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A FRAMEWORK FOR SUSTAINABLE SUPPLY CHAIN-ORIENTED INDUSTRIAL LOCATION DECISIONS

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ABSTRACT

The location of industrial sites is an important factor in defining the performance of the supply chain and long-term competitiveness. The cost and the infrastructure factors had traditionally influenced location decisions, and increasing environmental and social issues have broadened the focus to be on approaches related to sustainability. The conceptual framework presented in this paper incorporates the three aspects of economic efficiency, environmental responsibility, and social well-being in the process of selecting sites besides aligning the three with the drivers of the supply chain, which include cost, responsiveness, resilience, and green logistics. An examination of major research studies reveals how research of the past has utilized the application of multi-criteria decision-making techniques, geographic information systems, and hybrid models in the assessment of industrial locations. The suggested framework emphasizes the need to balance between efficiency and sustainability, offer managerial, policy and research perspectives. The future directions lay in the focus on quantitative validation, the incorporation of AI/ML, the utilization of digital twins, and the emergence of sustainable industrial networks. The research provides background to the further development of site selection as a strategic practice and sustainable one.

I. INTRODUCTION

One of the most serious decisions in manufacturing and logistics planning was always selected in the industrial location. The decision of location of a plant, a warehouse or a distribution hub is not a mere technical positioning; it is a strategic positioning that can determine the competitiveness of a firm in the long term. Predictive maintenance is now one of the most important aspects of Industry 4.0, and machine learning can facilitate sustainable manufacturing results [1]. The wrong location can escalate expenses, cause inefficiencies in the logistical processes, and even restrict access to markets, whereas a properly selected location can serve as a source of operational effectiveness and further expansion. Since the first industrial agglomerations of the 19 th century up till the contemporary global supply chains, site selection has continued to play a central role in industrialization. Sustainability issues have become an important part of facility location problems due to sophisticated modeling like Markov chains [2], [3].

The significance of site selection has a close relation with the design of the supply chain. A supply chain simply refers to a network of processes and systems that integrate raw materials to the final consumers. When one of the facilities is in the wrong location, the whole network can be affected by the increased transportation costs, delays, or even bad responsiveness. Conversely, a strategically based location will minimize distance to suppliers and market, enhance the level of service and decrease the total costs. This is why the problems of the supply chain design and facility location are frequently examined jointly in the framework of management science, operations research, and logistics planning. As Snyder and Daskin, as well as other scholars, have always pointed out, location decisions are very sensitive to the supply chain performance [3]. The location of the industrial sites is not only an issue to do with property, but it is one of the main aspects of supply chain competitiveness. Much of the existing literature highlights the close connection between the facility location and sustainability issues in international manufacturing [4]. The theme of facility location has been the focus of supply chain design where its direct impact has been the efficiency and cost of logistics [5]. Sustainability is one more important dimension that has become a crucial factor in location decisions in the last 20 years. Conventionally, firms used to assess locations using cost, infrastructure, and access to labor or places. However, this time, the environmental and social factors are important. Governments, consumers and international agencies are demanding industries to reduce their carbon footprint, adhere to social responsibility and to participate in regional development. The location of the site can enhance the sustainability profile of a firm by selecting a site that is near to renewable energy sources, where the local communities are supportive, or where the land use can promote practices of the circular economy. Conversely, choosing places without factoring in the environmental sensitivity can lead to pollution, land degradation, and social resistance.

Therefore, the location of industrial sites cannot be discussed outside of the context of sustainability. In particular, environmental sustainability has decisive role. There are manufacturing facilities that use huge portions of land, water and energy. In case there is a site in the areas that are more vulnerable to ecological destruction, chances of environmental destruction are eminent. The selection of the site should therefore incorporate the assessment of environmental impact, waste management possibilities, and the accessibility of renewable energy sources. Social sustainability is also urgent. Industrial plants increase job opportunities, yet, they may also lead to displacement, health risks, or even conflict with the local communities when they are not managed in a proper way. The perspectives of supply chain sustainability have been included more in the process of manufacturing facility location decisions [6]. Therefore, such problems as the skills of the local labor market, quality of life, community involvement are becoming mandatory to consider in the course of the site selection process. This broadened pivotal point has transformed site selection into a multi level problem. Supply chains have not been left behind in the global transformation towards sustainability. Not only cost efficiency is considered, but companies are also evaluated with respect to their capacity to develop green and socially responsible supply chains.

This change means that the site selection should not be restricted to operational aspects such as transportation or labor cost but that it should be adjusted to a larger agenda of creating resilient, green, and inclusive supply chain. To illustrate, logistics networks are considering carbon emission of the transportation process, which implies a closer location from key consumption centers or intermodal hubs to facilitate a greener freight flow. Equally, social-related issues, like the level of regional development, gender-sensitive labor market, and safe workplace conditions, indirectly influence the site location decisions. The intersection between site selection, supply chain design, and sustainability poses an interesting and complex research topic. The enduring and sustainable supply chains under disruption require strong facility location decisions [7]. In the light of these dynamics, the current paper will attempt to examine the nexus of industrial site selection, supply chain management, and sustainability in a systematic way. Although past researches have focused on these areas individually, this paper attempts to bring them together and point out how location decisions may concurrently affect the results of supply chain performance and sustainability. The objectives are fourfold:

- To investigate the strategic significance of the site of the industrial location in the supply chain design.
- To investigate how the dimensions of sustainability, both environmental and social, affect current site decisions.
- To combine the existing literature and the methods used in this interdisciplinary area.
- To develop a conceptual framework of combining sustainability and supply chain performance in the location analysis.

Through these achievements, through the paper, one can contribute to the discussion that is going on as to how industries can be competitive and sustainability expectations met. It offers theoretical knowledge based on literature and the practical implications on decision makers particularly in the emerging economies where the development of industries has to strike a balance between economic growth and the environment as well as social responsibility. The analysis of the current techniques is also applied to the clarification of the decision support methods that are best applicable to address the multi-criteria of the problem. Lastly, the conceptual framework in the latter sections provides the future research and application. The figure 1 shows the integrated approaching considering the sustainability.

