub-factor using the AHP method, a normalized matrix is obtained, defined as N. This is based on the corresponding comparison matrix A and is built as follows,

$$N = \frac{A}{\sum A} \tag{1}$$

f) **Validating the outcome of all the comparison matrix by consistency test:** Due to the nature of variation between human answers to queries, it is very important to determine the consistency of the comparison matrices to prove the prediction of priority vectors (Sneesl et al., 2022). When CR is discovered to be below or having an equal value to that of 0.10 (CR = 0.10), it implies that there is an acceptable level of consistency in the comparison matrix A. The steps that follow are usually used in this study:

- **Step 1**: Calculating the principal Eigenvalue (λmax) by using

$$AW = \lambda max \times W \tag{2}$$

- **Step 2:** Calculate the CI, where CI is the consistency index given by

$$CI = \frac{\lambda\text{max} - n}{n - 1} \tag{3}$$

- **Step 3:** Determine the RI, where RI is the random index. Notably, the RI is a predefined value that depends on the order of the matrix (n). It is typically obtained from a reference table based on the matrix order. Thus, the different number of criteria (n) corresponds to different values of RI as presented the in table-03.2.

Table 3: Predefined value of the random index (RI)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.31	1.41	1.45	1.49

- **Step 4:** Calculating CR by using

$$CR = \frac{CI}{RI} \quad (4)$$

- **Step 5:** Check if CR is acceptable: If the CR is less than or equal to 0.10 ($CR \leq 0.10$), it indicates that the amount of inconsistency in the comparison matrix A is acceptable, and the ranking results can be considered reliable.(Jusakulvijit, Bezama, & Thrän, 2021; Zytoon, 2020)

3.3 Consistency Ratio (CR) Handling:

If the Consistency Ratio (CR) is higher than 0.10, it means there's some inconsistency in how the comparisons were made. To fix this, you can follow these easy steps:

a) **Checking the Comparisons:** Go over the pairings and see which ones don't seem to match up logically. Make sure each judgment makes sense when looked at together.
b) **Talking it Out with Experts:** If the comparisons were made based on opinions from specialists, ask them to explain and clarify their choices. This helps ensure everyone's on the same page.
c) **Making Small Adjustments:** Slowly tweak the comparisons to see if the CR improves. Small changes can sometimes make a big difference.
d) **Revisiting the Criteria:** If the inconsistencies keep appearing, it might help to simplify or better define the criteria you're using so everything is clearer.
e) **Using Math Tools:** Sometimes, applying mathematical methods or algorithms can automatically refine the comparisons to make them more consistent.
f) **Recalculating the CR:** After making adjustments, check again to see if the CR is now 0.10 or less.

Following these steps helps keep your decision process accurate and trustworthy.

4.0 Data Collection and Analysis

4.1 Identification of the most significant criteria and Sub-Criteria

4.1.1 From literature review

After studying some previous research paper four main criteria area and five sub criteria areas within these criteria are found. The four main criteria are given below:

Environmental Impact

The term environmental impact refers to the effect that certain activities or actions have on the natural world.This can include changes to air quality, water, land, wildlife, and ecosystems caused by things like pollution, deforestation, climate change, and resource use. In simple terms, it's about how our actions can change or harm the environment, both positively and negatively.(Helal, Ahmed Uzzal, Abdullah Probal, & Sabira Nisha, 2024)

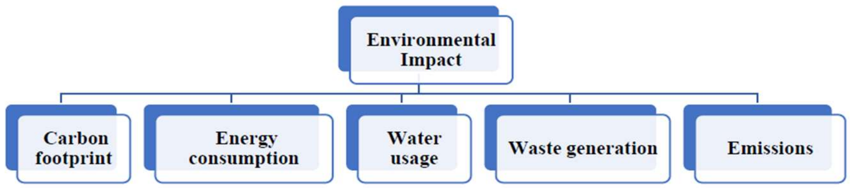

Figure 4: Structure of the sub criteria under the criteria "Environmental Empact"

Social Responsibility

Social Responsibility refers to the idea that individuals and organizations should act in a way that benefits society as a whole. This involves making decisions that not only consider profits or personal gain but also consider the impact on people, communities, and the environment.(Sharfuddin Ashbin, Ahnaf Hamim, Rehan, Didarul Islam, & Nazmul Alam Gazi, 2024)

Figure 5: Structure of the sub criteria under the criteria "Social Responsibility"

Economic viability

Economic viability refers to the ability of a project, business, or idea to be financially sustainable over time. It means that it can generate enough revenue to cover costs, support itself, and ideally make a profit. In simple terms, something is economically viable, it's likely to succeed financially and continue to operate in the long run.(Chowdhury, Nahian, Ahmed, Reza, & Rafi, 2023)

