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A Readiness-Based Framework for Green Logistics: Sustainable Transport, Alternative Fuels, and Operational Efficiency

Ajidhashini Thulaisdass and M. Suresh *

Amrita School of Business, Amrita Vishwa Vidyapeetham, Coimbatore 641112, India
* Correspondence: m_suresh@cb.amrita.edu

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Abstract: This study develops a Hierarchical Fuzzy Readiness Framework to assess organizational preparedness for adopting green logistics, sustainable transport, and alternative fuels. The framework consists of four enablers, eleven criteria, and forty-three attributes identified through a structured literature review and expert evaluations. Triangular fuzzy weights and performance ratings are used to calculate the fuzzy readiness level for sustainable green logistics implementation assessment index (*FRSGLI*), while the Fuzzy Performance–Importance Index (FPII) identifies areas requiring improvement. The framework is applied to a medium-sized road freight and logistics company in Tamil Nadu, India. Using Euclidean distance matching, the organization is classified as "Highly Ready". An FPII threshold of 0.40 identifies twelve attributes requiring immediate attention, particularly in investment planning, incentive access, carbon measurement, greenhouse gas reporting, and performance monitoring. The findings highlight the framework's usefulness in assessing organizational readiness and identifying capability gaps. As the study is limited to a single organization, further research is required to establish its reliability, validity, and applicability across different logistics organizations.

Keywords: green logistics; sustainable transport; alternative fuels; fuzzy logic; readiness assessment

1. Introduction

As climate commitments intensify under the Paris Agreement and successive COP frameworks, logistics operators face mounting regulatory, competitive, and stakeholder pressure to transition toward green logistics practices [1]. Logistics enterprises transition is multidimensional. Adopting sustainable transport strategies and alternative fuels is vital for regulatory compliance and long-term cost competitiveness and operational efficiency improvement enabled by digital logistics systems, lean practices, and carbon accounting prerequisite to realizing the full potential of decarbonization investments [2].

Logistics operators small and medium-sized enterprises continue to struggle with the technical complexity, capital requirements, and organisational change involved in green logistics transitions [3]. Critical diagnostic gap persists: logistics organizations lack structured tools to assess their current readiness level before committing to green logistics transformation [4].

Best development towards sustainable logistics is anticipated to include shifts towards sustainable modes of transportation as well as alternative fuel sources: electricity, hydrogen, biofuel, and synthetic fuels. The choice for a particular fuel source depends on technological feasibility, existing infrastructure, and the transport sector considered [5]. Factors that enable smart sustainable logistics are seen to include a company's preparedness, IT

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maturity, and stakeholder integration. The factors that barriers to sustainable logistics include financial aspects such as logistics costs and lack of governmental regulations [6]. Investments in green technology can fail to reach their expected performance if the company's internal functions are not invested in as well. One issue within sustainable logistics is that there is currently no universal definition of what constitutes 'green logistics'. There can also be differences in how companies and professionals perceive weights on the three pillars of sustainability. As well as how they perceive the indicators of sustainability [7]. This can showcase that green logistics can be perceived differently by different people.

Multi-criteria assessments of sustainable fuel logistics have likewise had to rely on fuzzy and grey-number techniques precisely because expert judgements about environmental, economic, and social performance [8]. This research will address the existing knowledge void in green logistics readiness assessment by establishing a fuzzy logic based green logistics readiness assessment system. Fuzzy logic, introduced by Zadeh (1965), can be used effectively for green logistics readiness assessment due to the fact that readiness assessments are based upon subjective, ambiguous and qualitative judgments made by experts [9].

Fuzzy and hybrid fuzzy multi-criteria methods have recently been applied to evaluate sustainable logistics performance under conditions of uncertainty, including fuzzy grey-number hybrid models for sustainable fuel logistics [8]. Fuzzy index-based tools for benchmarking lean, agile, resilience, and green paradigm adoption in industrial companies [10]. These studies confirm both the methodological appropriateness of fuzzy approaches for sustainability assessment and the continued absence, within this literature, of a dedicated, structured readiness diagnostic that logistics managers can apply prospectively before, rather than after, transformation investments are made.

The framework termed the fuzzy readiness level for green logistics implementation provides both an aggregate readiness score and a disaggregated fuzzy performance improvement index (FPII) to identify attributes requiring prioritised managerial action and the framework moves beyond descriptive sustainability benchmarking toward an actionable, diagnostic tool for guiding investment sequencing in sustainable transport, alternative fuel adoption, and operational efficiency improvement.

This study's novelty is in the formulation of the problems and the domain-specific integration of methods from other disciplines; it does not involve the development of a new fuzzy operator. Most existing literature on green logistics has focused on technology-related areas such as routing, fuel type selection, supplier evaluation for sustainability, emissions reduction and operational optimization. Conversely, the majority of fuzzy-based multi-criteria decision-making (MCDM) research is concerned with ranking alternative options (e.g., practices, risks, or suppliers) based on linguistic uncertainty. Fuzzy readiness frameworks have been used in various organizational contexts including agile organizations, Lean Six Sigma, health care, and industry 4.0. None of these frameworks provide a green logistics-specific hierarchical structure to evaluate at the same time: financial capability, environmental and regulatory capability, operational optimization systems and monitoring & compliance infrastructures.

The developed framework has been able to combine all three of the above through a total of four enablers, eleven criteria and forty-three attributes; in addition it produces two different outputs which are both complementary to each other. The first output is a classification based on an aggregate linguistic assessment of readiness for green-logistics implementation at the organizational level, and the second output is a diagnosis of the organization's current state in relation to each individual attribute (FPII). This will enable logistics managers to determine if their organization is ready to begin implementing green logistics, and/or scale up their existing green logistics initiatives.This allows them to identify areas where they may need to focus attention prior to making significant investments in sustainable transportation/alternative fuels.

2. Research Gap and Objective

Green logistics has generated extensive insights into best practices, technologies, and environmental impacts [11–13]. Firm-level diagnostic readiness assessment particularly using quantitative fuzzy logic methodology remains a significant gap. Studies adopt prescriptive or macro-level perspectives, with limited attention to the organisational enablers and impediments that determine whether an enterprise is genuinely prepared for green logistics adoption [4,14].

The literature confirms that awareness of alternative fuel technologies, strategic leadership commitment, and digital systems deployment are critical enablers of green logistics readiness [15]. This study takes a holistic approach to green logistics readiness by assessing sustainable transport, alternative fuels, and operational efficiency dimensions using a fuzzy logic methodology.

Fuzzy-based evaluation methods have been applied to green supply chain management, recent studies indicate that the resultant frameworks tend to be geographically or sector ally constrained and very rarely provide a comprehensive, firm-level diagnosis of organisational readiness across technology, finance, and management perspectives together [16]. The literature is replete with macro-level diagnosis and technology assessment while

being relatively light on the firm-level question a manager needs answered before committing capital: is my organization ready and, if not, where precisely is it lagging'? This gap is particularly meaningful because it concerns the diagnosis rather than the implementation phase of transformation.