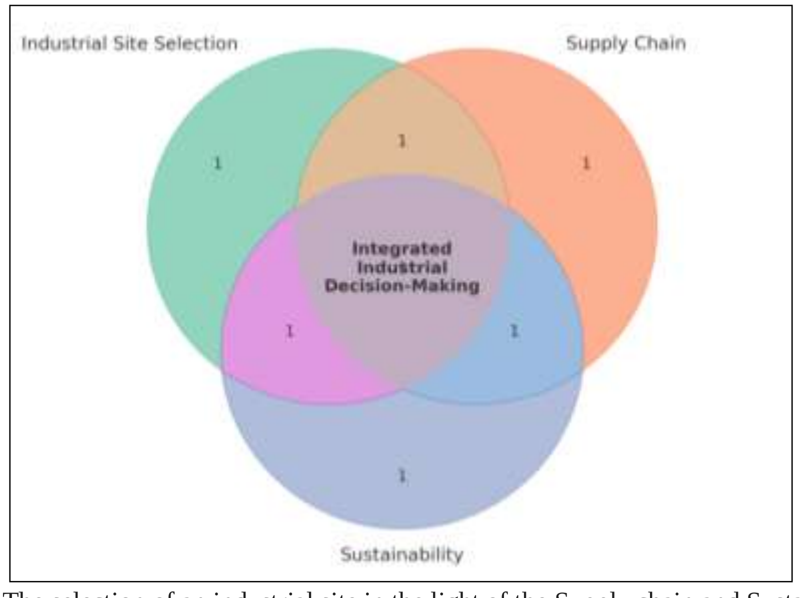

Figure 1: The selection of an industrial site in the light of the Supply chain and Sustainability.
Source: Authors, (2025).

The location of industrial sites is not simply about land and prices, but a multi-tiered decision experiencing the interface between effectiveness in the supply chain and sustainability obligation. With the shift of the industries to a more green and socially responsible functioning, the combination of these views is inevitable. This is the new challenge that this paper deals with and preconditions the creation of more comprehensive, multi-criteria approaches to the planning of the location of industry.

II. LITERATURE REVIEW

The topic of choice of industrial sites has decades of research following the urgent importance of the location to the industrial competitiveness, supply chain performance, and the development of the economy as a whole. Conventionally, researchers focused on economic and infrastructural aspects, but recent literature has broadened the perspective to include sustainability and resilience. The paper has followed the evolution of the site selection studies of classical cost-based methods to the present models that consider supply chain strategies, sustainability, and multi-criteria decision-making models In the past, the cost, availability of infrastructure, and logistical efficiency dominated the selection of the industrial sites. The decisions were mostly made with the aim of reducing the cost of transportation, the availability of good utilities, and the need to find areas with good labor market. Located at the beginning of the 20th century, the early location theories saw transportation and the cost of labor as the determinants of location. Subsequent literature continued with these premises, cementing the notion that location to raw material sources, energy sources and major transport routes was central to industrial development. Development of infrastructure such as road, rail, and port connectivity was also mentioned several times as a factor in the clustering of industries because it facilitated the easier movement of raw materials and completed products.

These conventional criteria were in a way rather limited in their scope but gave the first basis on which the future site selection frameworks were built Since the late 20th century, when supply chain management appeared as a separate field, the focus of research on the industrial site selection has changed to the network design and the value chain integration. Location is not viewed as a separate concept but as a point of a larger network of supply chains. Decisions of facility location were mixed with problems of proximity to suppliers, the level of distribution efficiency and the level of customer service. To illustrate, researchers wrote on the topic of reliable supply chain network design, as the balance of efficiency and strength in the context of disruption [3]. On the same note, Other researcher investigated competitive facility location in decentralized supply chains wherein the location influences competitive advantage in fragmented markets. These papers highlighted that location decisions do not just influence the cost of operations but also responsiveness, reliability and exposure to risk throughout the supply chain The literature has also been redefined with the integration of sustainability principles. The evaluation of industrial locations is now based on environmental, economic, and social aspects, also known as the triple bottom line.

Environmental issues relate to emissions, land degradation, and ecological effects of the activity of industry. Briassoulis was among the pioneers who tried to bring out environmental criteria in the Industrial siting, paving way to other studies, which incorporated ecological sensitivity in decision making [8]. More recently, Anvari and Turkay explored the concept of facility location through the prism of the triple bottom line, as they found that to come up with a sustainable location decision, trade-offs must be made between profitability [9]. One of the examples is the renewable energy that is available to be used, the compatibility of land use, and the social acceptance as the parameters of site selection. This change is representative of the larger trend in terms of sustainable supply chain management where financial metrics can no longer be used to gauge the performance of a network, and instead its performance can be assessed based on its ability to provide benefits to the environment and the community at large. Table 1 gives an overview of the difference between the conventional site selection requirements and the contemporary sustainability-based strategies, depicting the scope of research interest over the years.

Table 1: Conventional and Sustainability-Based Site Selection Criterion.

Criteria Category	Traditional Site Selection Criteria	Sustainability-Oriented Criteria
Cost Factors	Land cost, construction cost, transportation cost, labor cost	Life-cycle costs, energy efficiency, long-term environmental compliance costs
Infrastructure	Availability of utilities (water, electricity, gas), transportation networks (road, rail, port, airport)	Renewable energy infrastructure, smart grid access, eco-friendly transportation options
Logistics	Proximity to suppliers, markets, and distribution hubs	Reduced carbon footprint in transportation, multimodal green logistics systems
Labor & Workforce	Availability of skilled labor, wage rates	Fair labor practices, occupational health and safety, community employment benefits
Environmental	Rarely considered (land suitability, basic regulations)	Emissions, waste management, biodiversity impact, land-use compatibility
Social	Limited to labor availability	Community acceptance, social equity, cultural heritage preservation, urban-rural balance
Strategic/Resilience	Focus on minimizing operational costs and ensuring accessibility	Risk management, disaster resilience, adaptability to climate change, long-term sustainability

Source: Authors, (2025).

