Høgskolen i Østfold

Using an analytically-based decision-making process for assessing logistics service providers from sustainability quality factors in Aker Solution AS Company

Master Thesis

Arsalan Nikpasand

August-2023

Supervisor
Shima Pilehvar

Master in Green Energy Technology
Engineering Department
Faculty of Computer Science, Engineering, and Economics

Acknowledgment

I want to take this opportunity to express my sincere appreciation to all the people whose help was an essential milestone in completing this study. This task would not have been possible without the help of a few experienced and creative people.

Special thanks, to my supervisor, Shima Pilehvar, Associate Professor, Department of Engineering at Østfold University College, whose supportive guidance improved my scientific skills.

In addition, I am grateful to the Aker Solutions AS Supply Chain Management team for suggesting this exciting thesis topic, especially to Alexandra Koumara and Alexander Correia. Without the helpful information the company provided, this study could not have been as thorough without them.

Many thanks to my wife for her support and help which without it I could not have succeeded.

1. Contents

2. Abstract

Nowadays, by considering the importance of green transition and circular economy, sustainable service quality has become a crucial factor for logistics service providers (LSP) worldwide to gain a competitive advantage. This study introduces a unique framework for selecting the best logistics provider based on sustainable service quality. Nineteen attributes are identified related to sustainable service quality through a literature review and focused on group discussions with close attention to the energy industry. These attributes were categorized into six factors: Schedule, Cost, Quality, Infrastructure, Digitalization, and Innovation and HSSE, forming a developed framework for LSP evaluations. Data was summarized from Aker Solutions AS company, Supply Chain Management Department experts through a questionnaire-based survey. The collected data was then analyzed using factor analysis, and the framework was utilized to illustrate the selection process of the best logistics service provider based on sustainable service quality. The evaluation of the listed attributes was carried out using hybrid Fuzzy Analytic Hierarchy Process (AHP) and Fuzzy Technique for Order Preference. The proposed decision-making framework is provided to be used inside the company for LSPs evaluation. The study's findings revealed that LSPs should focus on developing competencies for adopting sustainable practices. To become the preferred choice of customers, providers should emphasize sustainable network optimization, reducing response times, providing reliable green services, flexibility in green processes, and fostering mutual trust with all stakeholders. The insights derived from this research can help logistics service providers develop strategies to ensure sustainable service quality for their customers.

3. Introduction

The term 'Logistics' is differently defined in various contexts around the globe. Most common terms are Materials Management, Materials Administration, Transportation, Freight Forwarding etc. Basically, Logistics is recognized as the 'lubricant' in between the Supply Chain Management functions and other key project stakeholders.

Although manufacturing and logistics have matured over the past few decades, pressure from saturated markets and new client demands has caused logistics systems to become more complex. Shortening product lifecycles, globalization of markets, demographic shifts, and customer needs for individualized products are significant factors, along with environmental considerations. These factors combine to create a dynamic and difficult environment for businesses, are being improved in the manufacturing sector. Since logistics still lacks a suitable covering concept [1].

The logistics industry has a significant impact on a nation's economic development. Due to the heavy reliance on fossil fuels and non-renewable natural resources for logistical activities, this sector is under pressure for increased environmental (i.e., atmospheric, land, and water) pollution. The ecology is negatively impacted by using heavy-duty vehicles for freight transportation. According to estimates, freight transportation is responsible for 8% of all carbon emissions related to energy [2]. The logistics industry is more at risk from these environmental issues such as rising pollution, carbon emissions, resource utilization, etc. than other industries [3].

Future growth in the logistics industry is anticipated to multiply, raising greater environmental challenges. For environmental protection, the logistics industry should develop and put into practice sustainable methods. Additionally, customers anticipate long-term service quality from logistics service providers (LSPs). As a result, choosing the right LSP based on sustainability has become a concern for all organizations worldwide. The performance of supply chains in terms of sustainability indicators would be significantly impacted by the choice of suitable logistics providers [4].

Numerous research on the selection of logistics providers has been conducted in the past. However, the focus of these studies was not on sustainable service quality qualities. The change in market conditions of the logistics sector is unavoidable. Important sustainable service quality characteristics must be identified and weighed so that clients may assess the effectiveness of logistics providers. Companies are being forced to pay more attention to their logistical activities by the pressure of rising company costs, commercial competitiveness, globalization of business activities, legislative pressure, and client demands. The choice of a suitable LSP is one of the crucial considerations that must be taken when conducting logistical activities. The right LSP candidate offers advantages in terms of resource and operational efficiency, cost savings, performance enhancement, organizational competitiveness, and long-term corporate growth. In order to maintain organizational strategic competitive advantage in the direction of sustainability goals, supply chain executives may face a strategic challenge with the LSP selection decision. Due to the existence of numerous qualitative and quantitative variables, selecting an appropriate sustainable LSP can be thought as a multi-criteria decision making (MCDM) process [5].