While a substantial body of recent literature has demonstrated how fuzzy logic and fuzzy multi-criteria methods are well-suited for evaluation under linguistic uncertainty e.g., In evaluating LARG paradigm uptake [10]. Assessing sustainability indicators across subsectors of logistics [7], and evaluating sustainable fuel logistics via fuzzy-grey methods [8] these applications primarily concern post hoc performance assessment, addressing how well an initiative or practice has been implemented, readiness assessment that should guide whether and how to undertake transformation.

Some frameworks developed integrate sustainable transport uptake, alternative fuel readiness, and operational efficiency capabilities in a single, structured, pre-implementation diagnosis. Therefore, firm-level readiness assessment, particularly using a fuzzy logic quantitative approach able to handle the imprecise, linguistic judgements characterizing self-evaluation by managers, represents a key and un addressed research gap. Further analyses suggest that readiness of organization, maturity of digital infrastructure and, as well, collaboration among stakeholder are critical and absent determinants for a successful smart sustainable logistics strategy [6]. What has been missing so far is not so much the list of determining factors, but the structured, quantitative tools to measure what is the degree of readiness with respect to these factors according to the vague language in which managers, at most, will assess organizational capabilities. This study develops a holistic approach to the evaluation of green logistics readiness integrating in a single, fuzzy logic methodology the areas of sustainable transport, alternative fuels and operational efficiency.

This research seeks to answer this question What methods can a logistics company use to evaluate their readiness for implementing green logistics when the required capabilities have many dimensions and management's decisions are subjective (linguistic) and uncertain? To achieve this objective, this study will accomplish three goals: (1) Identify and categorize the factors/drivers, criteria, and characteristics which make up the firms' level of readiness for green logistics; (2) Create and utilize a fuzzy logic-based system to convert experts' evaluations of readiness into a single, overall readiness rating expressed as a linguistic term; and (3) Identify the relatively weaker characteristics that would provide guidance to managers in determining their priorities. This study is focused on assessing an organization's level of readiness rather than quantifying the direct benefits of improved costs, reduced emissions, or enhanced operational efficiencies.

3. Literature Review

A conceptual framework has been created as part of a systematic literature review (a type of structured narrative review) of literature related to the organizational readiness for implementing green-logistics. A systematic literature review is being utilized to integrate multiple streams of research which are conceptually linked to one another but have different research methodologies. Rather than developing an aggregate statistical effect from the reviews, we will be analyzing these five streams of literature: (a) definitions and limits of green and sustainable logistics; (b) the organizational drivers and barriers to implementing environmentally friendly supply-chain practices; (c) the transition towards green and sustainable forms of transportation such as optimization of routes, loads, and vehicle fleets; green warehousing; (d) the organizational readiness and implementation assessment models; and (e) the use of fuzzy-logic and multicriteria methods to represent linguistic judgments in conditions of uncertainty. The environmental and operational scope of this conceptual framework was defined by studies in green logistics [2,12,13]

Various financial, regulatory, managerial and organizational factors, as well as several other variables, can either encourage or discourage the successful adoption of eco-friendly supply chain management practices [3,5]. Fuzzy assessment models have provided a basis upon which to create the hierarchical structure of an assessment model; a linguistic scale-based rating system for assessing each attribute; a technique for establishing a comprehensive readiness classification; and a means by which problems with attributes can be identified [17–20]

The involved extracting all statements related to implementation requirements, enabling capabilities, and recurring barriers to implementation found in the literature review. Statements were then transformed into an initial set of organization-level indicators.the remaining indicators were categorized based on their primary management function. Economic/Financial Readiness (SGL1) refers to a firm's ability to assess costs associated with implementing green initiatives, obtain funding for these initiatives, make long-term commitments to investing in new technologies, and minimize financial risk. Policy/Environmental Readiness (SGL2) refers to a firm's ability to comply with regulations, and its ability to measure and manage the environmental impact of its operations. Operational Optimization Readiness (SGL3) refers to a firm's systems and procedures for carrying out green

transport and warehousing activities. Monitoring/Compliance Readiness (SGL4) refers to a firm's ability to use data, accounting systems, target setting processes, auditing procedures, and regulatory risk management processes to monitor and improve implementation. The final hierarchy contained four enablers, eleven criteria, and forty-three attributes. These values are the result of consolidation through literature review and expert consultation.

3.1. Conceptual Foundations of Green Logistics

Mckinnon et al says green logistics as the integration of environmental sustainability principles into all kind of logistics activities reducing GHG emissions activities, energy consumption, and waste generation across the supply chain[11]. Green logistics transitions include sustainable fleet management policies, route optimisation, modal shift to rail, urban consolidation, and the adoption of alternative fuels options [21]. There is even an agreement about the scope, or what is it the field concerns. While a study attempting to consolidate several studies definitions on "green logistics", which can mean logistics for transport emissions (green log- transport), logistics for transportation, logistics for reverse and packaging and logistics for transportation, for warehousing and packaging, (green log- transport + packaging), (green log- warehousing), (green log- transport + warehousing), (green log- transport + warehousing + packaging), or total logistics emissions (green log-total) could verify that these different scopes exist and limit the ability to directly compare results regarding readiness/maturity, so we reinforce the idea that our framework define its variables and measures for such readiness rather than relying in any previous implied "green" measure of readiness [22].

3.2. Sustainable Transport and Fleet Decarbonisation

Green vehicle routing problems seek to minimize fuel consumption and emissions alongside service constraints [23]. Fleet electrification readiness is influenced by total cost of ownership trajectories, charging infrastructure availability, and battery technology maturity and some more [24]. The last few years have provided empirical support for this proposition. Panel data of Chinese logistics enterprises found a correlation "between digital transformation and operation efficiency" and specifically demonstrated that road transport firms' "digitalization process have always preceded the operational efficiency improvement" among various logistics sub-sectors, thus indicating a concurrent movement rather than an independent relation [25]. For the current research purpose, it reinforces the necessity of considering operating system, IT system, etc as distinct components in readiness. It thus also explains why it has not been sufficiently captured in previous green logistics assessments which tended to focus solely on technology adoption.

3.3. Alternative Fuels for Freight Logistics

The alternative fuel landscape for freight logistics includes CNG, LNG, HVO biodiesel, hydrogen fuel cells, and battery electric vehicles [24]. EV adoption in urban freight has accelerated with declining battery costs and charging infrastructure major barriers for heavy-duty applications in logistics activities [26].

A recent review of alternative fuels within air, land, and sea freight reinforced this: no one fuel pathway currently "wins" for any transportation mode; for air cargo, synthetic kerosene is deemed most viable despite challenges with biomass supply chain access, road freight will see further uptake of electricity on the back of battery cost declines, and ammonia and hydrogen continue to be most compelling contenders for shipping's climate abatement, though neither is entirely without its challenges in technical, economic, and policy terms [5]. Electric trucks, specifically in urban deliveries, uptake has risen with declines in battery prices, though availability of charging points is a significant hurdle to overcome particularly for heavy-duty applications [26,27]. What this body of literature ultimately highlights are that one cannot have a generic approach to assess alternative fuel "readiness".