The use of sustainability frameworks has also promoted the use of sophisticated decision support tools. The analytic hierarchical process (AHP), Analytic Network Process (ANP), Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) and entropy weighting are the most commonly used methods of multi-criteria decision-making that have been used to assess complex trade-offs among economic, environmental and social criteria. As an example, Yang and Lee hypothesized an AHP-based decision making model of facilities location choice [10], whereas Reisi used both AHP and ANP in industrial site location choice in Isfahan [11], where they indicated having the ability of interdependence of factors. Recent works have merged both GIS-based spatial analysis and MCDM, which enables more accurate and geographically sensitive analyses to be conducted [12], [13]. These mixed approaches combine the quantitative standards with spatial prescriptions that give decision-makers powerful tools to assess various possible locations. Many other multi-criteria techniques have been utilized in the context of renewable energy, including the selection of sites of solar power plants as well using AHP [14] The diversity of the methods used in multiple decades of research is evidence of the multidisciplinary character of the issue. Research has been inspired by disciplines such as operations research, environmental science, geography, and urban planning. As an example, in a review of literature on manufacturing facility location and sustainability, Chen provided a research agenda that highlighted the incorporation of green supply chain practices [4]. Ahmadi and Ghezavati created a competitive facility location model with sustainability [2] by Markov chains, and Rekik analyzed the spatial analysis of the choice of wind sites according to the supply chain sustainability point of view [15]. Together, these articles demonstrate how the models that used to be based on the costs have transformed into dynamic frameworks that consider the balance between the resilience, sustainability, and efficiency. The table 2 shows the overview of the major research and their findings.

Table 2: Overview of Major Research in the Field of Site Selection, SCM and Sustainability.

Author(s), Year	Objective / Focus	Methodology	Key Findings	Contribution
Rikalovic (2014)[12]	To evaluate industrial site alternatives with a spatial focus	GIS combined with multi-criteria decision-making	GIS integration improves visualization and decision accuracy in industrial siting	Introduced the role of GIS as a decision support tool for site selection
Rikalovic (2015)[16]	To propose a macro-level industrial site selection framework	GIS-based macro-location analysis	Provided a structured model for early screening of industrial zones	Expanded GIS applications into comprehensive macro-location analysis
Reisi (2018) [11]	Industrial site selection in Isfahan, Iran	AHP and ANP	Showed that hierarchical weighting improves reliability of location decisions	Demonstrated the effectiveness of AHP–ANP hybrid in real industrial contexts
Yang (1997) [10]	Facility location evaluation	Analytic Hierarchy Process (AHP)	Provided structured criteria ranking for facility sites	One of the earliest AHP applications in facility siting
Sundarakani (2021) [7]	Facility location under disruptions for sustainable supply chains	Robust optimization framework	Showed that resilient locations minimize supply chain risks	Linked location decisions with resilience and long-term sustainability
Abidi (2022)[1]	Industry 4.0 and predictive maintenance planning	Machine learning for sustainable manufacturing	Highlighted role of AI in reducing downtime and resource waste	Connected predictive analytics with sustainable site operations
Khanlari (2022)[17]	Review of power plant site selection studies	Literature review of MCDM methods	MCDM methods widely applied but context-specific	Synthesized decision-making methods in energy siting
Ahadi (2023)[14]	Site selection for solar power plants in Iran	AHP	Ranked renewable energy sites considering environmental criteria	Showed potential of AHP for clean energy infrastructure planning
Genc (2021)[13]	Offshore wind farm site selection in Turkey	GIS combined with MCDM	Demonstrated suitability mapping for offshore wind energy	Provided model for integrating renewable energy with spatial planning
Chang (2015)[18]	Plant location in logistics networks	AHP	Showed logistics-related factors as critical in siting	Strengthened SCM perspective in facility location
Huang (2020)[6]	Location selection from sustainability viewpoint	Hybrid MCDM	Found environmental and social aspects increasingly decisive	Integrated sustainability with SCM in site selection
Snyder (2007)[3]	Reliable supply chain design models	Mathematical optimization	Reliability considerations enhance facility network performance	Introduced reliability as a core factor in SCM facility planning
Daskin (2005)[5]	Facility location in supply chain design	Review and mathematical modeling	Location strongly influences supply chain costs and service	Provided foundational perspective on SCM–facility link
Ho (2008)[19]	Facility location in customer-driven supply chains	Optimization model	Customer demand directly impacts facility siting	Highlighted demand orientation in SCM site selection
Peker (2016)[20]	Logistics center site selection in Turkey	ANP with BOCR analysis	Case study validated ANP as robust tool for logistics siting	Offered empirical insights into logistics hubs
Li (2011)[21]	Logistics center location	Fuzzy set with TOPSIS	Managed uncertainty in site selection effectively	Advanced fuzzy MCDM in logistics planning
Li (2013)[22]	Reliable facility location under disruptions	Robust optimization	Reliability metrics improve siting in uncertain conditions	Linked disruption management with facility planning
Chen (2014)[4]	Review of manufacturing facility location & sustainability	Literature review	Sustainability rarely integrated into location models	Set a research agenda on sustainable site selection
Anvari (2017) [9]	Facility location through triple bottom line (TBL)	Optimization using TBL approach	Balanced economic, social, and environmental objectives	First to directly apply TBL to facility siting
Ahmadi (2020)[2]	Competitive facility location with sustainability	Markov chains and optimization	Modeled dynamic facility competition with sustainability criteria	Introduced time-dependent sustainability modeling
Rekik (2025)[15]	Sustainable wind site selection with SCM view	Spatial analysis + MCDM	Showed how SCM perspective improves renewable site selection	Linked renewable energy and sustainable SCM
Liu (2017)[23]	PV power plant siting in value chain	Grey cumulative prospect theory	Considered sustainability within energy value chain	Incorporated behavioral decision theory in siting
Puente (2007)[24]	Sustainable industrial area location	GIS with fuzzy logic	Enabled flexible evaluation of industrial zones	Early GIS–fuzzy integration for sustainability
Briassoulis (1995)[8]	Environmental criteria in facility siting	Conceptual analysis	Exposed neglect of environmental impacts in siting	Pioneering work in sustainability-oriented siting
Gundogdu (2011)[25]	Site selection with environmental priority	ELECTRE method	Highlighted importance of weighting environmental criteria	Applied ELECTRE in environmental facility planning
Kaya (2020) [26]	EV charging station siting in Istanbul	GIS + MCDM	Emphasized sustainable transport infrastructure	Brought mobility–sustainability into site selection
Arshad (2023)[27]	Sustainable landfill site selection	GIS + AHP-GDM	Community participation enhances outcomes	Applied participatory decision-making in siting
Ertuğrul (2008)[28]	Comparison of fuzzy site selection methods	Fuzzy AHP vs. Fuzzy TOPSIS	Both methods effective, with nuanced differences	Advanced methodological comparison
Sharma (2024)[29]	Manufacturing site selection	Hybrid of AHP, BWM, and factor rating	Multi-method approach improves robustness of results	Demonstrated hybrid decision-making framework

