

Assessment of Warehouse Location Selection in Manufacturing Industry

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Abstract

Warehouse location selection has emerged as one of the most important strategic decisions in modern Supply Chain and Logistics Management as it directly influences transportation efficiency, operational cost, inventory movement, delivery performance, customer satisfaction and overall business growth. In today's competitive business environment, warehouses are much more than mere storage spaces for goods. They play a crucial role in enabling faster deliveries, ensuring smooth inventory flow, enhancing operational efficiency, and helping organisations adapt to evolving customer demands. As globalisation, e-commerce and manufacturing activities continue to rise at a rapid pace, businesses are increasingly focusing on building stronger and more efficient logistics networks. Hence, the choice of a suitable warehouse location has become a major concern for both researchers and industry professionals.

Traditionally, the warehouse location decisions were driven by Transportation Connectivity, Infrastructure Availability, Labour Accessibility, Market Proximity, Raw Material Availability, Land & Operational Cost. These factors continue to be important because they have a direct impact on transportation costs, business continuity, inventory movement and overall logistics performance. However, the warehousing and logistics sector has undergone significant change in recent years, driven by growing environmental concerns, technological advancements and the increasing importance of Sustainable Logistics Practices. Today, the need for warehouse facilities is more than ever before with the ability to support sustainability initiatives like EV Charging Infrastructure, Solar Energy Systems, energy-efficient operations, and effective Waste-Management Systems. Although such changing industry requirements did exist, most of the previous warehouse location studies have primarily focused on traditional operational factors and paid relatively less attention to the modern sustainability-related requirements.

Therefore, the present study aims at assessing sustainable warehouse location selection in the Manufacturing Industry by incorporating both traditional logistics factors and modern sustainability-related criteria into a

practical evaluation framework. The present study considers three alternative locations of the warehouse in National Capital Region (NCR) of India, namely, Noida, Ghaziabad and Gurugram. The paper explores the importance of factors such as Transportation Connectivity, Infrastructure Availability, Labour Accessibility, Market Proximity, Raw Material Availability, Land & Operational Cost, EV Charging Infrastructure, Solar Energy Potential, Waste-Management Systems and Environmental Considerations in warehouse location choice decisions. The study also tries to fill the gap between classic warehouse location approaches and contemporary sustainability needs of the logistics industry.

The study is based on Exploratory and Descriptive Research Designs and gathers expert opinions through purposive sampling of professionals working in the logistics, warehousing, supply chain, manufacturing, transportation and distribution sectors. Primary data was collected by using a structured questionnaire based on a Seven-Point Likert Scale and secondary data was collected from the research papers, journals, books and academic databases. In order to analyse the data in a systematic manner, the SWARA method was used to determine the importance of the selected criteria, while the WASPAS method was used to evaluate and rank the alternatives for warehouse location.

The results show that Raw Material Availability, Labour Accessibility, Transportation Connectivity, Infrastructure Support and Land & Operational Cost are the most important factors affecting the location of warehouse choice in the manufacturing industry. The research further shows the increasing importance of sustainability factors such as Solar Energy Potential, Waste-Management Systems, EV Charging Infrastructure and Environmental Considerations in contemporary warehousing decisions. Based on the SWARA-WASPAS analysis, it was found that Noida is the most suitable and sustainable warehouse location among the selected NCR alternatives due to its strong performance in operational efficiency, infrastructure support, raw material accessibility and sustainability requirements.

The study adds value to existing research by providing a practical and industry-oriented framework that combines operational and sustainability factors in a simple and realistic way. The findings can help logistics professionals, supply chain managers, and organizations make more informed, efficient, and sustainable warehouse location decisions.

CHAPTER 1

1.0 INTRODUCTION

In the present business environment, warehousing has become an essential part of supply chain and logistics operations. Warehouses are no longer used only for storing goods; they now play a major role in improving operational efficiency, supporting faster deliveries, maintaining inventory flow, and meeting customer expectations. With the rapid growth of e-commerce, globalization, and changing consumer demand, businesses are focusing more on strengthening their logistics networks. Because of this, selecting the right

warehouse location has become one of the most important strategic decisions for organizations.

A suitable warehouse location can help companies reduce transportation expenses, improve delivery performance, and manage operations more effectively. On the other hand, an unsuitable location may increase logistics costs, create delays, and negatively affect customer satisfaction. Therefore, warehouse location selection has received significant attention from both researchers and industry professionals over the years.

Traditionally, warehouse location decisions were mainly based on factors such as transportation cost, distance from suppliers and customers, labor availability, land cost, and infrastructure facilities. These factors continue to be important because they directly influence the efficiency and profitability of logistics operations. Most earlier studies and traditional location theories also focused mainly on minimizing cost and improving operational performance while selecting warehouse locations.

However, the warehousing and logistics industry has changed significantly in recent years. Technological advancement, environmental concerns, and sustainable business practices are now influencing logistics operations across the world. Modern warehouses are increasingly adopting technologies such as automation, digital monitoring systems, smart inventory management, and data-driven logistics practices. Along with technological development, businesses are also becoming more aware of environmental sustainability and the need to reduce the environmental impact of warehousing activities.

As a result, sustainability has become an important consideration in warehouse planning and location selection. Companies are now looking for locations that can support sustainable operations through facilities such as EV charging infrastructure, solar energy systems, energy-efficient operations, and proper waste-management practices. These factors are becoming increasingly relevant because organizations are under pressure to adopt environmentally responsible practices and support long-term sustainable growth.

For example, the growing use of electric vehicles in transportation and logistics has increased the need for warehouses with proper EV charging facilities. Similarly, rising energy costs and environmental concerns have encouraged businesses to explore renewable energy options such as solar power for warehouse operations. Waste management has also become an important issue because warehousing activities often generate packaging waste, damaged materials, and disposal-related challenges. Therefore, modern warehouse location decisions must consider both operational efficiency and sustainability requirements.