One of the most applied MCDM processes is Analytic Hierarchy Process (AHP), which can handle data derived from many objectives, and is a popular choice for prioritization models. Thomas L. Saaty created the AHP, a multi-criteria decision-making procedure, in 1980. Since it gave a mechanism to cope with the uncertainties of complicated situations that are made up of numerous interconnected components, the invention of the AHP was seen as a significant contribution. Its capacity to address both qualitative and quantitative aspects and take into consideration the subjectivity of the decision-makers was seen as a milestone in the decision-making field [6]. According to Saaty [7], the strength of AHP resides in its capacity to take a difficult, unstructured problem and break it down into manageable, structured parts that can be given relative weights and priority. Deconstructing complex problems enables decision-makers to conduct logical analyses, better grasp complex situations, and avoid feeling overwhelmed and confused. The following are only a few of the benefits of the Analytic Hierarchy Process [8]:

1. It analyzes the capacity to address challenging issues.
2. It has the capacity to make intricate connections between interrelated things.
3. It can separate complicated issues into straightforward components that are dispersed over numerous levels of a hierarchy.
4. It enables pair-wise comparisons to determine priority for items at the same hierarchical level.
5. It transforms abstract opinions into quantifiable measures.
6. It enables the validation of data consistency.

The main contribution of this study is to present a methodology proposal for choosing the best logistics provider based on the sustainability of service quality. The focused group discussions are used to identify, shortlist, and group the sustainable service quality attributes. The service quality attributes were then ranked using fuzzy AHP, and the best LSP was chosen using the suggested framework. It will assist businesses in choosing LSPs that provide sustained service quality. The study's findings will also aid LSPs in creating plans for environmentally friendly logistics operations.

.

4. Background

The idea of sustainability is becoming more popular in developing nations, as markets are searching for the right direction to create their overall sustainable business development plans [9]. However, sustainability components in service quality frameworks have not received much attention in earlier studies on LSPs. In the majority of the service quality frameworks created for the selection of logistics providers in the literature, generic metrics including ordering practices, order sizes, information quality, timeliness, and personnel contact quality were taken into consideration [10]. Being globally competitive is a significant challenge for LSPs in terms of identifying sustainable choices. When choosing a logistics provider in the past, the majority of studies did not take sustainability factors into account in addition to service excellence. As a result, this study has filled in any gaps in the body of knowledge regarding how to evaluate LSPs in the context. In this section, a review of the articles in the recent 10 years has been performed. The focus of this literature review has been around different research questions such as:

- What qualities of sustainable service must LSPs have in order to ensure sustainability and the development of sustainable attributes during these years.
- The research methods used for the development of foundation for choosing the best logistics provider.

According to Tan et al.(2020), incorporation of IoT and big data into the logistics sector was investigated [11], this research suggested a blockchain-based architecture for green logistics. In order to identify current issues impeding the logistics sector's realization of green logistics, the article was conducted in three steps; At first step it investigated the logistics process in supply chains. Second, a seven-layer framework built on the blockchain was suggested Figure 1. In the last step advantages and disadvantages discussed to enable logistics professionals to perform a cost-benefit analysis. The main challenges have been a) the recording of logistics data is completed manually. b) Data sharing is a challenge among different stakeholders c) Logistics data leakage poses a threat to customers. The main goal aims to develop a blockchain-based framework with the integration of the Internet of Things (IoT) and big data for logistics management. Finally, they proposed that key applications can be Logistic Traceability, Vehicle routing, Energy saving management and Collaborative logistics. The benefits include Improving transparency, Establishing Trust, Enhancing collaboration and cooperation [11].