Source: Authors, (2025).

In spite of these developments, there are still great gaps in research. Among the most notable ones, the absence of integration within the three essential areas can be distinguished, namely, the site selection, the supply chain design, and the sustainability. A great part of the available literature deals with these dimensions separately. As an example, customary facility location studies are cost- and logistics-oriented and disregard environmental and social impacts. In contrast, sustainability-oriented research tends to focus on ecological or community effects, but minimises the consideration of supply chain performance. Furthermore, although MCDM techniques have received extensive use, most of them are industry- and location-specific, which restricts their applicability to different industries and geographic areas. Decision-support frameworks are also required that are able to build in uncertainty, resilience, and sustainability of global supply chains that are becoming more vulnerable to disruption (pandemics, geopolitical tensions, and climate change). Social dimension of sustainability is another under researched field.

Whereas the environmental and economic factors are growing in importance, lesser focus is given to other social issues like the well-being of the community, the acceptance of cultural diversity, and fair development. Research such as Anvari and Turkay emphasized the future opportunities of triple bottom line frameworks, but there is limited application [9]. Also, the introduction of new technologies, including artificial intelligence, digital twins, and Industry 4.0, into site selection and the supply chain design is still in its early stage. These tools have potential to facilitate real time, data-driven, and adaptive location decisions that consider sustainability issues. The literature has demonstrated a definite trend: costs-based models to supply chain- conscious approaches, and ultimately to schemes that incorporate sustainability. Nevertheless, there is still a problem of harmonizing these points of view into a consistent decision-making model. Filling this gap presents a possibility of coming up with comprehensive solutions that can guide the industries in ensuring that they not only choose sites that are economically viable, but also resilient, environmentally conscious, and beneficial to the society. This is the basis of the current study that aims at helping to fill the gap in terms of linking sustainability, supply chain management and the selection of an industrial site.

III. CONCEPTUAL FRAMEWORK

Write The literature review shows that the site selection of industries cannot be approached to be only a logistical or cost-minization issue but needs to be viewed as a component of a bigger system where supply chain efficiency, sustainability goals, and long-term resilience play with each other. Practically, these three areas overlap: site selection predetermines the extent to which a facility can become a part of a supply chain network, what effect it will have on the ecological and social environment and what will help a facility to remain competitive in a turbulent global economy. To overcome these interdependencies, a conceptual model is suggested to help decision-makers to analyze industrial locations in a structured, sustainability-based, and supply chain-centric perspective. Fundamentally, the framework has a focus on the incorporation of supply chain management effectiveness and the aspects of sustainability. The concept of supply chain efficiency is akin to cost-effectiveness, reliability, quickness of activities, and risk resilience linked to natural catastrophes, political instability, or market shocks. The following attributes are critical since a facility that is positioned in an inappropriate location can lead to bottle necks, increase logistics expenses and minimize responsiveness. Meanwhile, sustainability requires that industrial development should be consistent with environmental conservation, social responsibility and economic sustainability. The synthesis of these views makes the site selection an operation and social decision. The model is anchored on three pillars of sustainability namely- economic, environmental, and social, which constitute the basis of evaluation.

Economic criteria are also necessary, which include the cost of land, availability of labor, the utility and the economic benefits of the region over a long period. In contrast to the traditional methodology where the main focus was on short-term financial expenses, the economic aspect in this case spans to long-term sustainability such as life-cycle costs and risk-adjusted returns. Environmental dimension takes into consideration the emissions, land use, biodiversity, and resource efficiency. It signifies rising awareness of industrial processes in terms of climate change and ecological losses and it is necessary to consider the way in which a facility is in contact with the physical environment. Social sustainability focuses on acceptance by the community, fair employment, cultural maintenance, and quality life of the neighbors. This pillar has been quite neglected but is central to making sure that the growth of industries does not present social dissatisfaction or inequalities to the masses, instead it enhances the growth of the entire society. The close interaction of these three dimensions of sustainability with supply chain drivers which are mediating variables between site selection and operational outcomes takes place. Price is still a significant force, affecting the cost of logistics and the overall competitiveness of the supply chain. Proximity to suppliers, the market, and the transport infrastructure have a significant impact on speed, which is defined as the responsiveness of a supply chain. Resilience is one of the key drivers that become important particularly due to the most recent shocks in the world like pandemics, trade wars and natural calamities of climate-related disasters. Facilities situated in resilient regions, i.e. those which have diversified transport modes, predictable governance and adaptable infrastructure, are more likely to be shock resistant.