Fuzzy logic in readiness assessment: Fuzzy Logic, first proposed by Zadeh provides a mathematical framework for handling vague, imprecise, and linguistically expressed information characteristics endemic to readiness and sustainability assessments [9]. Fuzzy readiness level frameworks (FRL) have been used in various industries such as manufacturing, hospitality, and higher education [20,28]. The Fuzzy Performance Improvement Index (FPII) developed from FRL frameworks provide a unique benefit over most maturity models in providing a clear action-oriented diagnostic priority ranking [19].

The literature provides insight into the presence of an intersectional gap. Studies on green logistics provide explanations about technologies and activities that may assist in reducing environmental impacts; fuzzy multi-criteria approaches help in making comparisons when there is linguistic uncertainty and fuzzy readiness models determine if organizations are prepared to implement green logistics in their respective organizational contexts. This research brings together the three areas by applying a well-developed fuzzy readiness architecture to the financial, environmental, operational, and monitoring capabilities needed for firm-level green logistics

implementation. The research has resulted in a diagnostic and decision support tool designed for the specific context of green logistics implementation, and not a new theory of fuzzy sets or a replacement for post-implementation measurements of environmental performance.

4. Research Methodology

The framework has been evaluated using a single exploratory case study within a medium-size road-freight/logistic business in Tamil Nadu, India. The case organisation offers road-freight, warehouse and distribution management, last-mile delivery services, and has a mixed fleet of heavy goods vehicles/light commercial vehicles. The case organisation was chosen for its analytical relevance, due to its consideration of Green Logistics initiatives such as: Electrification of the fleet Alternative fuel adoption practices in transport with energy efficiency formal environmental Management Systems. The purpose of the case application was to assess the diagnostic applicability of the framework in a specific organisational context; therefore, it was not developed to prove the generalizability of the framework to all businesses in the industry. For reasons of confidentiality, the case organisation will be referred to as "the Case Organisation XYZ Company".

Five internal experts were chosen to participate in this study as they had to have firsthand knowledge of the logistics processes and decision-making regarding sustainability. In order to qualify for participation in this study, the experts needed to have had a minimum of five years' experience within the industry and to currently hold responsibilities related to logistics operations, sustainability/environmental management, fleet management or warehousing. The experts were asked to evaluate the potential indicators (enablers), criteria, and attributes based upon their relevance, clarity, conceptual overlap, and practicality for assessment. Their evaluations provided the basis for retaining, merging, removing, or re-wording indicator(s) and confirming the final hierarchical structure. the experts rated the relative importance of each indicator using a linguistic scale and provided performance ratings for each indicator. Due to the fact that all five participants were part of the same organization, their evaluations are considered to be an informed case-specific assessment and not independent external validation.

Zadeh was presented this method, named Fuzzy logic. The motivation for adopting a fuzzy set-theoretic approach here is to address the pervasive lack of precision and linguistically-expressed nature of information that is ubiquitous within the assessment of readiness and sustainability [9]. That is the knowledge elicited from expert judgements in this domain is more likely to be a qualitative description of "high", "moderate" or "poor" than an exact number. Fuzzy readiness level models have been explored in various domains (e.g., manufacturing and industry 4.0 readiness in the auto component industry [20] and healthcare readiness for lean six sigma implementation [19], using a derived fuzzy performance improvement index (FPII) based on fuzzy readiness level to enable attribute level guidance to prioritization over an aggregate readiness score.The notation used in the fuzzy logic readiness assessment model for sustainable green logistics implementation is presented in Table 1.

Table 1. Notations used for the fuzzy logic readiness assessment model for the implementation of SGL.

Indices	Abbreviations
O_i	Fuzzy performance rating for readiness for the implementation of SGL of the *ith* enabler
O_{ij}	Fuzzy performance rating for readiness for the implementation of SGL of the *jth criterion* in the *ith* enabler
O_{ijk}	Fuzzy performance rating for readiness for the implementation of SGL of the *kth* attribute *o*f the *jth* criterion in the *ith* enabler
P_i	Fuzzy importance for the implementation of SGL weight of the *i*th enabler
P_{ij}	Fuzzy importance weight for the implementation of SGL of the *jth* criterion in the *ith* enabler
P_{ijk}	Fuzzy importance weight for the implementation of SGL of the *kth attribute* of the *jth* criterion in the *ith* enabler
$RSGL_i$	Readiness for the implementation of SGL capability measure of the *ith* enabler
$RSGL_{ij}$	Readiness for the implementation of SGL capability measure of the *jth* criterion in the *ith* enabler
$RSGL_{ijk}$	Readiness for the implementation of SGL capability measure of the *kth attribute* of the *jth* criterion in the *ith* enabler
FRSGLI	Fuzzy Readiness Index of SGL
$RSGLL_i$	Fuzzy number of natural language expression set of readiness levels for SGL implementation
$fFRSGLI_i(x)$	Triangular fuzzy number of $FRGLI_i$
$fRSGLL_i(x)$	Triangular fuzzy number of $RGLL_i$

The assessment of organisational readiness for change had five steps. In step 1 the literature-informed hierarchy of attributes was reviewed and refined based upon consultation with experts. Step 2 involved experts assigning importance to and rating the current level of performance of each measure in relation to the linguistic scales outlined in Table 2. Step 3 translated the linguistic ratings into triangular fuzzy numbers which were then aggregated into the attribute level, the criterion level, the enabler level and the organisational level. In step 4 the composite fuzzy readiness index was compared to pre-defined readiness levels through application of the stated distance procedure.

In step 5 an existing fuzzy performance-importance index was applied to determine those attributes that needed managerial attention. Fuzzy logic was chosen for two reasons. Organisational readiness is not readily

quantifiable as a single precise value. And managers typically use descriptive language (i.e., low, medium, or high) when describing their organization's ability. Triangular fuzzy numbers allowed the preservation of the linguistic imprecision of the original data throughout the aggregation process without requiring respondents to make unjustified precise ratings [9,17]. Figure 1 indicates all the steps of the research method.