Although many studies have been conducted on warehouse location selection, most of the existing research still focuses mainly on traditional operational factors such as transportation cost, market proximity, and infrastructure availability. Very limited attention has been given to sustainability-related requirements that are becoming increasingly important in current warehousing and logistics operations. Because of this, there

remains a gap between traditional warehouse location studies and the practical sustainability needs of modern businesses.

Another issue identified in previous studies is the increasing use of highly technical and complex decision-making models for warehouse location selection. Many researchers have used advanced mathematical models and complicated analytical techniques to solve location selection problems. While these methods may provide detailed results, they are often difficult for managers and industry professionals to understand and apply in practical situations. In real business environments, companies usually prefer simple and practical methods that can support quick and effective decision-making without requiring advanced technical expertise.

Therefore, there is a need for a more practical and industry-friendly approach that can support sustainable warehouse location selection in a realistic manner. In this context, the present study uses the Factor Rating Method (FRM) to develop a practical framework for sustainable warehouse location selection. The Factor Rating Method is widely used because it allows organizations to evaluate different location alternatives in a simple and structured way by considering multiple important factors together.

The study aims to identify both traditional and sustainability-related factors that influence warehouse location decisions. By combining operational requirements with modern sustainability considerations, this research seeks to provide a practical framework that can help organizations make more balanced and effective warehouse location decisions.

1.2 Statement of the Problem:

Most of the existing studies on warehouse location selection mainly concentrate on traditional factors like transportation cost, distance from markets, and availability of basic infrastructure. Although these factors are important, very few studies have considered modern sustainability requirements such as EV charging facilities, solar energy potential, and effective waste-management systems, which are becoming increasingly relevant in today's warehousing and logistics sector. At the same time, many recent studies have adopted highly technical and complex decision-making models that are often difficult for managers and industry professionals to apply in practical situations. Therefore, there is a growing need for a simpler and more practical approach that can support sustainable warehouse location decisions in a more realistic and industry-friendly manner. In this context, the present study uses the Factor Rating Method (FRM) to develop a practical framework for sustainable warehouse location selection.

Warehouse location selection is one of the most important decisions in logistics and supply chain management because it directly affects transportation efficiency, operational performance, delivery speed, and customer satisfaction. Traditionally, organizations have selected warehouse locations mainly based on

factors such as transportation cost, market proximity, labor availability, and infrastructure facilities. Although these factors remain important, the warehousing industry is now facing new challenges related to sustainability and technological advancement.

Modern logistics operations increasingly require warehouse facilities that can support sustainable practices such as EV charging infrastructure, renewable energy usage, and efficient waste-management systems. However, many existing studies on warehouse location selection still focus mainly on traditional operational factors and provide limited attention to sustainability-related requirements.

At the same time, many recent studies use highly technical and complex decision-making models that are difficult for managers and industry professionals to apply in practical business situations. These approaches often require advanced analytical knowledge and may not be suitable for real-world industrial decision-making. As a result, organizations may face difficulties in selecting warehouse locations that are both operationally efficient and environmentally sustainable.

Therefore, there is a need for a simpler and more practical approach that can help organizations evaluate warehouse locations by considering both traditional operational requirements and modern sustainability factors. The present study addresses this issue by using the Factor Rating Method (FRM) to develop a practical framework for sustainable warehouse location selection.

1.3 Research questions:

RQ1. What are the major criteria affecting warehouse location selection in the manufacturing industry?

RQ2. What is the suitable technique to determine the weight of the selection criteria.

RQ3. What is the suitable technique for assessing the alternate warehouse locations to select the best warehouse location.

1.4 Research Objectives

The specific objectives of the study are:

1. To identify the factors affecting warehouse location selection.
2. To determine the weight of the factors using SWARA (STEP-WISE WEIGHT ASSESSMENT RATIO ANALYSIS)
3. To assess the alternative locations of the warehouse using WASPAS (Weight Aggregated sum product Assessment).

CHAPTER 2

2.0 Literature Review

Warehouse and facility location selection has become an important area of research because it directly affects transportation efficiency, operational cost, inventory management, customer service, and overall supply chain performance. Many researchers have attempted to identify the most suitable methods and criteria for selecting warehouse and manufacturing locations. (Sharma et al., 2024) explained that manufacturing site selection is a strategic decision that influences operational efficiency, accessibility to resources, and organizational growth. Their study used the Factor Rating Method (FRM), Analytic Hierarchy Process (AHP), and Best Worst Method (BWM) to evaluate alternative manufacturing locations based on factors such as raw material availability, labor, transportation, utilities, and environmental impact. The study highlighted that raw material availability plays a major role in location selection decisions. Similarly, (Çetinkaya et al., 2022) stated that warehouse location decisions strongly influence investment cost, operating efficiency, and customer service performance. Their research used the Best Worst Method (BWM) and found that market size and customer demand are among the most important factors affecting warehouse location selection. In another study, (Rahman et al., 2018) applied the AHP method for facility location selection in the plastic manufacturing industry of Bangladesh and emphasized the importance of transportation, communication networks, infrastructure, labor availability, and access to raw materials while selecting industrial locations.

Several researchers have also focused on the application of multi-criteria decision-making methods to improve the effectiveness of warehouse and facility location selection. (Suman et al., 2021) conducted a comparative study using AHP and Fuzzy AHP methods for facility location selection in the furniture industry of Bangladesh. Their study considered factors such as transportation, skilled labor, energy availability, environmental impact, and proximity to customers. The research identified energy availability as one of the most influential factors in selecting suitable facility locations. Likewise, (Ashrafzadeh et al., 2012) explained that warehouse location selection is a multi-criteria problem involving both quantitative and qualitative factors. The authors proposed the use of Fuzzy Analytic Hierarchy Process (FAHP) to manage uncertainty and incomplete information in warehouse location decisions. The study highlighted that inappropriate warehouse location decisions may increase transportation cost, reduce operational efficiency, and negatively affect organizational competitiveness. Furthermore, (Ocampo et al., 2020) applied the TOPSIS method within a group decision-making environment and stated that warehouse location selection requires the evaluation of multiple operational and strategic criteria. Their research emphasized that warehouse location decisions influence supply chain efficiency, distribution performance, and long-term organizational competitiveness.