Lastly, green logistics connects sustainability to the performance of the supply chain and focuses on practices such as carbon reduction, multimodal transport, and use of renewable energy in the distribution system. This structure revolves around a systematic decision making process. Since the process of industrial site selection is a multidimensional and complicated process, there is no single criterion that would define the outcome. Rather, a multi-criteria evaluation strategy is promoted, which is a combination of quantitative and qualitative measures.Spatial decision support systems Multi-criteria systems improve sustainable planning of industrial areas as seen in Spain[30]. Such multi-method alternatives as factor rating, AHP, and BWM enhance the strategies of manufacturing sites selection [29]. The methodological basis is given by Multi-Criteria Decision-Making (MCDM) tools like AHP, TOPSIS, ANP and entropy weighting. These approaches enable decision-makers to place comparative emphasis on economic, environmental, and social aspects, to compare possible locations in a systematic manner, and to find the best trade-offs. As an example, AHP could be applied to subdivide the decision into levels, TOPSIS could be applied to rank alternatives to an ideal solution and entropy methods could be applied to give objective weighting in case subjectivity is an issue. The use of GIS-based spatial analysis also helps to reinforce the framework and enable such areas as the geographic and environmental data to be integrated into the process of evaluation, which means that the site selection could be not only theoretically sound but also relevant in the geographic sense.

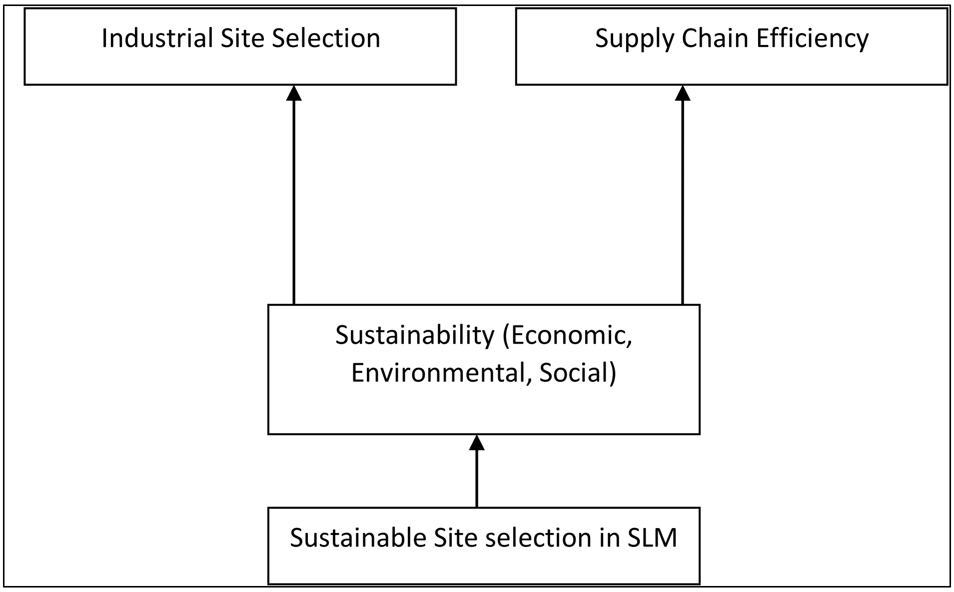

Figure 2: Sustainable Site Selection Conceptual Framework Proposal in SCM.
Source: Authors, (2025).

Figure 2 shows the proposed framework that illustrates the connection between sustainability dimensions, drivers in the supply chain and the decision making process. It puts site selection in the centre, and sustainability requirements on one side and the need drivers on the supply chain on the other connected by a loop of decisions. Table 3 provides some of the most important indicators of economic, environmental, and social aspects of sustainability in site selection.

Table 3: Site selection sustainability key indicators.

Dimension	Indicators	Description / Rationale
Economic	Land cost, construction cost, utility costs	Determines financial feasibility and investment requirements
	Proximity to suppliers and customers	Reduces logistics costs and improves responsiveness
	Availability of skilled labor	Enhances productivity and operational quality
	Life-cycle cost assessment	Considers long-term operational and maintenance costs
Environmental	Emissions and pollution potential	Measures ecological impact of operations
	Renewable energy availability	Supports transition to low-carbon industrial activity
	Land use and biodiversity impact	Ensures compatibility with environmental conservation
	Waste management infrastructure	Facilitates sustainable operations and circular practices
Social	Community acceptance	Evaluates local support and reduces conflict risk
	Employment opportunities	Assesses contribution to local socio-economic development
	Occupational health and safety	Ensures well-being of workers and compliance with standards
	Equity and cultural preservation	Protects cultural heritage and fosters inclusive growth

Source: Authors, (2025).

The theoretical framework makes a number of contributions to the discipline. To begin with, it serves as an intermediary between sustainability research and site selection studies that are supply chain-driven by developing a single model. Second, it puts operational criteria that define sustainability based on quantifiable indicators and this guarantees evidence-based, but not rhetorical, decision-making. Third, it points to the importance of having resilience and adaptability that are becoming critical in an age of global uncertainty. Through this, it takes the discourse towards an integrated analysis of the various fragmented analyses to an integrated model that can guide industrial planners, policymakers and supply chain managers. The suggested framework identifies the location of industrial sites as a multi-dimensional issue, in which the efficiency, sustainability, and resilience need to be matched. It also acknowledges that industrial facilities are economic drivers and social-environmental players and hence their location should not be based on only short-term operational interests but also long-term sustainability goals. The combination of this allows building the next level of research and practical work on sustainable supply chain management and industrial planning.

IV. RESULTS AND DISCUSSIONS

The designed conceptual framework can provide a cross-cutting view at the industrial site selection, which interconnects the supply chain efficiency and sustainability demands. This integration is not just theoretical but has serious implications on businesses, policy-makers and urban planners who are confronted with complicated trade-offs in determining new industrial locations. The significance of the discussion here will be the managerial, policy, practical application by firms that have limited data, and the issues that are likely to emerge in the real world application

IV.1 MANAGERIAL IMPLICATIONS OF THE FRAMEWORK

To business leaders and operations managers, the framework offers a roadmap that is structured in a way that can help in making investment decisions when new industrial facilities are to be established. The conventional site selection process tended to focus on the cost of operations, availability of suppliers and transportation systems. Although these are still very vital factors, in the present day, managers also have to consider energy efficiency, the availability of renewable resources, waste management mechanisms and social well being of the employees and the communities around them.