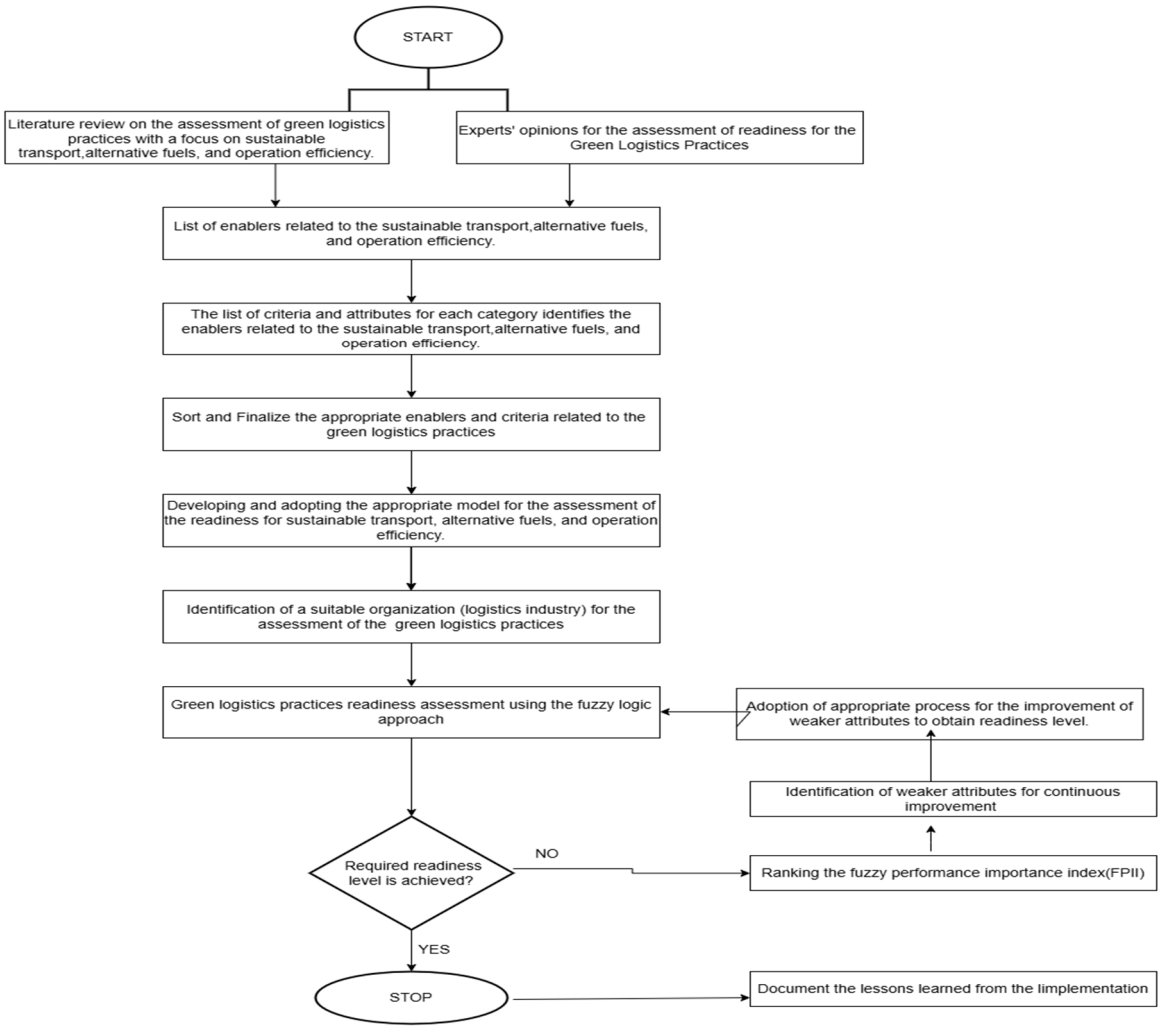

Figure 1. Framework for the assessment of readiness for the implementation of SGL.

Table 2. Linguistic variables and fuzzy intervals for weightage and rating.

Linguistic Variable	(a, b, c)	Linguistic Variable	(a, b, c)
Very Low (VL)	(0, 0.05, 0.15)	Worst (W)	(0, 0.5, 1.5)
Low (L)	(0.1, 0.2, 0.3)	Very Poor (VP)	(1, 2, 3)
Fairly Low (FL)	(0.2, 0.35, 0.5)	Poor (P)	(2, 3.5, 5)
Medium (M)	(0.3, 0.5, 0.7)	Fair (F)	(3, 5, 7)
Fairly High (FH)	(0.5, 0.65, 0.8)	Good (G)	(5, 6.5, 8)
High (H)	(0.7, 0.8, 0.9)	Very Good (VG)	(7, 8, 9)
Very High (VH)	(0.85, 0.95, 1)	Excellent (E)	(8.5, 9.5, 10)

Linguistic variables were converted to triangular fuzzy numbers (TFN_S) following established procedures in Table 2 [17]. The aggregated importance weights (P_{ij}) and performance ratings (O_{ij}) are presented [29].

5. Findings

5.1. Development of the Conceptual Model

From the literature review and expert consultation, 4 enablers,11 criteria and 43 attributes were developed for the assessment, as shown in Table 3. The criteria cover the strategic, technical, operational, regulatory, and organisational dimensions of green logistics readiness.

Table 3. Framework for sustainable green logistics index (*FRSGLI).*

Enablers	Criteria	Attributes
Economic & Financial Readiness (SGL_1)	Cost–benefit assessment capability(SGL_{11})	ROI evaluation practices (SGL_{111})
		Longterm cost analysis (SGL_{112})
		Total cost of ownership assessment (SGL_{113})
		Economic feasibility evaluation(SGL_{114})
		Fuel price risk analysis(SGL_{115})
	Green investment readiness(SGL_{12})	Access to green financing (SGL_{121})
		Availability of preferential loan schemes (SGL_{122})
		Investor interest (SGL_{123})
		Government grants and subsidies (SGL_{124})
		Organisational willingness to invest (SGL_{125})
	Financial planning and risk management(SGL_{13})	Green budgeting practices (SGL_{131})
		EV procurement capital planning (SGL_{132})
		Training investment planning (SGL_{133})
		Maintenance budgeting (SGL_{134})
		Financial risk mitigation tools (SGL_{135})
Policy & Environmental Readiness(SGL_2)	Regulatory compliance capability(SGL_{21})	Emission standard adherence (SGL_{211})
		Environmental certification (SGL_{212})
		Transport regulation compliance (SGL_{213})
		ISO / EMS certification (SGL_{214})
		ESG disclosure mechanisms (SGL_{215})
	Environmental monitoring capacity (SGL_{22})	Carbon and emission monitoring systems (SGL_{221})
		Baseline carbon foot printing (SGL_{222})
		Life cycle assessment capability (SGL_{223})
		GHG reporting tools (SGL_{224})
		Carbon reduction evaluation frameworks (SGL_{225})
Operational Optimisation Readiness(SGL_3)	Route and load optimisation (SGL_{31})	Dynamic route planning (SGL_{311})
		Load consolidation strategies (SGL_{312})
		Optimisation software utilisation (SGL_{313})
	Smart logistics systems(SGL_{32})	Telematics deployment(SGL_{321})
		Control tower systems(SGL_{322})
		Predictive maintenance systems(SGL_{323})
	Green warehousing capability(SGL_{33})	Energy efficient facility design(SGL_{331})
		Warehouse automation readiness(SGL_{332})
		Emissions monitoring systems(SGL_{333})
Monitoring & Compliance Readiness(SGL_4)	Carbon accounting and reporting(SGL_{41})	Emission scope coverage(SGL_{411})
		Data management systems(SGL_{412})
		Third party audit mechanisms(SGL_{413})
	Benchmarking and target setting(SGL_{42})	Industry benchmarking systems(SGL_{421})
		Science based target setting(SGL_{422})
		Realtime performance dashboards(SGL_{423})
	Regulatory risk management(SGL_{43})	Regulatory awareness mechanisms(SGL_{431})
		Risk mitigation frameworks(SGL_{432})
		Legal audits and compliance reviews(SGL_{433})

5.2. Case Organisation

The study was carried out in XXY logistics company, a medium-sized road freight and logistics enterprise operating in, Tamil Nadu, India. The company provides integrated logistics and transportation services, including road freight, warehousing, distribution management, and last-mile delivery operations. XXY logistics company operates a mixed fleet of heavy goods vehicles and light commercial vehicles to support its third-party logistics activities. The organisation manages distribution centres and transportation networks that facilitate both inbound and outbound supply chain operations for its customers. XXY logistics company has initiated discussions on fleet electrification, alternative fuel adoption, and energy-efficient transportation practices, and is also exploring the implementation of formal environmental management systems.