In addition to manufacturing and logistics industries, warehouse location selection has also been studied in

sector-specific and global business contexts. (Jantachalobon, 2023) analyzed warehouse location selection strategies for a cosmetic company using the AHP method and Center of Gravity Theory. The study identified transportation cost, labor, rent, and equipment as important factors affecting warehouse location decisions and concluded that selecting a suitable warehouse location can significantly reduce transportation expenses and improve operational performance. Similarly, (Yaman et al.) examined warehouse location selection in the medical sector and highlighted factors such as transportation facilities, infrastructure availability, climate conditions, proximity to hospitals, and service accessibility.

Their study explained that warehouse location decisions in the healthcare sector are highly important because medical products require safe handling and fast delivery. (Brahimi et al., 2013) also studied warehouse location decisions in the lube oil industry by integrating production, inventory, and distribution planning into the decision-making process. Their research focused on minimizing transportation, inventory, and operational costs while improving supply chain performance. In another important study, (Kalantari, 2013) reviewed global manufacturing facility location decisions and explained that globalization has increased the importance of economic, political, infrastructural, social, and market-related factors in site selection decisions. The author proposed a clustering-based framework and transformed decision criteria into binary variables to simplify complex location evaluation processes and support better decision-making.

2.1 Analysis of Criteria Used in Previous Warehouse Location Studies:

The table clearly shows that earlier researchers gave major importance to different factors affecting warehouse and facility location selection. Most of the studies mainly focused on traditional operational factors such as transportation facilities, market proximity, infrastructure availability, labor accessibility, raw material availability, supplier connectivity, and land cost while selecting suitable warehouse or industrial locations. The table clearly shows that earlier researchers gave major importance to different factors affecting warehouse and facility location selection. Most of the studies mainly focused on traditional operational factors such as transportation facilities, market proximity, infrastructure availability, labor accessibility, raw material availability, supplier connectivity, and land cost while selecting suitable warehouse or industrial locations. These factors were considered important because they directly influence operational efficiency, transportation cost, inventory movement, and overall business performance.

The table also shows that researchers used several decision-making methods such as AHP, FAHP, BWM, TOPSIS, MCDM, CoG Theory, and optimization models to make the location selection process more systematic and reliable. Through these methods, researchers tried to reduce uncertainty and support better decision-making for organizations. Most of the previous studies highlighted that transportation connectivity, infrastructure quality, market demand, and raw material proximity are among the most important factors influencing successful warehouse location decisions.

Another important observation from the table is that some recent studies have started giving attention to sustainability-related factors such as environmental regulations, energy efficiency, waste-management systems, and green operational practices. This shows that warehouse location decisions are no longer based only on cost and operational efficiency, but are now also influenced by environmental and sustainability concerns.

The findings of these studies are strongly connected with the present research. Similar to earlier studies, the current research also focuses on important operational factors such as transportation, infrastructure, labor availability, and market proximity while evaluating warehouse locations. However, the present study further extends the existing research by including modern sustainability-related factors such as EV charging infrastructure, solar energy potential, and waste-management systems, which have received limited attention in many earlier studies.

In addition, many previous researchers used highly technical and complex analytical models which may be difficult for industry professionals to apply in practical situations. In contrast, the present study uses the Factor Rating Method (FRM) to develop a simpler, more practical, and industry-friendly framework for sustainable warehouse location selection. Therefore, the current study not only aligns with previous research but also attempts to address the existing research gap by combining traditional operational requirements with modern sustainability considerations in a more realistic and easy-to-understand manner.

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Table 1: List of latest study on warehouse location selection

Factors	Methods	Descriptions	Authors Names
Raw materials, Location, Labor, Transport, Utilities, Environmental impact	FRM, AHP, BWM	Combined AHP and BWM with FRM to evaluate industrial locations and identified raw material availability as the most critical factor.	Sharma et al., 2024
Market size/demand, Labor, Costs, Infrastructure, Environmental regulations	Literature Review, BWM, Questionnaire/Expert Survey	Used expert opinions and BWM to determine market demand as the most important warehouse selection factor.	Çetinkaya & Akdaş, 2022
Raw materials, Transport, Labor, Proximity to customers, Energy, Economic zone, Environment	AHP, FAHP, Survey (34 Experts)	Compared AHP and Fuzzy AHP to analyze facility locations and reduce uncertainty in expert decision-making.	Suman et al., 2021
Distance, Storage capacity, Rental costs, Transportation fees	CoG Theory, AHP, Cost-Benefit Analysis	Applied CoG Theory and AHP to optimize warehouse location selection and reduce operational costs.	Jantachalobon, 2023
Costs (labor, land, transport), Skilled labor, Climate, Infrastructure	Fuzzy AHP, Hierarchy Tree Modeling, Linguistic Scale Metrics	Built a two-step hierarchical fuzzy tree structure and translated vague expert ratings into mathematical weights.	Ashrafzadeh et al., 2012
Strategy metrics, Conflicting group criteria, Priority variations	TOPSIS Group Decision-Making, Expert Priority Allocation Models, Outranking Analysis	Used TOPSIS-based group decision-making to simplify warehouse site selection under uncertain conditions.	Ocampo et al., 2020