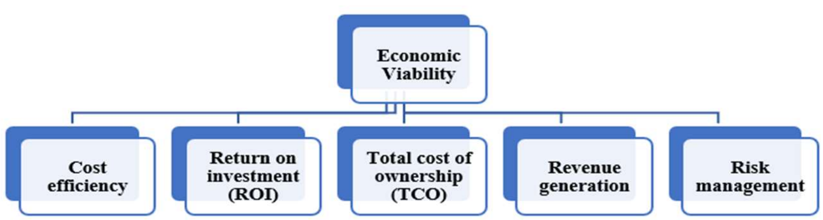

Figure 6: Structure of the sub criteria under the criteria "Economic viability"

Operational Efficiency

Operational Efficiency refers to the ability of an organization to deliver products or services in the most cost-effective manner while ensuring high quality. It means doing more with less—such as reducing waste, minimizing costs, and enhancing productivity—so that resources like time, money, and materials are used as effectively as possible.(Islam, Abrar, Mim, & Noshin, 2024)

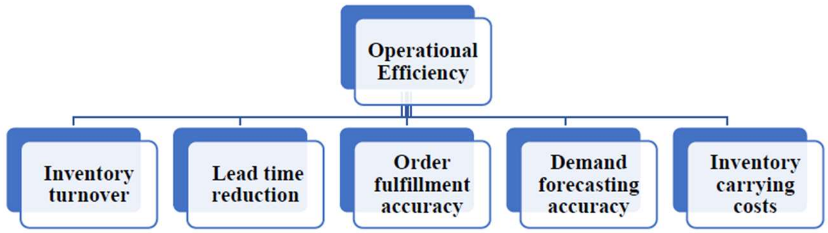

Figure 7: Structure of the sub criteria under the criteria Operational Efficiency

Table 4: Analysis of Criteria and Sub-criteria from Literature Review

Criteria	Sub-criteria	How it is important	Reference
1.Environmental Impact	1.Carbon footprint	A carbon footprint focuses on the environmental aspects of inventory measures and encourages companies to make more sustainable decisions around logistics, limited waste, and the use of eco-friendly materials. 784s with access to more green space indoors or out will cost less, even as they meet green goals.	(Ghosh et al., 2020; Helal et al., 2024)
	2.Energy consumption	In the context of saving energy, power consumption in inventory management is important because less energy expenditure in storage, transportation and other operations helps to reduce factors of production cost and environmental pollution. Implementing energy-efficient practices aligns with sustainability objectives and	(Helal et al., 2024; Islam et al., 2024)

		contributes to improved operational efficiency.	
	3.Water usage	The utilization of water in inventory management is crucial due to its effect on resource sustainability, especially in relation to cooling systems, cleaning, and manufacturing processes. The efficient management of water resources lowers costs, conserves essential resources, and promotes environmentally sustainable operations.	(Hatfield & Dold, 2019)
	4.Waste generation	Minimizing waste generation in inventory management reduces environmental pollution and disposal costs while improving resource efficiency. Sustainable waste practices, like recycling and repurposing, support a circular economy and enhance operational sustainability.	(Helal et al., 2024; Org P A G E, Jawad, Hossain, Islam, & Khan, 2024)
	5.Emissions (e.g., greenhouse gases, pollutants)	Controlling emissions in inventory management is vital to reducing greenhouse gases and pollutants from transportation, storage, and operations. Lower emissions align with environmental regulations, improve air quality, and support sustainability goals.	(Helal et al., 2024; Org P A G E et al., 2024)
2. Social Responsibility	1.Labor practices	Ethical labor practices in inventory management ensure fair wages, safe working conditions, and respect for workers' rights. Sustainable labor practices enhance workforce well-being, increase productivity, and foster a socially responsible brand image.	(Org P A G E et al., 2024; Sharfuddin Ashbin et al., 2024)
	2.Supplier diversity	Promoting supplier diversity within inventory management encourages inclusivity by supporting businesses of various sizes and backgrounds. This approach enhances innovation,	(Org P A G E et al., 2024; Sharfuddin Ashbin et al., 2024)

		strengthens community ties, and aligns with ethical procurement objectives.	
	3.Community engagement	Engaging with the community in inventory management fosters trust, supports local economies, and addresses societal issues. This engagement strengthens stakeholder relationships and promotes sustainable practices beneficial to both the business and the community.	(Org P A G E et al., 2024; Sharfuddin Ashbin et al., 2024)
	4.Health and safety standards	Compliance with health and safety standards in inventory management ensures a secure working environment, preventing accidents and injuries. This commitment promotes employee well-being, operational efficiency, and long-term sustainability.	(Org P A G E et al., 2024; Sharfuddin Ashbin et al., 2024)
	5.Human rights compliance	Human rights compliance in inventory management ensures ethical treatment of workers, prevents exploitation, and upholds dignity across the supply chain. This fosters social responsibility, enhances brand reputation, and aligns with global sustainability goals.	(Org P A G E et al., 2024; Sharfuddin Ashbin et al., 2024)
3. Economic Viability	1.Cost efficiency	Cost efficiency in inventory management is pivotal as it minimizes waste, optimizes the utilization of resources, and decreases expenses, thereby supporting financial sustainability. This efficiency facilitates investment in environmentally friendly practices and technologies, aligning with broader sustainability objectives.	(Chowdhury et al., 2023; Islam et al., 2024)
	2.Return on investment (ROI)	The return on investment (ROI) in sustainable inventory management evaluates the financial advantages of eco-friendly practices, such as reduced waste and lower energy costs. A favorable ROI encourages further investment in sustainable technologies	(Chowdhury et al., 2023; Islam et al., 2024)