5.3. Fuzzy Logic Method and Assessment

Following the approach adopted by [18,29],three levels of calculations are performed: (1) The fuzzy readiness level for sustainable green logistics implementation assessment (*FRSGLI*) is calculated using fuzzy arithmetic operations on the aggregated TFNs; (2) the *FRSGLI* composite index is matched with natural linguistic expressions by converting the triangular fuzzy number back into a linguistic variable using the Euclidean distance method; and (3) Weaker attributes are identified by calculating the fuzzy performance improvement index (FPII) and ranking score. Managerial measures are then offered to recommendation and suggestions for identified gaps, with continual progress as the approach toward obtaining a 'Very Highly Ready' condition.

5.4. Green Logistics Readiness Index

Based on the steps outlined in the methodology, the *FRSGLI* composite readiness index was calculated [30]. The results are presented in Tables 4–6. The attribute-level fuzzy performance–importance index values and ranking scores are presented in Table 7.

Table 4. Criteria rating fuzzy sustainable green logistics implementation assessment (*FRSGLI*).

Criteria	Attribute	Fuzzy Performance Average Rating (O_{ijk})	Attributes Importance Average Weight (P_{ijk})	Criteria Rating
SGL_{11}	SGL_{111}	(3.4, 5.3, 7.2)	(0.76, 0.86, 0.94)	(3.8560, 5.5821, 7.3013)
	SGL_{112}	(4.6, 6.2, 7.8)	(0.85, 0.95, 1.00)	
	SGL_{113}	(2.8, 4.7, 6.6)	(0.70, 0.80, 0.90)	
	SGL_{114}	(4.6, 6.2, 7.8)	(0.85, 0.95, 1.00)	
	SGL_{115}	(3.6, 5.3, 7.0)	(0.70, 0.80, 0.90)	
SGL_{12}	SGL_{121}	(2.8, 4.7, 6.6)	(0.79, 0.89, 0.96)	(3.3321, 5.0998, 6.8605)
	SGL_{122}	(2.6, 4.4, 6.2)	(0.70, 0.80, 0.90)	
	SGL_{123}	(2.8, 4.7, 6.6)	(0.70, 0.80, 0.90)	
	SGL_{124}	(2.8, 4.7, 6.6)	(0.85, 0.95, 1.00)	
	SGL_{125}	(5.4, 6.8, 8.2)	(0.85, 0.95, 1.00)	
SGL_{13}	SGL_{131}	(3.8, 5.6, 7.4)	(0.70, 0.80, 0.90)	(4.4151, 6.0012, 7.5905)
	SGL_{132}	(3.6, 5.3, 7.0)	(0.85, 0.95, 1.00)	
	SGL_{133}	(5.0, 6.5, 8.0)	(0.76, 0.86, 0.94)	
	SGL_{134}	(5.4, 6.8, 8.2)	(0.70, 0.80, 0.90)	
	SGL_{135}	(4.4, 5.9, 7.4)	(0.70, 0.80, 0.90)	
SGL_{21}	SGL_{211}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(5.1544, 6.5784, 7.9941)
	SGL_{212}	(4.6, 6.2, 7.8)	(0.76, 0.86, 0.94)	
	SGL_{213}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	
	SGL_{214}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	
	SGL_{215}	(2.8, 4.7, 6.6)	(0.70, 0.80, 0.90)	
SGL_{22}	SGL_{221}	(3.2, 5.0, 6.8)	(0.85, 0.95, 1.00)	(2.7659, 4.5859, 6.4041)
	SGL_{222}	(2.6, 4.4, 6.2)	(0.85, 0.95, 1.00)	
	SGL_{223}	(2.6, 4.4, 6.2)	(0.70, 0.80, 0.90)	
	SGL_{224}	(2.6, 4.4, 6.2)	(0.85, 0.95, 1.00)	
	SGL_{225}	(2.8, 4.7, 6.6)	(0.85, 0.95, 1.00)	
SGL_{31}	SGL_{311}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(6.4667, 7.6000, 8.7333)
	SGL_{312}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	
	SGL_{313}	(6.2, 7.4, 8.6)	(0.85, 0.95, 1.00)	
SGL_{32}	SGL_{321}	(6.2, 7.4, 8.6)	(0.85, 0.95, 1.00)	(5.6813, 7.0098, 8.3374)
	SGL_{322}	(5.0, 6.5, 8.0)	(0.79, 0.89, 0.96)	
	SGL_{323}	(5.8, 7.1, 8.4)	(0.82, 0.92, 0.98)	
SGL_{33}	SGL_{331}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	(3.7600, 5.4706, 7.1857)
	SGL_{332}	(3.6, 5.3, 7.0)	(0.70, 0.80, 0.90)	
	SGL_{333}	(3.2, 5.0, 6.8)	(0.85, 0.95, 1.00)	
SGL_{41}	SGL_{411}	(2.6, 4.4, 6.2)	(0.70, 0.80, 0.90)	(4.2800, 5.8588, 7.4286)
	SGL_{412}	(5.4, 6.8, 8.2)	(0.85, 0.95, 1.00)	
	SGL_{413}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	
SGL_{42}	SGL_{421}	(4.0, 5.6, 7.2)	(0.70, 0.80, 0.90)	(4.0545, 5.6414, 7.2211)
	SGL_{422}	(2.6, 4.4, 6.2)	(0.76, 0.86, 0.94)	
	SGL_{423}	(5.4, 6.8, 8.2)	(0.85, 0.95, 1.00)	
SGL_{43}	SGL_{431}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(5.8750, 7.1500, 8.4207)
	SGL_{432}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	
	SGL_{433}	(6.2, 7.4, 8.6)	(0.85, 0.95, 1.00)	

Table 5. Fuzzy index of readiness for the implementation of SGL of criteria rating and (*FRSGLI*).

Readiness for SGL Enabler	Readiness for SGL Criteria	Criteria Rating	Criteria Weightage
SGL_1	SGL_{11}	(3.856, 5.582, 7.301)	(0.76, 0.86, 0.94)
	SGL_{12}	(3.332, 5.099, 6.860)	(0.85, 0.95, 1.00)
	SGL_{13}	(4.415, 6.001, 7.590)	(0.73, 0.83, 0.92)
SGL_2	SGL_{21}	(5.154, 6.578, 7.994)	(0.85, 0.95, 1.00)
	SGL_{22}	(2.765, 4.586, 6.404)	(0.73, 0.83, 0.92)
SGL_3	SGL_{31}	(6.467, 7.600, 8.733)	(0.85, 0.95, 1.00)
	SGL_{32}	(5.681, 7.009, 8.337)	(0.85, 0.95, 1.00)
	SGL_{33}	(3.760, 5.471, 7.186)	(0.70, 0.80, 0.90)
SGL_4	SGL_{41}	(4.280, 5.859, 7.429)	(0.73, 0.83, 0.92)
	SGL_{42}	(4.055, 5.641, 7.221)	(0.70, 0.80, 0.90)
	SGL_{43}	(5.875, 7.150, 8.421)	(0.85, 0.95, 1.00)

Table 6. Fuzzy index of readiness for the implementation of SGL of enabler rating and (*FRSGLI*).