With the proposed framework, the managers will be able to match strategic supply chain objectives with long-term sustainability results. Indicatively, a company can find an area near the important suppliers to lower the cost of logistics but should also consider whether that place will be compliant with the environmental standards and access to clean energy. This is likely to lead businesses to stop focusing on cost decisions in the short term and to take a lifecycle approach to their location choices in which the location chosen will add value to both the supply chain performance and corporate social responsibility goals. Moreover, the fact that the framework is multi-criteria allows decision-makers to set priorities on conflicting issues. As an example, a site can be of low cost but low on environmental sustainability. Rather than engaging in entirely financial trade-offs, managers may implement weighted evaluation criteria to locate balance solutions, which meet organizational targets and stakeholder anticipations

IV.2 POLICY APPLICABILITY: GOVERNMENT, URBAN PLANNERS AND REGULATORS

The governments and city planners have important role in the environment of site selection decisions. The framework explains the necessity of formulating unified industrial policies by the policymakers that will at once boost economic development, minimize environmental degradation, and secure the livelihoods of the community. The framework can help urban planners steer zoning requirements and investment of infrastructure. As an example, giving access to renewable energy in industrial clusters, waste recycling facilities, and effective transport networks will make sure that further development of the site can correspond to the sustainability objectives. Equally, the regulators are able to set clear guidelines regarding carbon emissions, water usage, and welfare of labor, and makes sure that the industries that are situated in a specific area make a contribution towards the sustainable development goals. Furthermore, the framework emphasizes the significance of the collaboration between the public and the private. The governments can encourage businesses to select sustainable locations by offering tax breaks, subsidies on green infrastructure, and workforce development assistance. This is because, through this collaborative strategy, the perceived trade off between cost and sustainability is minimized and companies can then find it effortless to embrace responsible site selection.

IV.3 IMPLEMENTATION BY NON-LARGE DATA BUSINESSES

One of the challenges commonly facing companies especially small and medium enterprises (SMEs) is the inability to access full datasets to assess site selection. Megabusinesses can afford to carry out geographic information system (GIS), carbon footprint, and multi-criteria decision-making analyses. Nevertheless, simple heuristics like proximity and cost can be used by SMEs. Nevertheless, it is possible to incorporate the proposed framework in such cases by relying on the qualitative evaluations and simplified scoring tools. For example:

- Based on observable variables (availability of renewable energy, distance to markets, social acceptance), firms are able to rank the prospective locations.
- Proprietary datasets may be replaced by publicly available data provided by government agencies and other international organizations.
- Missing quantitative data can be supplemented by expert judgment and stakeholder consultations, which will make decisions more balanced.

This enables the scalability of the framework: large businesses can apply it to advanced analytics, whereas small businesses can apply it in simpler versions without compromising the original sustainability focus.

IV.4 PROBLEMS WITH REAL-WORLD IMPLEMENTATION

In Regardless of its advantageous aspects, the framework has a number of practical obstacles:

1. Data Availability and Accuracy- Consistent environmental and social information is usually hard to get on regional scales. This could curtail proper sustainability assessment.
2. Stakeholder Conflicting Interests - Businesses, communities, and governments might have conflicting criteria, which results in negotiation challenges.
3. Dynamic Global Supply Chains - Supply Chain networks are changing fast and long-term site decisions become exposed to disruptions posed by geopolitical tensions, pandemics, or scarcities of resources.
4. Cost of Implementation - The firms might also find the sustainable site development costlier because of initial costs on green infrastructure although the benefits are huge in the long run.
5. Uncertainty around Regulation - In certain areas, industrial policies and environmental regulations are altered on a regular basis, posing a problem to long-term planning.

To overcome such challenges, it is necessary to make decisions repeatedly and monitor them. The framework is to be viewed not as a single exercise but a dynamic process which should be growing along with market conditions, with the development of technologies and the changes of policies. The figure 3 shows the flow chart considering the MCDM approach for the site location selection

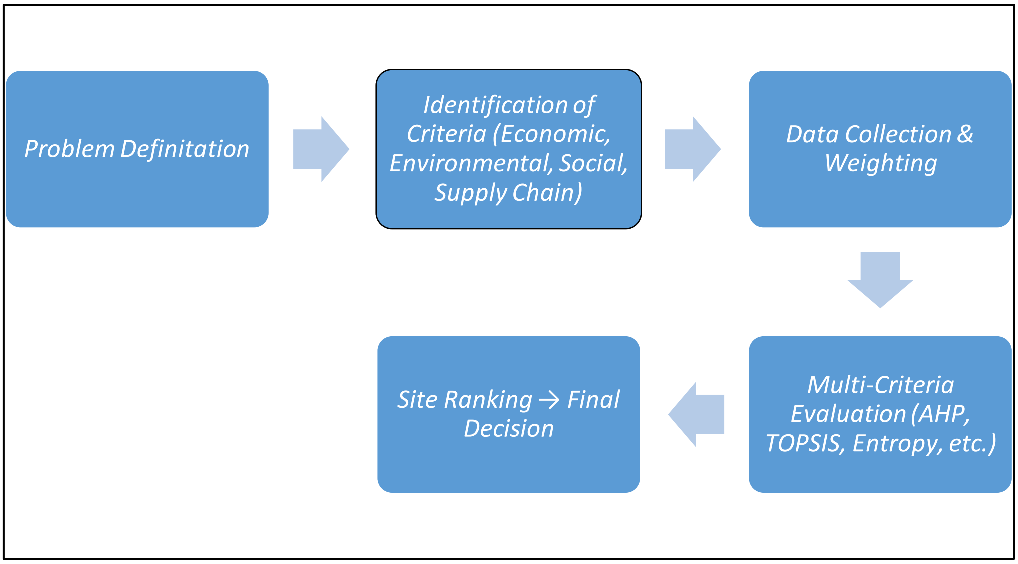

Figure 3: MCDM Process Flowchart of Site selection
Source: Authors, (2025).