		and practices, thereby ensuring long-term viability.	
	3.Total cost of ownership (TCO)	The total cost of ownership (TCO) in inventory management encompasses long-term expenses, including maintenance, energy, and disposal costs, thereby promoting sustainable decision-making. By assessing TCO, businesses can make economically sound choices that diminish environmental impact and enhance operational efficiency.	(Chowdhury et al., 2023; Islam et al., 2024)
	4.Revenue generation	Revenue generation within sustainable inventory management is driven by the efficient use of resources, which reduces costs and improves product availability. By integrating sustainability, businesses can attract environmentally conscious consumers, creating new market opportunities and enhancing long-term profitability.	(Chowdhury et al., 2023; Islam et al., 2024)
	5.Risk management	Risk management in sustainable inventory practices is essential for identifying and mitigating environmental, financial, and operational risks. By proactively addressing potential disruptions, businesses can maintain resilience, ensure compliance, and safeguard long-term sustainability objectives.	(Chowdhury et al., 2023; Islam et al., 2024)
4. Operational Efficiency	1.Inventory turnover	Inventory turnover is vital for sustainable practices as it reduces excess stock, thereby minimizing waste and storage costs. Efficient turnover enhances resource utilization, improves cash flow, and supports a lean, environmentally friendly supply chain.	(Org P A G E et al., 2024; Truong & Le, 2024; Yu et al., 2020)
	2.Lead time reduction	Minimizing lead time in inventory management decreases waste, enhances responsiveness, and reduces the necessity for excess stock. This leads to a more efficient use of resources,	(Org P A G E et al., 2024; Truong & Le, 2024; Yu et al., 2020)

		lowers carbon footprints, and aligns with sustainability goals.	
	3.Order fulfillment accuracy	Accurate order fulfillment is crucial for sustainable practices as it reduces returns, minimizes waste, and optimizes inventory levels. Enhanced accuracy in fulfillment improves customer satisfaction and operational efficiency, supporting resource conservation and sustainability efforts.	(Org P A G E et al., 2024; Truong & Le, 2024; Yu et al., 2020)
	4.Demand forecasting accuracy	Precise demand forecasting in inventory management helps avert overproduction and understocking, thereby reducing waste and the strain on resources. This accuracy ensures the efficient use of materials, energy, and storage, supporting both economic and environmental sustainability.	(Org P A G E et al., 2024; Truong & Le, 2024; Yu et al., 2020)
	5.Inventory carrying costs	Inventory carrying costs are essential for sustainable practices as they indicate the financial and environmental implications of holding excess stock. By minimizing these costs, businesses can reduce waste, optimize storage, and enhance resource efficiency, thereby promoting sustainability.	(Org P A G E et al., 2024; Truong & Le, 2024; Yu et al., 2020)

4.1.2 From Survey and Expert Panel

A survey form was sent to Padma Tank Limited and Bengal Plastic Limited for Delphi. They did not remove any criteria but added one criterion and three subtitles under that criterion. The criteria are given below:

Technological Integration

Technological Integration in the Plastic Industry refers to the incorporation of advanced technologies into various processes involved in the production and handling of plastic materials. This can include using automation, robotics, data analytics, and software solutions to improve efficiency, quality, and sustainability

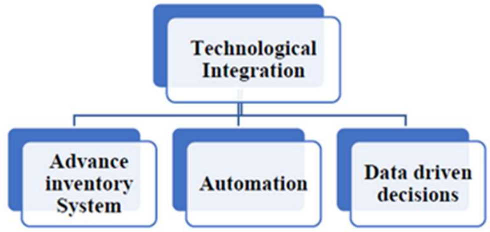

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Figure 8: Structure of the sub criteria under the criteria Technological Integration