Readiness for SGL Enable	Readiness for SGL Criteria	Enabler Rating (O_i)	Enabler Weightage (P_i)	Fuzzy Readiness for the Implementation of SGL
SGL_1	SGL_{11}	(3.840, 5.540, 7.240)	(0.76, 0.86, 0.94)	(4.531, 6.060, 7.578)
	SGL_{12}			
	SGL_{13}			
SGL_2	SGL_{21}	(4.050, 5.649, 7.232)	(0.82, 0.92, 0.98)	
	SGL_{22}			
SGL_3	SGL_{31}	(5.399, 6.761, 8.116)	(0.82, 0.92, 0.98)	
	SGL_{32}			
	SGL_{33}			
SGL_4	SGL_{41}	(4.805, 6.267, 7.714)	(0.76, 0.86, 0.94)	
	SGL_{42}			
	SGL_{43}			

Table 7. Fuzzy performance importance index (FPII) and ranking score.

Attribute	Fuzzy Performance Average Rating (Oijk)	$P'_{ijk} = (1, 1, 1) - P_{ijk}$	FPII	Ranking Score
SGL_{111}	(3.4, 5.3, 7.2)	(0.76, 0.86, 0.94)	(0.816, 0.742, 0.432)	0.7027
SGL_{112}	(4.6, 6.2, 7.8)	(0.85, 0.95, 1.00)	(0.690, 0.310, 0.000)	0.3217 *
SGL_{113}	(2.8, 4.7, 6.6)	(0.70, 0.80, 0.90)	(0.840, 0.940, 0.660)	0.8767
SGL_{114}	(4.6, 6.2, 7.8)	(0.85, 0.95, 1.00)	(0.690, 0.310, 0.000)	0.3217 *
SGL_{115}	(3.6, 5.3, 7.0)	(0.70, 0.80, 0.90)	(1.080, 1.060, 0.700)	1.0033
SGL_{121}	(2.8, 4.7, 6.6)	(0.79, 0.89, 0.96)	(0.588, 0.517, 0.264)	0.4867
SGL_{122}	(2.6, 4.4, 6.2)	(0.70, 0.80, 0.90)	(0.780, 0.880, 0.620)	0.8200
SGL_{123}	(2.8, 4.7, 6.6)	(0.70, 0.80, 0.90)	(0.840, 0.940, 0.660)	0.8767
SGL_{124}	(2.8, 4.7, 6.6)	(0.85, 0.95, 1.00)	(0.420, 0.235, 0.000)	0.2267 *
SGL_{125}	(5.4, 6.8, 8.2)	(0.85, 0.95, 1.00)	(0.810, 0.340, 0.000)	0.3617*
SGL_{131}	(3.8, 5.6, 7.4)	(0.70, 0.80, 0.90)	(1.140, 1.120, 0.740)	1.0600
SGL_{132}	(3.6, 5.3, 7.0)	(0.85, 0.95, 1.00)	(0.540, 0.265, 0.000)	0.2667 *
SGL_{133}	(5.0, 6.5, 8.0)	(0.76, 0.86, 0.94)	(1.200, 0.910, 0.480)	0.8867
SGL_{134}	(5.4, 6.8, 8.2)	(0.70, 0.80, 0.90)	(1.620, 1.360, 0.820)	1.3133
SGL_{135}	(4.4, 5.9, 7.4)	(0.70, 0.80, 0.90)	(1.320, 1.180, 0.740)	1.1300
SGL_{211}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(0.990, 0.385, 0.000)	0.4217
SGL_{212}	(4.6, 6.2, 7.8)	(0.76, 0.86, 0.94)	(1.104, 0.868, 0.468)	0.8407
SGL_{213}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(0.990, 0.385, 0.000)	0.4217
SGL_{214}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	(1.380, 1.240, 0.780)	1.1867
SGL_{215}	(2.8, 4.7, 6.6)	(0.70, 0.80, 0.90)	(0.840, 0.940, 0.660)	0.8767
SGL_{221}	(3.2, 5.0, 6.8)	(0.85, 0.95, 1.00)	(0.480, 0.250, 0.000)	0.2467 *
SGL_{222}	(2.6, 4.4, 6.2)	(0.85, 0.95, 1.00)	(0.390, 0.220, 0.000)	0.2117 *
SGL_{223}	(2.6, 4.4, 6.2)	(0.70, 0.80, 0.90)	(0.780, 0.880, 0.620)	0.8200
SGL_{224}	(2.6, 4.4, 6.2)	(0.85, 0.95, 1.00)	(0.390, 0.220, 0.000)	0.2117 *
SGL_{225}	(2.8, 4.7, 6.6)	(0.85, 0.95, 1.00)	(0.420, 0.235, 0.000)	0.2267 *
SGL_{311}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(0.990, 0.385, 0.000)	0.4217
SGL_{312}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(0.990, 0.385, 0.000)	0.4217
SGL_{313}	(6.2, 7.4, 8.6)	(0.85, 0.95, 1.00)	(0.930, 0.370, 0.000)	0.4017
SGL_{321}	(6.2, 7.4, 8.6)	(0.85, 0.95, 1.00)	(0.930, 0.370, 0.000)	0.4017
SGL_{322}	(5.0, 6.5, 8.0)	(0.79, 0.89, 0.96)	(1.050, 0.715, 0.320)	0.7050
SGL_{323}	(5.8, 7.1, 8.4)	(0.82, 0.92, 0.98)	(1.044, 0.568, 0.168)	0.5807
SGL_{331}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	(1.380, 1.240, 0.780)	1.1867
SGL_{332}	(3.6, 5.3, 7.0)	(0.70, 0.80, 0.90)	(1.080, 1.060, 0.700)	1.0033
SGL_{333}	(3.2, 5.0, 6.8)	(0.85, 0.95, 1.00)	(0.480, 0.250, 0.000)	0.2467 *
SGL_{411}	(2.6, 4.4, 6.2)	(0.70, 0.80, 0.90)	(0.780, 0.880, 0.620)	0.8200
SGL_{412}	(5.4, 6.8, 8.2)	(0.85, 0.95, 1.00)	(0.810, 0.340, 0.000)	0.3617 *
SGL_{413}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	(1.380, 1.240, 0.780)	1.1867
SGL_{421}	(4.0, 5.6, 7.2)	(0.70, 0.80, 0.90)	(1.200, 1.120, 0.720)	1.0667
SGL_{422}	(2.6, 4.4, 6.2)	(0.76, 0.86, 0.94)	(0.624, 0.616, 0.372)	0.5767
SGL_{423}	(5.4, 6.8, 8.2)	(0.85, 0.95, 1.00)	(0.810, 0.340, 0.000)	0.3617 *
SGL_{431}	(6.6, 7.7, 8.8)	(0.85, 0.95, 1.00)	(0.990, 0.385, 0.000)	0.4217
SGL_{432}	(4.6, 6.2, 7.8)	(0.70, 0.80, 0.90)	(1.380, 1.240, 0.780)	1.1867
SGL_{433}	(6.2, 7.4, 8.6)	(0.85, 0.95, 1.00)	(0.930, 0.370, 0.000)	0.4017

* Weaker attributes.