Proximity to ports/customs/markets, Utilities, Disaster risk, Health proximity, Land structure	Multi-Criteria Decision-Making, Special Material Handling Criteria Systems	Applied TOPSIS and expert priority models to evaluate warehouse alternatives under conflicting decision criteria.	Yaman & Akkartal, 2022
Strategic supply costs, Production limits, Distribution costs, Inventory metrics	Mixed Integer Linear, Full Factorial Experimental Design, Sensitivity Analysis	Developed a healthcare warehouse location framework considering safety, infrastructure, and emergency accessibility.	Brahimi & Khan, 2013
Cost attributes, Labor pool, Infrastructure, Market/Supply Chain, Macro-environment regulations, economic scales (GDP/taxes)	Literature Review, Binary Transformation, Similarity Coefficients, Hierarchical Clustering	Used optimization modeling to improve 3PL warehouse allocation and inventory efficiency.	Kalantari, 2013
Raw material proximity, Utility availability, Market proximity, Transport, Labor	AHP, Pairwise Consistency Analysis	Applied AHP and consistency analysis to identify raw material proximity and transportation connectivity as key location factors.	Rahman et al., 2018

The studies reviewed show that the selection of warehouse and facility location is an important strategic decision which is influenced by several operational and business-related factors. Most of the researchers pointed out that the availability of raw material, transportation connectivity, accessibility of labour, infrastructure facilities, market proximity and environmental considerations, etc., are some of the factors that play a major role in selecting suitable warehouse or industrial locations. Various methods such as AHP, FAHP, BWM, TOPSIS, CoG Theory, and MCDM were used to make the decision-making process more systematic and accurate.

TABLE 2: List of criteria for warehouse location selection

Criteria Type	Criteria Code	Evaluation Criteria	Type (Benefit / Non-Benefit)	Operational Description	Academic References (From Your Uploaded Library)
Traditional Logistical Factors	C1	Transportation Cost	Non-Benefit (C)	Total expenditures incurred during raw material inbound hauling and finished product outbound distribution.	Brahimi & Khan (2013); Sharma et al. (2024); Ashrafzadeh et al. (2012); Jantachalobon (2023)
	C2	Proximity to Customers / Market	Non-Benefit (C)	Geographic closeness to primary demand clusters, distribution channels, and urban consumer markets to maximize delivery speed.	Cetinkaya & Akdaş (2022); Ocampo et al. (2020); Suman et al. (2021)
	C3	Infrastructure Quality & Availability	Benefit (B)	Access to reliable road networks, continuous power grids, water supply, and advanced telecommunication infrastructure.	Rahman et al. (2018); Yaman & Akkartal (2022); Ulutaş et al. (2021); Suman et al. (2021)
	C4	Procurement / Land Cost	Non-Benefit (C)	Capital expenditures related to purchasing real estate or long-term lease/rental values for the facility area.	Kalantari (2013); Ashrafzadeh et al. (2012); Jantachalobon (2023)
	C5	Labor Availability & Cost	Benefit (B)	The regional presence of both skilled logistical workers and affordable general warehouse labor forces.	Kalantari (2013); Rahman et al. (2018); Suman et al. (2021); Ashrafzadeh et al. (2012)
	C6	Proximity to Suppliers / Manufacturing Plants	Benefit (B)	Distance to the primary manufacturing units to ensure seamless inbound product flow and minimal intermediate storage delays.	Brahimi & Khan (2013); Ocampo et al. (2020); Ulutaş et al. (2021)
Modern Sustainability & Operations	C1	Electric Vehicle (EV) Grid Readiness	Benefit (B)	Availability of high-voltage industrial power lines and local capacity to deploy heavy-duty commercial vehicle charging infrastructure.	Cetinkaya & Akdaş (2022); Sharma et al. (2024)

C2	Renewable / Solar Energy Potential	Benefit (B)	Architectural and geographical capability of the warehouse site to support rooftop solar array harvesting and battery microgrids.	Cetinkaya & Akdaş (2022); Suman et al. (2021)
C3	Eco-Friendly Waste Management Systems	Benefit (B)	Local access to institutional recycling networks and specialized industrial systems for sustainable circular packaging waste disposal.	Rahman et al. (2018); Suman et al. (2021); Ocampo et al. (2020)
C4	Environmental Regulations & Natural Risks	Non-Benefit (C)	Regional exposure to strict carbon penalties, structural zoning limitations, and localized climate/natural disaster vulnerabilities.	Yaman & Akkartal (2022); Suman et al. (2021); Ocampo et al. (2020)

CHAPTER 3

3.0 Research Methodology

The present study follows both exploratory and descriptive research designs to examine the important factors affecting sustainable warehouse location selection in the manufacturing industry. The exploratory research design was used because the study aims to explore and identify both traditional operational factors and modern sustainability-related factors that influence warehouse location decisions. The research particularly focuses on understanding how sustainability factors such as EV charging infrastructure, solar energy potential, and waste-management systems are becoming increasingly important in modern warehousing and logistics operations.

At the same time, the study also follows a descriptive research design because it systematically analyzes and describes the opinions, preferences, and responses provided by industry experts regarding warehouse location selection criteria. The descriptive approach helped organize and present the collected data in a structured and meaningful way. The combination of exploratory and descriptive research designs helped develop a practical and industry-oriented framework for sustainable warehouse location selection.

3.1 Data Collection Method

- The study is mainly based on **Primary Data**.
- Data was collected through a **structured questionnaire survey**.
- A **Seven-Point Likert Scale** was used to measure the importance of different criteria.