Table 5: Analysis of criteria and sub criteria from experts

Criteria	**Sub-criteria**	**How it is important**	**Reference**
Technological Integration	1.Advance inventory System	An advanced inventory system helps plastic manufacturers go greener by keeping just the right amount of stock, cutting waste with accurate demand guesses, and using resources more efficiently. That means less environmental impact, smoother operations, and cost savings, all in line with sustainability goals.	Expert Feedback
	2. Automation	Automation in inventory management for the plastic manufacturing industry boosts sustainability by increasing operational efficiency, minimizing human error, and optimizing resource allocation. This results in reduced waste and energy consumption, leading to a lower environmental footprint and enhanced adherence to sustainability goals.	Expert Feedback
	3. Data driven decisions	Data-driven decisions in the plastic manufacturing industry are essential for sustainable inventory management because they enable precise demand forecasting and smarter stock control. This leads to less waste, more efficient use of resources, and stronger alignment with sustainability goals, boosting overall operational efficiency.	Expert Feedback

5. Analysis and Result

5.1 Result Analysis of main criteria

First, Table 5 shows the Economic Viability (weight = 0.254) rank first among the Five main criteria, followed by Environmental Impact (weight = 0.232), Social Responsibility (weight = 0.19), technological Integration (weight = 0.164) and Operational Efficiency (weight = 0.16)

Furthermore, the consistency test indices suggest that the consistency index (0.0082), relative importance (1.12), and consistency ratio (0.00732 < 0.10) of the main criteria are acceptable. This shows the significance of the main factors to determine sustainable practices in inventory management in plastic manufacturing industry. Figure 5.1 represents the rank analysis of main criteria.

Table 6: Result for main criteria

Criteria	Environmental Impact	Social Responsibility	Economic Viability	Operational Efficiency	Technological Integration	Criteria Weight	Rank
Environmental Impact	0.2	0.1	0.25	0.4	0.21	0.232	2nd
Social Responsibility	0.15	0.16	0.35	0.2	0.09	0.19	3rd
Economic Viability	0.3	0.34	0.16	0.15	0.32	0.254	1st
Operational Efficiency	0.17	0.14	0.13	0.16	0.2	0.16	5th
Technological Integration	0.18	0.26	0.11	0.09	0.18	0.164	4th
Consistency Test	Largest eigenvalue λmax = 5.0328 Consistency Index, CI = 0.0082 Random Index, RI = 1.12 [n =5] Consistency Ratio, CR = 0.00732 < 0.1						

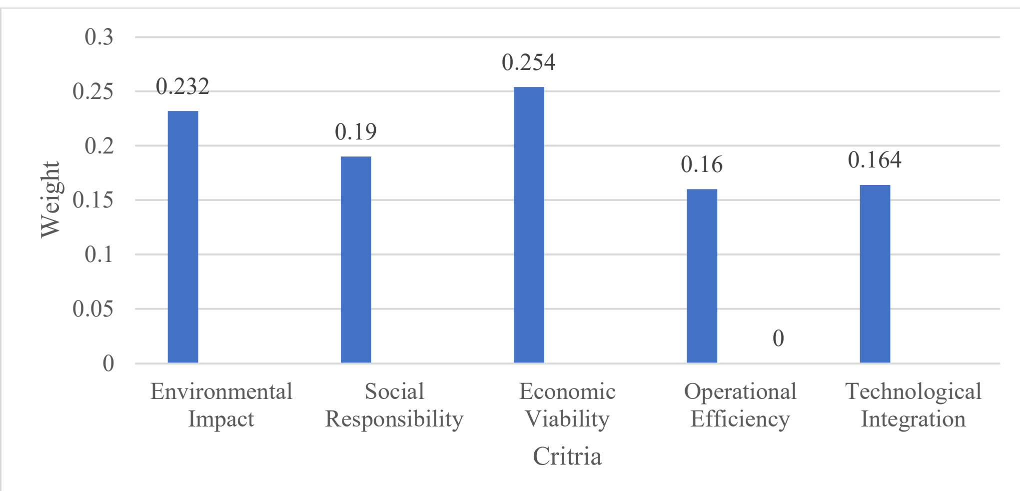

Figure 9: Rank Analysis of Main Criteria

5.2 Result Analysis of Environmental Impact:

Second, the weight analysis of Environmental Impact sub criteria shown in Table 6. According to the data, Water usage (weight = 0.254) are judged to be the most relevant and important sub-criteria, followed by Carbon footprint (weight = 0.25), Waste generation (weight = 0.206), Emissions (weight = 0.166), and Energy consumption (weight = 0.124).

Furthermore, the consistency test indices suggest that the consistency index (0. 0.011), relative importance (1.12), and consistency ratio (0. 0.0098 < 0.10) of the Environmental Impact sub criteria are acceptable. Figure 5.2 represents the rank analysis of. Sub-criteria Environmental Impact.