The composite *FRSGLI* index for the case organization was (4.531, 6.060, 7.578). Using Euclidean distance, matching this fuzzy value to the five linguistic intervals of readiness shown in Table 6 gives a total organization readiness as "Highly Ready" (second from the top, or on the very low end of the interval (5.5, 7.0, 8.5). This suggests that XXY logistics company possesses some evidence of green logistics strategy with targets and senior management involvement (and hence the "Highly Ready" label as per Table 8), but not the full continuous improvement or integrated readiness implied by "Very Highly Ready".

Table 8. Strategic alignment level for the green logistics and fuzzy intervals.

Linguistic Term	Green Logistics Readiness Interpretation	Fuzzy Intervals
Very low ready(VLR)	No green logistics strategy; no emission reduction targets; no leadership commitment	(0, 1.5, 3.0)
Low ready(LR)	Isolated green initiatives; ad hoc fuel trials; limited cross-functional engagement	(1.5, 3.0, 4.5)
Moderately ready(MR)	Partial readiness; some policies and pilots; limited alternative fuel and digital integration	(3.5, 5.0, 6.5)
Highly ready(HR)	Clear strategy; measurable targets; leadership drives green logistics transition actively	(5.5, 7.0, 8.5)
Very highly ready(VHR)	Fully integrated; long-term vision; transparent governance; continuous improvement culture	(7.0, 8.5, 10)

$$D(FRSGLI, RSFML_i) = \sqrt{\sum(fFRSGLI(x) - fFRSGLL_i(x))^2}$$

$$D\,(FRSGLI, \text{VHR}) = [(4.531 - 7)^2 + (6.060 - 8.5)^2 + (7.578 - 10)^2]^{1/2} = 4.2333$$

$$\mathbf{D\,(FRSGLI, HR) = [(4.531 - 5.5)^2 + (6.060 - 7)^2 + (7.578 - 8.5)^2]^{1/2} = 1.6354}$$

$$D\,(FRSGLI, \text{MR}) = [(4.531 - 3.5)^2 + (6.060 - 5)^2 + (7.578 - 6.5)^2]^{1/2} = 1.8294$$

$$D\,(FRSGLI, \text{LR}) = [(4.531 - 1.5)^2 + (6.060 - 3)^2 + (7.578 - 4.5)^2]^{1/2} = 5.2933$$

$$D\,(FRSGLI, \text{VLR}) = [(4.531 - 0)^2 + (6.060 - 1.5)^2 + (7.578 - 3)^2]^{1/2} = 7.8913$$

The proposed model was applied to measure the *FRSGLI* of the case logistics enterprise. The *FRSGLI* composite index values obtained were (4.53149, 6.05955, 7.57783) as shown in Tables 4–6. Then obtaining the fuzzy scores index was converted back into the corresponding linguistic term using the Euclidean distance method. Five linguistic readiness terms were adapted from extant literature [31], as shown in Table 8. Matching the computed index with the linguistic label having the minimum Euclidean distance (*D* value), the green logistics readiness of the case organisation was found to be 'Highly Ready' (Figure 2).

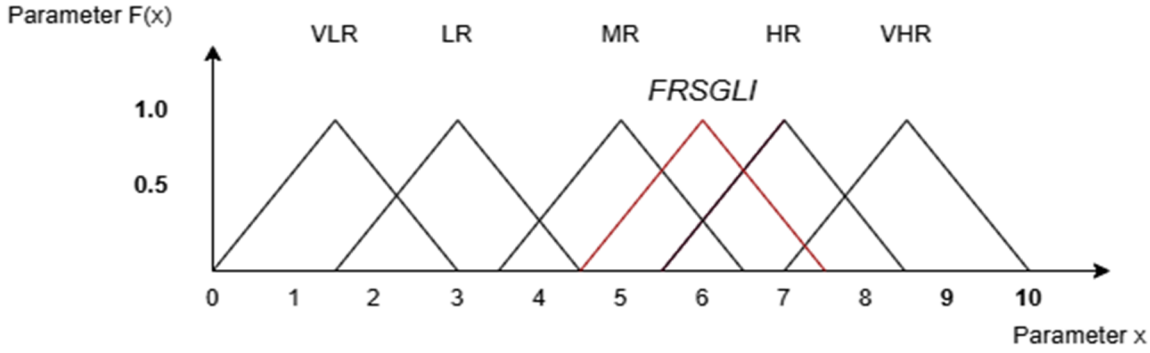

Figure 2. Linguistic levels to match the sustainable green logistics.

The ranking score was calculated for all 43 attributes of the *FRSGL*, as shown in Table 7. The minimum score was 0.2117 for GHG reporting tools (SGL_{224}), in this research the maximum score was 1.3133 for maintenance budgeting (SGL_{134}) sustainable green logistics context.

As per our management threshold value of 0.40 was fixed by applied to identify weaker attributes of this study.12 attributes scored below the threshold, namely SGL_{112}, SGL_{114}, SGL_{124}, SGL_{125}, SGL_{132}, SGL_{221}, SGL_{222}, SGL_{224}, SGL_{225}, SGL_{333}, SGL_{412}, SGL_{423} indicating that these areas require prioritised managerial focus to enhance the overall Green Logistics Readiness of the organisation, as shown in Table 9.

Table 9. Weaker Attributes.

Attributes	Ranking Score
Longterm cost analysis (SGL_{112})	0.3217
Economic feasibility evaluation (SGL_{114})	0.3217
Government grants and subsidies (SGL_{124})	0.2267
Organisational willingness to invest (SGL_{125})	0.3617
EV procurement capital planning (SGL_{132})	0.2667
Carbon and emission monitoring systems (SGL_{221})	0.2467
Baseline carbon foot printing (SGL_{222})	0.2117
GHG reporting tools (SGL_{224})	0.2117
Carbon reduction evaluation frameworks (SGL_{225})	0.2267
Emissions monitoring systems (SGL_{333})	0.2467
Data management systems (SGL_{412})	0.3617
Real-time performance dashboards (SGL_{423})	0.3617

6. Results and Discussion

The Fuzzy readiness index used for this research was determined to fall within the "Highly Ready" category as defined by the established linguistic matching procedure. As the case organization has several capabilities which will facilitate the adoption of Green Logistics. This does not imply that each of these capabilities is at the same stage of maturity or that the organization has successfully implemented Green Logistics. Based upon the results of the attribute-level FPII analysis, the case organization needs to address certain areas related to financial planning, carbon management, data and monitoring. It is imperative to interpret both the overall category and the disaggregated diagnoses. The overall category provides an overview of the level of readiness of the organization. The disaggregated diagnoses provide specific areas where further development of capabilities is required.