3.2 Sampling Technique

- This research used the purposive sampling technique.
- Responses were collected from **10 industry experts** associated with:
 - Logistics
 - Warehousing
 - Supply Chain Management
 - Manufacturing

- Transportation
- Distribution sectors

3.3 Alternatives Selected

The study evaluated three warehouse location alternatives in NCR:

- Noida
- Ghaziabad
- Gurugram

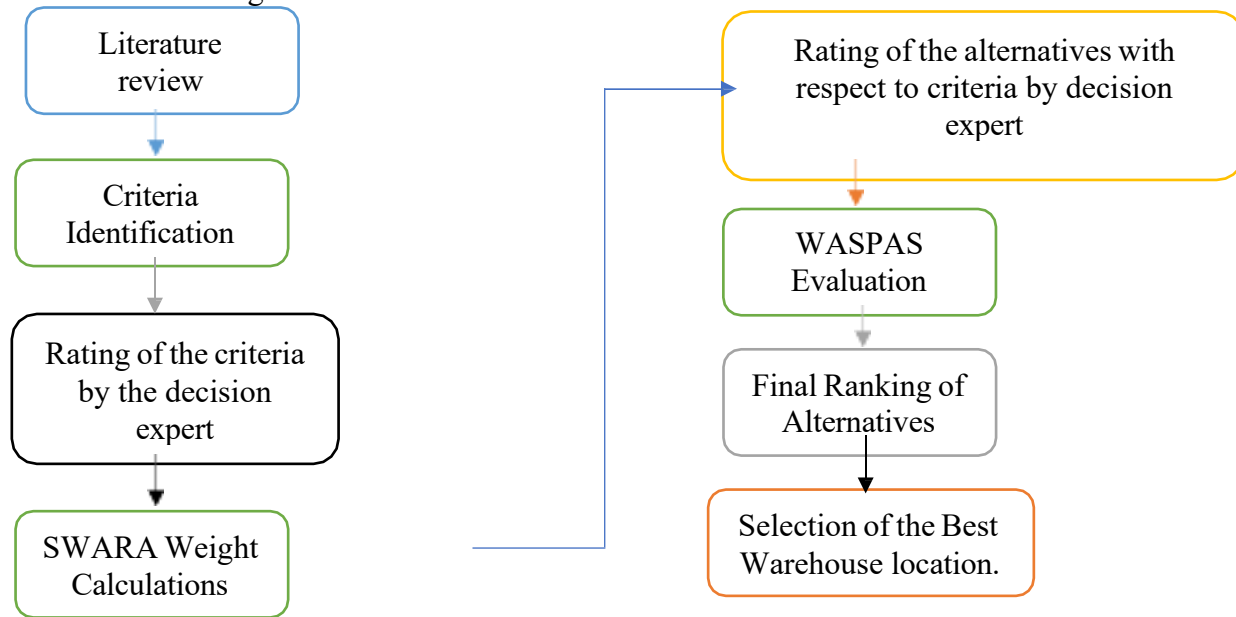


Figure 1: Research methodology

3.4 Research methods

For criteria weight determination SWARA method will used first. For alternative evaluation WASPAS method will be used.

3.5 SWARA Method: (Step-wise Weight Assessment Ratio Analysis)

The SWARA method was used to determine the relative importance and weights of different warehouse location selection criteria based on expert opinions. This method helped prioritize the criteria according to their importance and practical influence on warehouse location decisions.

Under the SWARA approach, experts evaluated the importance of each criterion step-by-step, and the relative weights were calculated accordingly. The method helped identify the most influential factors affecting sustainable warehouse location selection. One of the major advantages of the SWARA method is that it is simple, flexible, and easier to apply in practical decision-making situations.

Steps of SWARA Method:

Step 1: "We applied the SWARA method to turn real-world expert insights into precise mathematical weights for our criteria."

Step2: Give ranking to the criteria

we had industry experts sort the criteria from absolute deal-breakers to minor "nice-to-haves," based on what actually matters in day-to-day warehouse operations.

Step 3: Finding the Relative Gap (S_j)

Once the criteria were ranked, we measured how much more important each factor was compared to the one right above it, revealing the exact "importance gap" between them.

(a) S_j represents the comparative importance of the current criterion compared to the previous criterion.

(b) This step helped measure how much less important one criterion is compared to another.

Step 4: Calculation of Coefficient (K_j)

The coefficient value for each criterion was then calculated using the comparative importance values.

Formula: $K_j = S_j + 1$

Where:

- K_j = Coefficient value
- S_j = Comparative importance value

This step helped adjust the importance level of each criterion systematically. Step 5: Calculation of

Recalculated Weight (Q_j)

The recalculated weight of each criterion was then determined. Formula:

$$Q_j = \frac{Q_{j-1}}{K_j} \quad \text{---}$$

Where:

Q_j = Recalculated weight K_j = Coefficient value

Step 6: Calculation of Final Normalized Weights (W_j)

Finally, the normalized weight of each criterion was calculated. Formula: $W_j = \frac{Q_j}{\sum Q_j}$

W_j = Final normalized weight of criterion Q_j = Recalculated weight

3.6 WASPAS method (Weighted Aggregated Sum Product Assessment)

Step 1: Preparation of Decision Matrix

A decision matrix was prepared by assigning ratings to each warehouse location alternative against all selected criteria.

Step 2: Normalization of Decision Matrix

The collected data was then normalized to make the values comparable.

Formula for Beneficial Criteria

**Linear
Normalization**

↓

Beneficial	$\bar{X}_{ij} = \frac{X_{ij}}{X_j^{Max}}$
Non-beneficial	$\bar{X}_{ij} = \frac{X_j^{min}}{X_{ij}}$

$\bar{X}_{ij}$ = Normalized value x_{ij} = Original value

This step helped standardize the data before further calculations.

Step 3: Calculation of Weighted Sum Model (WSM):

The Weighted Sum Model score for each alternative was calculated using the normalized values and SWARA weights.

Formula:

$$Q_i^{(1)} = \sum_{j=1}^n \bar{x}_{ij} w_j$$

Step 4: Calculation of Weighted Product Model (WPM)

Step 5: This step provided another evaluation measure for comparing the alternatives. Formula:

$$Q_i^{(2)} = \prod_{j=1}^n (\bar{x}_{ij})^{w_j}$$

Step 6 : Final Ranking of Alternatives: In the final step, all the warehouse location alternatives were compared and ranked based on their final WASPAS scores. The location with the highest score was considered the most suitable and sustainable option because it performed better across the selected criteria and expert evaluations.