The discussion points out that incorporating supply chain efficiency and sustainability in site selection has ceased being a choice but rather a necessity of long-term competitiveness. The framework provided fills the gap between managerial requirements and policy requirements and sustainability objectives and provides an effective channel through which decisions can be made even in cases where detailed datasets are not available. There are still challenges but through the concerted efforts and innovative strategies, companies and policy makers can together define industrial environments that promote economic, environmental and social sustainability.

V. CASE-BASED INSIGHT

Be The recent development of sustainability in the field of supply chain management has created an array of research which integrates site selection, environmental, social, and economic goals. The previously conducted studies demonstrate the way various tools, including multi-criteria decision-making (MCDM), spatial analysis using GIS, optimization models, and hybrid methods, have been implemented in various industries. These insights, based on the case reviews, can be used to identify which methodological improvements and gaps remain unresolved in sustainable site selection practices. Table 4 presents a comparative view of some of the selected studies that have largely found their way in the literature and can offer viable teachings on sustainable supply chain design.

Table 4: Comparison of Published Frameworks/Models in Literature.

Author(s), Year	Context / Industry	Methodology	Key Criteria Considered	Main Findings	Limitations / Notes
Kuru (2025)[31]	Furniture industry, Turkey	GIS + MCDM (Weighted Linear Combination)	37 criteria (natural, socio-economic, built environment)	Identified optimal sub-regions minimizing cost and ecological harm	Case-specific, may not generalize beyond İnegöl
Ruiz (2012)[31]	Industrial areas, Northern Spain	GIS-based Spatial Decision Support System (SDSS)	Sustainability-focused location factors	SDSS produced digital maps for suitable zones, integrated lifecycle approach	Limited to regional context, data-intensive
Emeksiz (2022)[32]	Bioenergy facility, Turkey	Hybrid MCDM (Entropy + MAUT)	Biomass resources, energy potential, regulations	Identified optimal bioenergy sites, demonstrated Turkey's large biodiesel/bioethanol potential	Focused only on energy sector
Thanh(2008)[33]	Complex supply chains	MILP model (dynamic facility location)	Cost, supplier selection, facility expansion	Enabled dynamic planning of facility expansion under demand growth	Ignores environmental/social sustainability
Rikalovic (2014)[12]	Industrial site selection, Serbia (Vojvodina)	GIS + MCDM	Spatial/geographic, economic, logistics	Successful GIS-based spatial decision support tool for industrial site selection	Regional application, may not scale globally
Wang (2024)[34]	Green logistics	Low-carbon optimization + GA + PSO	Carbon emissions, transport efficiency, cost	Reduced emissions and logistics cost; robust under demand/geography variations	Requires high-quality logistics data

Source: Authors, (2025).

V.1 GIS AND SPATIALLY DRIVEN APPROACHES INSIGHTS

In The use of GIS-based decision support systems is one of the most powerful themes in the literature. Ruiz used spatial decision models which enabled policy makers and managers to map out trade-offs at several places [30]. GIS can be used to select a site taking it a step ahead of the calculation of costs and including environmental risk, the ease of transport, and socio-economic conditions within a region.

As an example, Ruiz designed a system of industrial zones in Northern Spain creating digital suitability maps combining factors with sustainability interest [30]. This strategy increased the transparency of the decision making process since managers were able to visualize the effects of siting decisions. Equally, Rikalovic found the usefulness of spatial decision support in industrial development in Serbia [12]. Their research proved the visualization of location suitability as a way of increasing the communication line between planners and stakeholders and it is easy to justify the final decisions. The greatest weakness of GIS-based models is regional dependence. Such systems are very dependent on locally available datasets, which are not necessarily easy to transfer to other settings without significant customization. However, GIS has been one of the pillars of sustainable site selection whenever the project involves regional planning.

V.2 MULTI-CRITERIA DECISION-MAKING OF INDUSTRIAL AND ENERGY PROJECTS

The second research stream is dedicated to MCDM methods, whereby the sustainability indicators are prioritized and weighted to determine the optimal location. The Turkish furniture industry study by Kuru is remarkable in its scope, with 37 various criteria in the natural, socio-economic, and built environment dimensions [31]. This outlines one of the main managerial lessons, which is that sustainable site selection can demand much more variables to be factored in than the conventional cost-based methods. Emeksiz present another powerful example because they used entropy weighting and MAUT (Multi-Attribute Utility Theory) to choose places where bioenergy factories could be located [32]. Their framework was adapted to renewable energy supply chains unlike traditional models of industrial location that ignored energy potential, biomass resources, and regulatory conditions. Their results highlight the ability of sustainability-focused site selection to be consistent with national energy transformation objectives. Such cases demonstrate that MCDM methods can be applied in various industries and are flexible. But they also need to have expert input and good weighting of criteria which are subjective. Entropy techniques (objective weighting) alleviate the subjectivity problem but in the majority of studies, expert opinion is used in conjunction with quantitative data, which creates room to inconsistency.

V.3 DYNAMIC SUPPLIES CHAIN OPTIMIZATION MODELS

Though the GIS and MCDM methodology dominate the literature of site selection, optimization-based models present an alternative approach. The article by Thanh applied mixed-integer linear programming (MILP) model to investigate dynamic facility location in sophisticated supply chains [33]. The focus of their research was on minimization of costs, selection of suppliers and growth plans with time. Even though the model produced a good performance on the logistics efficiency, it did not considered much on the environmental and social sustainability dimensions. This is indicative of a larger problem in optimization literature: much of the work is still oriented to the economic goals, and the concept of sustainability is often addressed as a constraint to achieve, but not as an end by itself. However, optimization models show how facility expansion, market volatility and demand growth can be incorporated into site selection.