Table 7: Result for Environmental Impact

Sub-Criteria	Carbon footprint	Energy consumption	Water usage	Waste generation	Emissions	Weighted criteria	Rank
Carbon footprint	0.29	0.32	0.35	0.15	0.14	0.25	2nd
Energy consumption	0.15	0.12	0.13	0.11	0.11	0.124	5th
Water usage	0.24	0.33	0.12	0.25	0.33	0.254	1st
Waste generation	0.14	0.11	0.15	0.34	0.29	0.206	3rd
Emissions	0.18	0.12	0.25	0.15	0.13	0.166	4th
Consistency Test	Largest eigenvalue λmax = 5.044 Consistency Index, CI = 0.011 Random Index, RI = 1.12 [n =5] Consistency Ratio, CR = 0.0098 < 0.1						

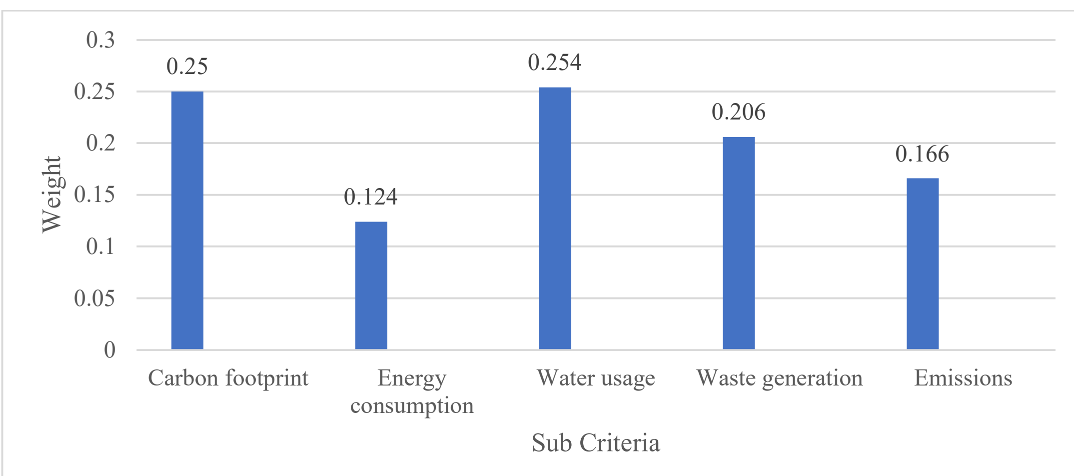

Figure 10: Rank Analysis of Sub-criteria Environmental Impact

5.3 Result Analysis of Social Responsibility:

Thirdly, the weight analysis of Social Responsibility sub criteria shown in Table 7 According to the data, Supplier diversity (weight = 0.242) are judged to be the most relevant and important sub-criteria, followed by Health and safety standards (weight = 0.22), Human rights compliance (weight = 0.19), Labor practices (weight = 0.186), and Community engagement (weight = 0.162).

Furthermore, the consistency test indices suggest that the consistency index (0. 0.015), relative importance (1.12), and consistency ratio (0. 0.0134 < 0.10) of the Social Responsibility sub criteria are acceptable. Figure 5.3 represents the rank analysis of. Sub-criteria social responsibility.

Table 8: Result for Social Responsibility

Sub-Criteria	Labor practices	Supplier diversity	Community engagement	Health and safety standards	Human rights compliance	Weighted criteria	Rank
Labor practices	0.31	0.11	0.23	0.19	0.09	0.186	4th
Supplier diversity	0.22	0.28	0.17	0.21	0.33	0.242	1st
Community engagement	0.19	0.16	0.21	0.09	0.16	0.162	5th
Health and safety standards	0.17	0.33	0.12	0.23	0.25	0.22	2nd
Human rights compliance	0.11	0.12	0.27	0.28	0.17	0.19	3rd
Consistency Test	Largest eigenvalue λmax = 5.0602 Consistency Index, CI = 0.015 Random Index, RI = 1.12 [n =5] Consistency Ratio, CR = 0.0134 < 0.1						