Formula:

$$Q_i = 0.5Q_i^1 + 0.5Q_i^2$$

CHAPTER 4

4.0 Data Analysis & Interpretation:

Data Analysis and Interpretation are important parts of a research study because they help transform collected responses into meaningful findings. Data analysis refers to examining and organizing the data collected from respondents using methods such as SWARA and WASPAS.

In this study, the collected responses were analyzed to identify the importance of different warehouse location factors and evaluate the selected alternatives. Interpretation, on the other hand, explains what the results actually mean and why certain factors or locations performed better than others. In simple terms, data analysis provides the results, while interpretation helps understand their practical meaning and significance in the context of the research study.

3 TABLE OF RESPONSES

Independent ratings										
0	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
R1	5	5	6	5	6	5	5	4	4	5
R2	6	6	6	7	7	7	7	7	7	7
R3	6	6	6	4	6	3	6	5	7	7
R4	5	4	4	5	4	5	6	5	6	4

R5	6	7	7	6	7	7	1	4	4	4
R6	6	7	7	5	6	7	6	4	5	6
R7	6	6	6	4	6	5	4	6	5	6
R8	7	4	4	4	7	6	7	4	6	7
R9	4	6	4	4	6	6	5	6	4	3
R10	4	4	6	4	4	4	4	4	4	4
MEAN	5.50	5.50	5.60	4.80	5.90	5.50	5.10	4.90	5.20	5.30

The questionnaire responses were collected from industry experts using a five-point importance rating scale to measure the significance of each criterion in warehouse location selection decisions.

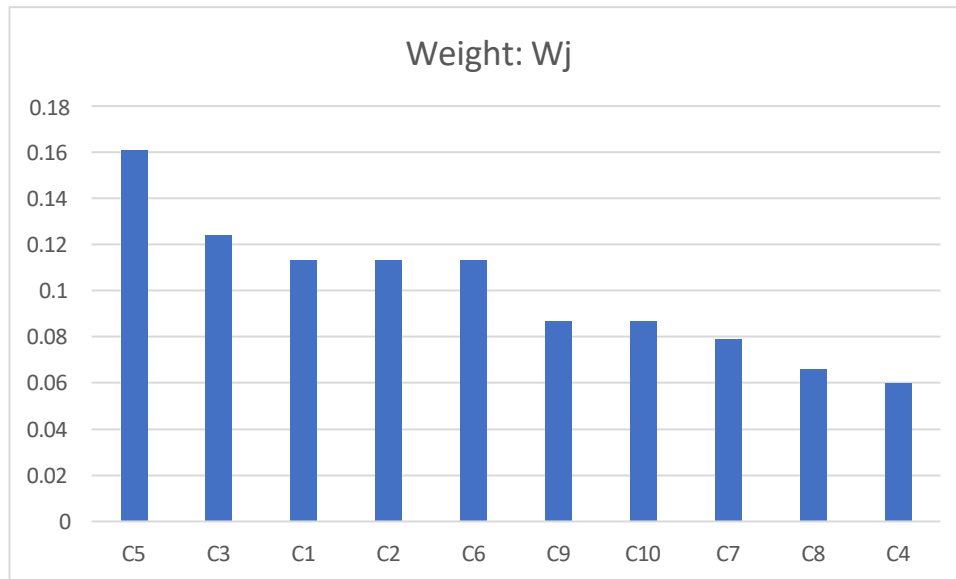
4.1 Criteria weight determination by SWARA

The collected data was analyzed using two multi-criteria decision-making techniques: SWARA. These techniques were selected because they help evaluate decision criteria systematically and support practical decision-making in complex industrial problems.

Table 4:

Criteria	Description	Mean	Sj	Kj	Qj	Wj
C5	Raw material availability	5.90		1	1	0.161
C3	Labour accessibility	5.60	0.30	1.30	0.769	0.124
C1	Transportation connectivity	5.50	0.10	1.10	0.699	0.113
C2	Infrastructure availability	5.50	0.00	1.00	0.699	0.113
C6	Land & Operational cost	5.50	0.00	1.00	0.699	0.113
C9	Solar energy potential	5.20	0.30	1.30	0.538	0.087
C10	Environmental and natural risks	5.20	0.00	1.00	0.538	0.087
C7	Waste Management facilities	5.10	0.10	1.10	0.489	0.079
C8	EV Charging Infrastructure	4.90	0.20	1.20	0.408	0.066
C4	market proximity	4.80	0.10	1.10	0.370	0.060
					6.210	

Table : 4.6



4.2 Alternative evaluation by WASPAS Method

After calculating the criteria weights through the SWARA method, the WASPAS method was applied to evaluate and rank the warehouse location alternatives.

TABLE 5: Mean & standard deviation of alternatives rating for AI

Location	Respondent	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
NOIDA	R1	5	6	6	6	5	6	6	6	5	5
	R2	7	7	7	7	7	7	7	7	7	7
	R3	6	5	6	6	6	6	5	6	6	6
	R4	5	5	4	5	4	4	4	4	4	6
	R5	6	6	6	4	4	6	2	2	3	3
	R6	7	6	6	5	6	5	7	5	6	6
	R7	6	6	7	5	6	5	5	5	5	4
	R8	5	7	5	5	5	5	4	5	5	5
	R9	5	6	6	6	6	6	6	6	6	6
	R10	5	6	6	7	5	5	5	5	5	5
	MEAN	5.7	6	5.9	5.6	5.4	5.5	5.1	5.1	5.2	5.3
	SD	0.823	0.667	0.876	0.966	0.966	0.850	1.524	1.370	1.135	1.160

TABLE 6: Mean & standard deviation of alternatives rating for AII

Location	Respondent	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Ghaziabad	R1	5	5	6	6	5	5	5	5	5	5
	R2	7	6	6	7	5	5	5	5	6	6
	R3	6	6	5	6	5	5	6	6	6	6
	R4	4	4	4	5	4	5	5	5	4	4
	R5	3	3	3	3	3	3	3	3	2	2
	R6	6	7	5	7	6	4	5	5	5	5
	R7	5	5	5	5	5	5	5	5	5	5
	R8	5	5	5	6	6	5	4	4	6	6
	R9	6	6	6	6	6	6	6	6	6	6
	R10	5	5	5	5	5	5	5	5	5	5