V.4 LOW-CARBON AND GREEN LOGISTICS SOLUTIONS

More contemporary research builds on classic models, entrenching low-carbon ambitions. As an example, Wang integrated low-carbon logistics planning with evolutionary algorithms (genetic algorithm and particle swarm optimization) [34]. It demonstrated the potential to determine the impact of site selection on the outcome of supply chain sustainability, as the model balanced the efficiency of transport, emissions of carbon, and cost. The practical implication of the study by Wang is that logistics models that are carbon conscious need quality data about transportation flows and emission factors. Such detailed data might not be available yet to many companies, especially the small and medium ones (SMEs).

V.5 COMPARATIVE REFLECTIONS

Comparing these studies, some themes appear:

1. Integration Depth - There are those models which integrate a broad range of sustainability criteria and those which put a great deal of emphasis on cost [31,33]. This demonstrates a spectrum between efficiency-based and totally sustainability-based site selection.
2. Methodological Diversity - GIS-based research is the best in visualization and regional planning, whereas MCDM procedures are more appropriate to criteria prioritization and structured decision-making. Optimization models are highly mathematical rigorous, but they tend to be poor in terms of integration of sustainability.
3. Data Requirements- The intensity of data is very different. GIS and low-carbon logistics models require spatial and emissions data and this is not always available everywhere. On the other hand, MCDM can be applied using a combination of expert knowledge and limited data, which means that it is more flexible in situations where there is a lack of data.
4. Scalability-Most studies that were reviewed were region or industry specific which questions scalability. The framework that is successful in bioenergy in Turkey might not necessarily be applicable to logistics hubs in East Asia.

V.6 EMERGING GAPS AND LESSONS

A critical analysis of the cases indicates that there are a number of gaps:

- Triple Bottom Line Integration - Few studies are able to incorporate economic, environmental, and social aspects at the same time. The majority of the frameworks focus either on cost or environmental impact, and social sustainability is not well represented.
- Rigid and Flexible Systems: Although optimization models are dynamic supply chains, most sustainability-oriented frameworks are among the stand-still ones that do not address disruptions like climate risks, pandemics, or geopolitical shocks.

• SME Adoption - A number of the models reviewed are data-intensive and highly complex, which is not conducive to smaller businesses that do not have analytical resources. Extended broader usage requires simplified frameworks or what are known as decision-support tools.

The literature indicates that sustainable site selection in supply chain management is changing and disjointed. The various industries and regions are focused on various aspects, and currently, there is no single way which offers the global solution. Nevertheless, the overall evidence demonstrates the crucial role of integrating spatial, multi-criteria, and optimization techniques to make it sustainable and efficient.

VI. FUTURE RESEARCH DIRECTIONS AND CONCLUSION

VI.1 FUTURE RESEARCH DIRECTIONS

Despite the fact that much progress has been achieved in the area of incorporating sustainability in the process of industrial sites selection, there are still a number of spheres that need further investigation. One of the key requirements is quantitative validation. Most of the existing systems are based on theoretical models, judgment of experts, or use cases. Although useful, these methods are not widely tested on an industry-wide and geographical level. The sustainability of the site selection models and the impact of the dynamic economic, regulatory, and technological factors on long-term results would be more reliable with broader datasets and longitudinal research. A new technology has more opportunities. Artificial intelligence and machine learning (AI/ML) may be used to increase predictive capability of site selection. Interpreting big and complicated data, AI can extract unobservable patterns and trade-offs, enabling one to minimize the impact of subjective views. Trained machine learning models can forecast the applicability of new locations based on previous decisions, and geospatial data and deep learning may enhance environmental assessment accuracy. Adaptive decision-making is also a potential use of reinforcement learning, with models changing over time as new data is received. Besides this, digital twins and simulation tools will have a powerful role to play.

A digital twin may simulate supply chain and environmental dynamics at a candidate location, facilitating decision-makers to execute scenarios on energy consumption, emissions, transportation flows, and effects on the community prior to resource allocation. Simulations show long-term sustainability trade-offs (e.g. between cost efficiency and carbon reduction). These technologies can be coupled with optimization algorithms to formulate real time updating decision systems, which would provide resilience in changing environments. The next future focus is to adopt a network-level perspective of sustainability. The decision of the location of the industrial sites has always been considered at the firm level, whereas the modern supply chain requires regional and global coordination. Such joint models as eco-industrial park, renewable energy cluster, and green logistics hubs can demonstrate how a common infrastructure and a common sustainability agenda can be useful. Applying this reasoning to cross-border supply chain networks would assist in meeting global sustainability and decarbonization goals, as well as improving reaction to climatic and geopolitical shocks. The proposed future research must focus on integrating quantitative validation, AI/ML, network-based simulations using digital twins, and network-oriented viewpoints. These innovations will enable stronger, dynamic, and international site selection methods.

VI.2 CONCLUSION

This paper has indicated the strategic importance of the industrial site selection as an interface between the supply chain management and sustainability. The location choices do not only affect the cost and efficiency but the environment and the welfare of the community. The outlined framework combines the drivers of supply chains, including cost efficiency, responsiveness, resilience, and green logistics with the aspects of sustainability, and it is a balanced presentation of the modern-day decision-making. The most important innovation is that it is viewed as a supply chain design problem and a sustainability concern at the same time. Contrary to the traditional method, in which all the attention was given to economic standards, the framework emphasizes the role of minimizing the ecological footprint, complying with regulations, and promoting social deliverables. The holistic approach enhances competitiveness and also fosters the overall sustainable development agenda. The paper offers an empirical investigation by offering a conceptual basis to encourage future research to operationalize and test the framework using real-life data and hi-tech innovations. The final vision is a decision-support system, which is both efficient and responsible providing practical advice to the managers, policymakers, and planners. By so doing sustainable site selection may not merely be a simple business requirement but also a source of long-run resilience of industry and society.

VII. AUTHOR'S CONTRIBUTION

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Supervision: Parveen Sharma and Anil Baliram Ghubade.
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