This study proposed to construct and apply a set of standard procedures to determine how ready logistics companies are to engage in the green logistics practice. The developed structural model consists of four readiness dimensions economic and financial readiness (SGL_1), policy and environmental readiness (SGL_2), operational optimisation readiness (SGL_3), and monitoring and compliance readiness (SGL_4)which were further detailed into 11 criteria and 43 attributes. This framework's layered structure is based on the process of implementing green practices in which Financial and Policy readiness are prerequisites to make decisions; Operational optimisation facilitates actual implementation; finally, monitoring and control would allow organizations to ensure that the implementation resulted in the desired environmental outcome. Our findings showed that the FRSGL of the case organisation (4.531, 6.060, 7.578), when mapped onto linguistic terms of readiness on the scale of 1 to 10 using the Euclidean distance measure, qualified it as "highly ready".

We find that "highly ready" is somewhat ambiguous and requires careful interpretation; simply relying on such aggregated classification would over simplify and obscure underlying strengths and weaknesses. The relatively wide spread of the resulting FRSGL is an indicator of high uncertainty around this figure and points to a varied level of organizational readiness across various dimensions. The triangularity indicates significant disagreement among respondents. Narrower interval at each level would imply higher consistency in responses.

This is corroborated by the attribute-level results as presented in Table 7, which highlighted certain weak spots Table 9 despite the overall favourable aggregated readiness level. This is a fundamentally different kind of readiness challenge than a general "low readiness" status and has direct implications for the target areas of improvement in the Table 10.

The use of a 0.40 FPII threshold was determined to be appropriate by the Case Organization for use in screening out those areas of attribute weakness that would require immediate attention from management.While there may be other ways to establish such thresholds based on statistical boundaries or industry standards, in this study, the determination of what constituted a threshold value was made on a case-specific basis.The all attributes with values less than the established threshold were designated as needing immediate management attention within this study.On the other hand, attributes with values greater than the threshold should not necessarily be assumed to have achieved maturity. Further multi-organizational studies are needed to evaluate whether the threshold will remain consistent and provide useful guidance in a variety of logistical environments.

Table 10. suggestions for improvement of weak attributes in green logistics readiness.

Weaker Attributes	Suggestions for Improvement
SGL_{112}	Carry out detailed cost-benefit studies comparing green logistics options with conventional ones over the long run, including fuel and maintenance savings.
SGL_{114}	Use simple payback period and ROI calculations before approving green logistics investments.
SGL_{124}	Assign a person/team to track and apply for available government subsidies and incentive schemes for green transport.
SGL_{125}	Get top management commitment through small pilot projects that show cost savings, before scaling up investment.
SGL_{132}	Plan EV purchases year-wise based on budget availability and vehicle replacement schedule.
SGL_{221}	Set up basic emission tracking tools for vehicles and warehouses to monitor fuel use and emissions regularly.
SGL_{222}	Calculate the current carbon footprint of operations to use as a starting point for setting reduction targets.
SGL_{224}	Adopt standard GHG reporting formats and use simple software/spreadsheet tools for emission reporting.
SGL_{225}	Create a basic framework with clear targets to check progress on carbon reduction efforts periodically.
SGL_{333}	Install sensors or use fleet telematics to track emissions continuously and flag unusual increases.
SGL_{412}	Maintain a central system/spreadsheet to store fuel, distance, and emission data for easy tracking.
SGL_{423}	Build a simple dashboard showing fuel use, emissions, and vehicle utilization so managers can review performance quickly.

7. Conclusions

The purpose of this research was to develop a fuzzy logic based assessment tool for evaluating an organization's preparedness to implement green logistics. The tool is composed of four enablers (economic/financial, policy/environmental, operational optimization, and monitoring/compliance) and includes 11

criteria and 43 attributes. The conceptual contribution of this work is in combining the capability areas that are usually studied independently in green logistics, environmental management, and organizational readiness literature. Methodologically, the work adapted an existing fuzzy-readiness model to allow for the uncertainty associated with the use of linguistic expert ratings and to link the overall readiness assessment to management priorities based on the attributes of each enabler.

The reported Fuzzy Readiness Index and associated "Highly Ready" classification for the Case Organization were developed through application of the Composite Fuzzy Readiness Index to the Case Organization. The FRI provided a positive aggregate classification of "Highly Ready", the existing FPII Analysis indicated areas where additional focus on improving certain capabilities would be beneficial.

The *FRSGLI* provides a basis for creating a structured dialogue, establishing priorities, and developing plans for improving readiness; The *FRSGLI* alone will not provide evidence that reductions in emissions, cost, or delivery time have occurred. Because the *FRSGLI* was applied to a single organization utilizing a relatively small group of internal experts to develop the *FRSGLI*, this represents an exploratory case study demonstrating the potential utility of the *FRSGL*I in a specific context. Future research should include studies involving multiple organizations and longitudinal studies to assess the consistency of the *FRSGLI* over time, evaluate the appropriateness of the managerial threshold for the *FRSGLI*, and determine whether increases in readiness are correlated with quantifiable environmental and operational benefits.

This research is limited in several ways.The framework was applied to a single medium-sized logistics organization. The indicators' weights, classification of readiness levels and attributes that indicate priorities for action cannot be generalized to the broader logistics industry. The expert group was comprised of five internal employees from the same company whose assessments may have been influenced by their collective knowledge and functional roles within the organization.This assessment is based upon a snapshot (cross-section) of perceived capabilities rather than actual changes in either an organization's environment or its operational effectiveness over time. The framework's hierarchical nature and the use of managerial thresholds need to be tested across different types of organizations, geographical locations, sizes of vehicle fleets, and logistics sub-sectors. Future research will need to include larger and more representative groups of experts; assess whether experts agree on which aspects of the framework are most relevant (inter-rater reliability); evaluate how well the framework accurately reflects what it claims to measure (content validity); analyze how well findings from one firm can be compared to other firms; and measure how improvements in readiness relate to reductions in emissions and/or improvements in operational performance over time.

Future research should focus on applying *FRSGL* methodology across large numbers of logistics firms from various geographies and sub-sectors to understand industry-specific and context specific characteristics and vulnerabilities. It is also encouraged that longitudinal studies are carried out on organisations following the use of FRSGL to observe changes in readiness and how focused policy and firm level interventions in specific weak points affect this evolution of readiness.

Author Contributions

T.A.: Conceptualization; Methodology; Formal analysis; Writing original draft preparation. M.S.: Conceptualization; Data curation; Investigation; Validation; Writing review and editing; Supervision; Resources; Project administration. Both authors have read and agreed to the published version of the manuscript and take responsibility for their respective contributions.

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Institutional Review Board Statement

The study was conducted in accordance with the relevant institutional and national ethical guidelines and was approved by the Institutional Human Ethics Committee (IHEC) of Amrita Vishwa Vidyapeetham (Reference No.: IHEC/2025/215; Date of approval: 3 June 2025).

Informed Consent Statement

Informed consent was obtained from all individual participants involved in the study.

Data Availability

All the data available in the manuscript (Tables 4–6).

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Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

During the preparation of this manuscript, the authors used Grammarly for English language editing and grammatical corrections. Draw.io was used for figure preparation and editing. The authors reviewed and revised the content and take full responsibility for the accuracy, integrity, and final content of the published article.

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