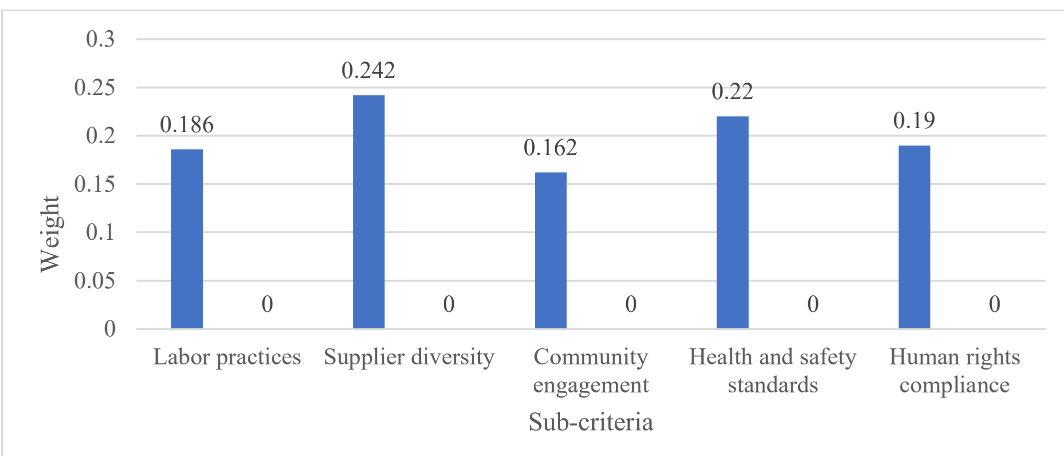

Figure 11: Rank Analysis of Sub-criteria Social Responsibility

5.4 Result Analysis for Economic Viability:

The weighted analysis of sub-criteria of Economic Viability is shown in Table 8. According to the result obtained, Cost efficiency (weight = 0.312) is judged to be the most relevant and important sub-factor for Return on investment (ROI), followed by crisis type (weight = 0.2), Revenue generation (weight = 0.184) and Risk management (weight=0.124).

Moreover, the calculated values of CI (0.0251), and CR (0.0224 < 0.10) suggest that the consistency of the comparison matrices used in the analysis is acceptable, affirming the reliability of the ranking results. Figure 5.4 represents the rank analysis of. Sub-criteria Economic viability.

Table 9: Result for Economic Viability

Sub-Criteria	Cost efficiency	Return on investment (ROI)	Total cost of ownership (TCO)	Revenue generation	Risk management	Weighted criteria	Rank
Cost efficiency	0.42	0.2	0.38	0.5	0.06	0.312	1st
Return on investment (ROI)	0.12	0.4	0.08	0.21	0.19	0.2	2nd
Total cost of ownership (TCO)	0.15	0.12	0.17	0.07	0.4	0.18	4th
Revenue generation	0.08	0.24	0.25	0.11	0.23	0.184	3rd
Risk management	0.23	0.04	0.12	0.11	0.12	0.124	5th
Consistency Test	Largest eigenvalue λmax = 5.1007 Consistency Index, CI = 0.0251 Random Index, RI = 1.12 [n =5] Consistency Ratio, CR = 0.0224 < 0.1						

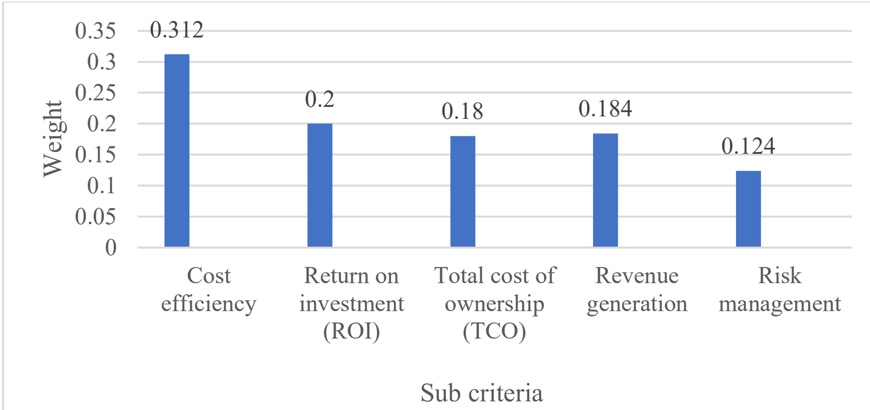

Figure 12: Rank Analysis of Sub-criteria Economic Viability

5.5 Result Analysis of Operational Efficiency:

The sub-criteria analysis within the ''Operational Efficiency'' category provides valuable insights into the factors that play a significant role in the context of Sustainable Practices in Inventory Management. The sub-criteria rankings and them associated weights include Inventory carrying costs (weight=0.332), Inventory turnover (weight = 0.324), Order fulfillment accuracy (weight = 0.144), Demand forecasting accuracy (weight = 0.14), and Lead time reduction (weight = 0.1), as presented in Table 9.

The calculated values CI (0.073), and CR (0.0651<0.10) indicate that the consistency of the comparison matrices used in the analysis is acceptable, affirming the reliability of the ranking results. Figure 5.5 represents the rank analysis of. Sub-criteria operational efficiency.