	MEAN	5.2	5.2	5	5.6	5	4.8	4.9	4.9	5	5
	SD	1.135	1.135	0.943	1.174	0.943	0.789	0.876	0.876	1.247	1.247

TABLE 7: Mean & standard deviation of alternatives rating for AIII

Location	Respondent	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Gurugram	R1	5	6	6	6	6	6	7	7	6	6
	R2	5	4	7	6	7	3	7	5	6	7
	R3	6	6	6	5	6	4	5	5	5	4
	R4	5	6	5	5	6	4	5	5	6	3
	R5	3	4	4	4	4	3	5	4	6	4
	R6	7	6	5	5	5	5	5	6	6	6
	R7	4	5	5	6	5	5	5	6	6	5
	R8	4	5	5	5	4	6	5	4	6	5
	R9	6	6	6	5	6	5	6	5	6	6
	R10	5	5	5	5	5	5	5	5	5	5
	MEAN	5	5.3	5.4	5.2	5.4	4.6	5.5	5.2	5.8	5.1
	SD	1.155	0.823	0.843	0.632	0.966	1.075	0.850	0.919	0.422	1.197

TABLE 8: Mean value of the responses

MEAN										
LOCATION	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
L1	5.70	6.00	5.90	5.60	5.40	5.50	5.10	5.10	5.20	5.30
L2	5.20	5.20	5.00	5.60	5.00	4.80	4.90	4.90	5.00	5.00
L3	5.00	5.30	5.40	5.20	5.40	4.60	5.50	5.20	5.80	5.10
MIN	5.00	5.20	5.00	5.20	5.00	4.60	4.90	4.90	5.00	5.00
MAX	5.70	6.00	5.90	5.60	5.40	5.50	5.50	5.20	5.80	5.30
MAX OF MAX	6.00									
MIN OF MIN	4.60									

TABLE 9: Normalised table

Normalize table	0.113	0.113	0.12	0.060	0.161	0.11	0.08	0.07	0.09	0.09
Location	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
L1	0.807	0.867	0.983	0.929	1.000	0.836	1.078	1.020	1.115	0.943
L2	0.885	1.000	0.833	0.929	1.080	0.958	1.122	1.061	1.160	1.000
L3	0.920	0.981	0.900	1.000	1.000	1.000	1.000	1.000	1.000	0.980

Table 10: Weighted sum matrix

Location	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Calculate the total relative significance
L1	0.091	0.098	0.122	0.056	0.161	0.095	0.085	0.067	0.097	0.082	0.954
L2	0.100	0.113	0.103	0.056	0.174	0.108	0.089	0.070	0.101	0.087	1.001
L3	0.104	0.111	0.112	0.060	0.161	0.113	0.079	0.066	0.087	0.085	0.978

TABLE 11: Weighted product matrix

Location	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	product
L1	0.976	0.984	0.998	0.996	1.000	0.980	1.006	1.001	1.010	0.995	0.946
L2	0.986	1.000	0.978	0.996	1.012	0.995	1.009	1.004	1.013	1.000	0.993
L3	0.991	0.998	0.987	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.974

Table 12: final location selection

Location	sum	product	SCORE	RANK
L1	0.954	0.946	0.950	III
L2	1.001	0.993	0.997	I
L3	0.978	0.974	0.976	II

4.3 Discussion on the findings

The SWARA method was applied to determine the importance of the selected warehouse location criteria based on expert opinions and industry responses. The final weight values clearly show which factors industry professionals consider most important while selecting a sustainable warehouse location. The results indicate that Raw Material Availability (C5) received the highest weight value of 0.161, making it the most influential factor in the decision-making process. This shows that easy access to raw materials plays a major role in ensuring smooth warehouse and manufacturing operations.

The second most important factor was Labour Accessibility (C3) with a weight value of 0.124. This indicates that the availability of skilled and reliable labor is also an important requirement for efficient warehouse operations. Further, Transportation Connectivity (C1), Infrastructure Availability (C2), and Land & Operational Cost (C6) received equal weight values of 0.113, showing that transportation facilities, infrastructure support, and operational cost efficiency are equally important while selecting a warehouse location.

The results also show that sustainability-related factors are gradually becoming important in warehouse decision-making. Solar Energy Potential (C9) and Environmental & Natural Risks (C10) both achieved weight values of 0.087, highlighting the growing focus on sustainable and environmentally responsible warehouse operations. Similarly, Waste Management Facilities (C7) received a weight value of 0.079, while EV Charging

Infrastructure (C8) and Market Proximity (C4) received comparatively lower weights of 0.066 and 0.060 respectively.

Based on the final SWARA weights, the criteria were ranked in the following decreasing order: $C5 > C3 > C1$

$= C2 = C6 > C9 = C10 > C7 > C8 > C4$

The ranking clearly shows that industry experts gave higher priority to operational continuity factors such as raw material availability, labor accessibility, transportation connectivity, and infrastructure support while evaluating warehouse locations.

After calculating the criteria weights using the SWARA method, the WASPAS method was applied to evaluate and rank the warehouse location alternatives. Three alternatives, namely L1 (Noida), L2, and L3, were evaluated using normalized values, weighted calculations, and final WASPAS scores. The results showed that L1 (Noida) achieved the best overall performance among all alternatives and was identified as the most suitable warehouse location option based on the selected criteria and expert evaluations.

The final ranking of the warehouse location alternatives is as follows: $L1 (Noida) > L3 > L2$

The findings indicate that Noida performed better in terms of raw material accessibility, transportation connectivity, infrastructure facilities, labor availability, and overall operational feasibility compared to the other alternatives. Therefore, based on the combined SWARA-WASPAS analysis, Noida (L1) was selected as the most suitable and sustainable warehouse location for the present study.