Table 10: Result for Operational Efficiency

Sub-Criteria	Inventory turnover	Lead time reduction	Order fulfillment accuracy	Demand forecasting accuracy	Inventory carrying costs	Weighted criteria	Rank
Inventory turnover	0.34	0.27	0.46	0.22	0.33	0.324	2nd
Lead time reduction	0.11	0.09	0.09	0.09	0.12	0.1	5th
Order fulfillment accuracy	0.07	0.09	0.09	0.32	0.15	0.144	3rd
Demand forecasting accuracy	0.14	0.27	0.09	0.09	0.11	0.14	4th
Inventory carrying costs	0.34	0.28	0.27	0.48	0.29	0.332	1st
Consistency Test	Largest eigenvalue λmax = 5.292 Consistency Index, CI = 0.073 Random Index, RI = 1.12 [n =5]						

	Consistency Ratio, CR = 0.0651 < 0.1

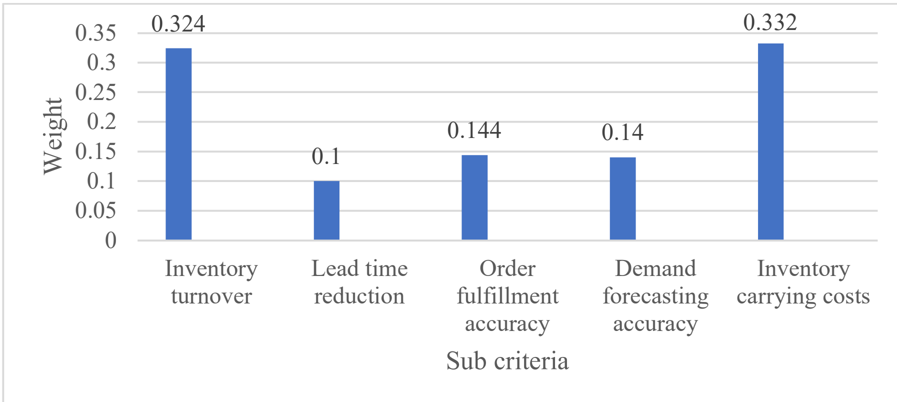

Figure 13: Rank Analysis of Sub-criteria Operational Efficiency

5.6 Result Analysis of Technological Integration:

Finally, the weight analysis of technological integration sub criteria shown in Table 10. The respondents view automation (weight = 0.44) to be more significant than Advance inventory System (weight = 0.33) and Data driven decisions (weight = 0.18) among the two types of sub criteria.

Furthermore, the consistency test indices suggest that the consistency index (0.0086), relative importance (0.58), and consistency ratio (0.0148 < 0.10) of the Technological Integration criteria is acceptable. Figure 5.6 represents the rank analysis of. Sub-criteria Technological Integration.

Table 11: Result for Technological Integration

Sub-Criteria	Advance inventory System	Automation	Data driven decisions	Weighted criteria	Rank
Advance inventory System	0.39	0.42	0.33	0.33	2nd
Automation	0.4	0.43	0.5	0.44	1st
Data driven decisions	0.21	0.15	0.18	0.18	3rd
Consistency Test	Largest eigenvalue λmax = 3.0172 Consistency Index, CI = 0.0086 Random Index, RI = 0.58 [n =3] Consistency Ratio, CR = 0.0148 < 0.1				

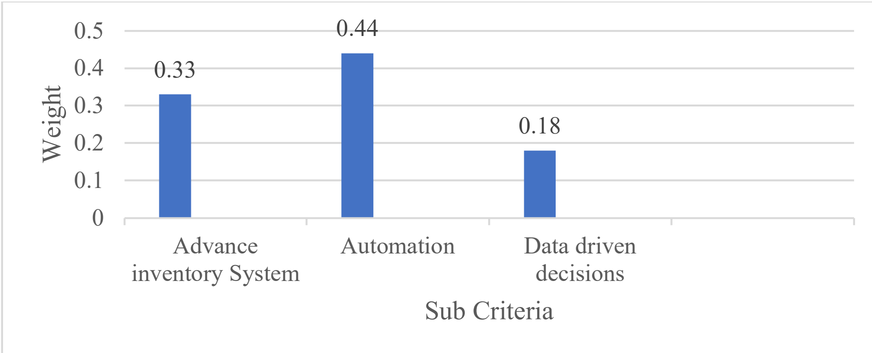

Figure 14: Rank Analysis of Sub-criteria Technological Integration

5. Discussion

We present a convenient and usable model in our study that can be used to bring inventory management closer to sustainability in the context of supply chain management with the help of the Analytic Hierarchy Process (AHP). It steps you through the process of balancing the economic, environmental, social, operational and technological considerations in order to assist the individual with their daily sustainability decisions in their inventory systems. The findings demonstrate that Economic Viability and Environmental Impact as the best pillars in all criteria and sub criteria were 8.35 and 8.06 points, respectively. Ranking one category over another demonstrates the extent of its importance, which allows making more informed, rightful decisions. This work is the supply chain management developed with the help of Delphi and AHP contributing to its development in the practical expert-oriented manner. The Delphi method was used to seek a wide range of views of the experts to determine the important factors of a sustainable inventory management in emerging economies. AHP next offers an unambiguous path to rank these drivers based on comparing them in pairs, allowing the inventory strategies to be both data-driven and adjusted to the challenges and competitive environment of real-life sustainability issues. Among all the criteria, economic viability is the most significant one because it emphasizes their ability to make the businesses financially stable. The sub-criteria covered by it are cutting of costs, improvement in profit margins and good returns on investment. Environmental Impact such as carbon footprints reduction and resources flow and the Social Responsibility, such as employee workers and the community engagement are other notable ones. Such a ranking indicates that sustainability of supply chain management is a complex endeavor in which economic, environmental and social aspects of supply chain management complement one another. Using inventory practices aligned to these criteria makes sustainability and competitive advantage stronger. Financial sustainability comes in view of economic viability, that funds can be re-invested in greener, more sustainable activities. Reputation and compliance to international standards are enhanced through consideration of environment and social issues leading to credibility among stakeholders. This organic strategy addresses everyday processes and gets businesses ready to meet the evolving requirements of the market enabling them to remain competitive amidst the new growing economies around the world. Five categories are taken into analysis, namely, Environmental Impact, Social Responsibility, Economic Viability, Operational efficiency, and Technological Integration. It unveils the strategic decision-making priorities and trade-off in the supply chain management. CP is more economically viable with Cost Efficiency and ROI coming next in order to achieve faster and marketable financial achievement. The second reason, Environmental Impact, indicates the increasing popularity of rational utilization and save nature. Social Responsibility is the third one as it emphasizes ethical activities such as multiple supplier networks and excellent health or safety. Technological Integration and Operational Efficiencies is also in view to providing sustainable practices and enhanced inventory management. The accuracy of their judgment is high with all the consistency ratios being lower than 0.1 and this makes these rankings credible in terms of strategic planning in supply chain management. Overall, the findings balance economic, environmental, and social priorities, with financial sustainability at the core. This research recommends a future approach that integrates financial objectives, sustainability, and technological advancement in order to help create comprehensive sustainable success.

6. Conclusion

This paper addresses the role Delphi and AHP may play in strategic inventory management to increase sustainability and provide businesses operating in the emerging markets with a competitive advantage in the context of the supply chain management. It provides an explicit, practical arrangement that fits in of day-to-day choices and aligns economic, environmental and social objectives. The results indicate Economic Viability to be the most important criteria that emphasize financial stability and cost effectiveness. This is followed by Environmental Impact which aims at conserving resources and reducing carbon footprints, then again Social Responsibility- improved working conditions and closer ties with the community. It brings action as well, as it helps transform ideas of sustainability into reality. The Delphi-AHP couple offers a robust, systematic approach to criterion prioritization, so inventory strategies can achieve their sustainability objectives alongside attaining market realities. As an action, to minimize carrying costs, maximize profits, and remain solvent, begin with an Economic Viability. Maintain Environment as the top-looked-after value to become resource alia and reduce the emission levels, in accordance with the international principles. Stress Social Responsibility as a means to advance managing worker welfare and community activity as a way to generate trust. Adopt Technological Integration-smarter forecasting and automation-in order to get inventory work more precise and effective. In total, this paper contributes to supply chains management through a connection between theory and practice in developing economies. It provides a procedural guide by which sustainability may be incorporated in inventory choices through Delphi and AHP and outlines Economic Viability, Environmental Impact, Social Responsibility, and Technological Integration as more important values.

6.1 Managerial Implications

This paper demonstrates that supply chain management can dedicate itself to sustainability through a clever combination of intuitive wisdom and systematic priority formation in emerging economies. It uses Delphi and AHP together resulting into selection of the most significant goals, such as reduction of costs, lowering environmental impact and community support, making decision clear and executable. The strategy assists managers in giving attention to less expensive stock, eco- friendly action and improved technology, rendering the supply chain healthier and more compliant. In brief, considerate planning in the supply chain management results in sustainable productivity, liability, and competitive priority.

6.2 Future Research Work and Limitations

In the future, future research may explore the applicability of the Delphi-AHP model in various fields such as manufacturing, retail, medical, and agricultural sectors in order to assist the sectors in discovering sustainability priorities and challenges in the supply chain management unique to them. Researchers may also integrate advanced technologies- AI, machine learning and big data to make their decision-making more precise, scalable, and real-time adaptable. The impact of prioritized sustainability criteria implementation could be measured in the long-term through longitudinal research that determined business performance and competitive advantage in supply chain management. The such work would be tested comparatively in more diverse economies which would involve developed economies in order to identify common strands and variations in sustainability interests. The other direction is to investigate the influence of various stakeholders- customers, workers and policymakers- in defining what is prioritized and the practical application of these criteria in supply chain management. Adaptive dynamic structures would be created to adapt to rapidly-evolving markets, emerging innovations and shifting regulations. As AHP is such a backbone, it has its hardships. Careful decision making based on an expert opinion inpairwise comparison may introduce bias. The data required is good, and in emergent economies it may be scanty. The method may incur a lot of resources, particularly to the small companies. A mixture of AHP with the big data and AI can be highly beneficial in terms of overcoming potential complexity and increasing the accuracy in supply chains management.

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