CHAPTER 5.0

Conclusion , limitation and future research

The present study concludes that the choice of warehouse location has become one of the most important strategic decisions in modern Supply Chain and Logistics Management as it directly impacts operational efficiency, transportation cost, inventory movement, delivery performance, customer satisfaction and long-term business growth. The findings of the study reveal that traditional operational factors such as Raw Material Availability, Labor Accessibility, Transportation Connectivity, Infrastructure Availability and Land & Operational Cost still play a major role in warehouse location decisions within the Manufacturing Industry. These factors remain very important because they have a direct impact on operational continuity, distribution efficiency and overall logistics performance.

The research also highlights that sustainability-related factors are gradually becoming important in modern warehousing operations. With the growing emphasis on sustainable business practices and increasing environmental concerns, factors such as EV Charging Infrastructure, Solar Energy Potential, Waste-Management Systems, and Environmental Considerations are now being given more attention. This implies that organizations are looking beyond just cost reduction and operational efficiency and are also focusing on environmentally responsible and future-ready warehouse operations.

The last SWARA-WASPAS evaluation results selected Noida as the most suitable location for the warehouse among the selected alternatives in the NCR due to its better infrastructure support, transportation

connectivity, labor accessibility, raw material availability, and sustainability readiness. The results suggest that a proper mix of traditional operational factors and sustainability-related factors can help organizations to make more practical and effective warehouse location decisions.

Based on the findings of the study, several practical recommendations can be made for industry professionals and organizations. First, companies should not select warehouse locations based on transportation cost or land price alone. Alternatively, organizations should take a more balanced approach that considers operational efficiency as well as sustainability-related factors. Second, businesses should invest more in sustainable warehouse infrastructure, such as EV charging facilities, renewable energy systems, and effective waste-management practices to support long-term operational and environmental sustainability. Third, it is recommended that logistics and supply chain professionals adopt practical and easy to understand evaluation approaches that could facilitate faster and more realistic decision making in industry settings.

The study also recommends that organizations regularly review changing environmental regulations, technological advancements and future logistics requirements when planning warehouse expansion or relocation decisions. Moreover, government authorities and industrial development agencies can promote sustainable warehousing by improving transportation connectivity, industrial infrastructure, renewable energy availability, and environmental support systems in industrial regions.

In summary, the study concludes that the sustainable warehouse location selection needs to balance the traditional operational requirements and modern sustainability needs. The research results can help Logistics Professionals, Supply Chain Managers, warehouse planners and organizations to make better, practical, efficient and sustainable warehouse location decisions in the changing manufacturing and logistics environment.

Research Limitations The present study has certain limitations that should be considered while understanding the findings. The research was limited to three warehouse locations within the NCR region and focused mainly on selected operational and sustainability-related factors. The findings were based on expert opinions collected through questionnaire surveys, and therefore individual opinions and judgments may vary among respondents. In addition, the study used the SWARA-WASPAS methods for analysis, and the results may differ if other analytical techniques or additional criteria are considered in future research.

Future Research Scope The present study provides several opportunities for future research in sustainable warehouse location selection. Future researchers can expand the study by evaluating more warehouse locations across different regions and industries for broader analysis. Additional factors such as carbon emissions, green technologies, climate risk, and smart logistics systems can also be included for more detailed and practical evaluation. Future studies may further integrate advanced technologies such as GIS and Artificial Intelligence (AI) and compare different MCDM techniques to improve decision-making accuracy and practical applicability in real industrial environments.

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APPENDIX:

Appendix A: Survey Questionnaire

RESEARCH TITLE : Assessment of warehouse location selection in manufacturing industry Study location :

Delhi National Capital Region (NCR)

Alternatives : Noida , Ghaziabad , Gurugram Dear Respondent,

I am doing a research study on warehouse location selection in the manufacturing industry for my MBA dissertation. This questionnaire aims to identify the extent to which traditional logistics factors and modern sustainability-related criteria are important in the decision-making process for locating warehouses.

The study evaluates four alternative locations for a warehouse in the NCR region based on both traditional logistics factors and modern sustainability-related criteria.

Your expertise and experience are very valuable to this research.

The data collected by this questionnaire will be used purely for academic purpose and all responses will be treated with utmost confidentiality.

Thank you for your important participation and support.

Section 1: Respondent information:

1: Enter your name ? -----

2: Enter your gmail?-----3: Age group

- (a) 21-25 yrs
- (b) 25-30 yrs
- (c) 30-35 yrs
- (d) More than 35 yrs 4: Respondent profile ?

- (a) Senior supply chain manager

- (b) Operations manager
- (c) Logistics managers
- (d) Transportation manager
- (e) Procurement manager
- (f) Assistant logistics managers
- (g) Other_____

4: Your core _manufacturing industry ?

- (a) Automotive & fast-moving industry
- (b) Electronics
- (c) Fast moving consuming goods (FMCG)
- (d) Pharmaceutical industry
- (e) Other_____

5: Total industry experience in the supply chain /logistics operations ?

- (a) Less than 5 years
- (b) 5-10 years
- (c) 11-15 years
- (d) More than 15 years

Section 2 : Criteria-wise questions

(6) what priority you give the costs related to bring to raw materials to the warehouse and delivering products to customer ?

- 1 – Very Low Importance
- 2 – Low Importance
- 3 – Marginally Low Importance
- 4 – Moderate Importance
- 5 – Marginally High Importance
- 6 – High Importance
- 7 – Critical / Extremely High Importance

(7) Rate this location based on how effectively it can reduce product transportations and delivery costs customers and distribution networks ? (eg. NOIDA)

- 1- Very poor
- 2- poor
- 3- Below average
- 4- average
- 5- good
- 6- very good
- 7- Excellent

Google survey form link: <https://forms.gle/5Kqvv6UGN3Aam7q56>