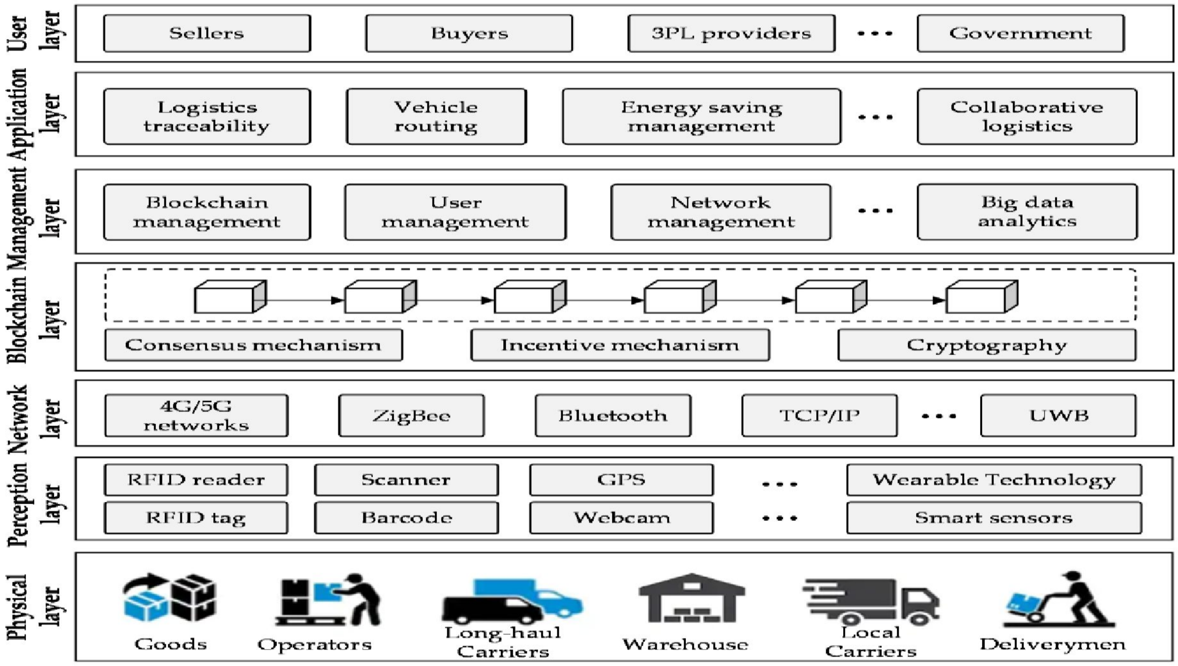

Figure 1 Block-Chain Framework for Green Logistics [11]

Mishra, A.R., et al. (2021) investigated reverse logistics (RL) and implementation of that in circular economy [5]. The term RL refers to all procedures or actions involved in recycling goods and resources. They discussed that companies forced to pay more attention to their RL activities and select 3PRLP as their third-party reverse logistics provider and as a result company costs, commercial competitiveness, globalization of business activities, governmental pressure, and customer demand is raised significantly. Considering many factors in choosing the best 3PRLP candidate necessitates, a multi-criteria decision-making (MCDM) procedure was chosen. They introduced a hybrid technique based on the traditional Combined Compromise Solution method and proposed a discriminating measure within the context of hesitant fuzzy sets in order to select the most suitable sustainable 3PRLP (S3PRLP). They argued that this method gave a fresh method for assessing weights of criteria that is based on the discrimination measure and resolved a case study. The findings suggested that the methodology can suggest a more workable performance when dealing with specific and erratic knowledge and qualitative data. The weights of the criteria have been evaluated by combining an objective weighting approach based on a proposed discrimination measure with a subjective method. The automotive industry were selected which required for large-scale production due to major flow of raw materials, components, completed goods, and scrap materials. Six 3PRLP candidates in 13 criteria have been evaluated. Such as Green warehousing, Pollution control cost, Green product and eco-design cost, RL cost, Green R&D and innovation, Air emissions, Environmental management system, Flexibility, Quality, Financial risk, Health and safety practices, Social responsibility and Employment Practices. The study's limitations were 1) that there weren't many decision-making experts involved in the case study; 2) that the relationships between the criteria weren't taken into consideration; and 3) that the belongingness degrees of some elements weren’t always real numbers, which may have limited the technique's applicability [5].

Jazairy et.all (2020) analyzed pressures and modifiers that affects decisions about the procurement and provision of green logistics [3]. Their main focus was that Shippers (also known as logistics purchasers) and logistics service providers (LSPs) are two actors within supply chains who are subject to institutional pressures (regulatory, market, and competitive). They argued that institutional pressures on both parties to adopt green supply chain management techniques may lead shippers to seek out green logistics services from LSPs. The level of pressure on the two characters and the actions they take are also moderated by a number of other factors. Empirical data were provided from three shippers and five LSPs. Consequently, based on the various supply chain roles played by the participants, these pressures and moderators are contrasted. The findings sought to advance the theory by 1) including the moderating factor roles and 2) offering additional applications within particular shipper-LSP scenarios. Additionally, by highlighting how their firm's and market's features reduce the demands placed on them to purchase or provide green logistics services and by offering insights on factors impacting their responsiveness, this research sought to support managers inside shipper and LSP organizations. The institutional pressures were considered Regulatory, Market and Competitive. They contributed to incorporating the influence of pressure/response moderators to engage in Green Supply Chain Management (GSCM) practices, providing further applications in specific shipper-LSP contexts. Theoretical framework included institutional pressures (social and cultural pressures) to implement GSCM practices, firm and market characteristics (industry, operating country, visibility, internationalization, size) as pressure moderators, and managerial commitment (interpretation of pressures, top management support, economic condition, organizational structure, collaboration opportunities) as a response moderator. Conceptual framework is presented in Figure 2.

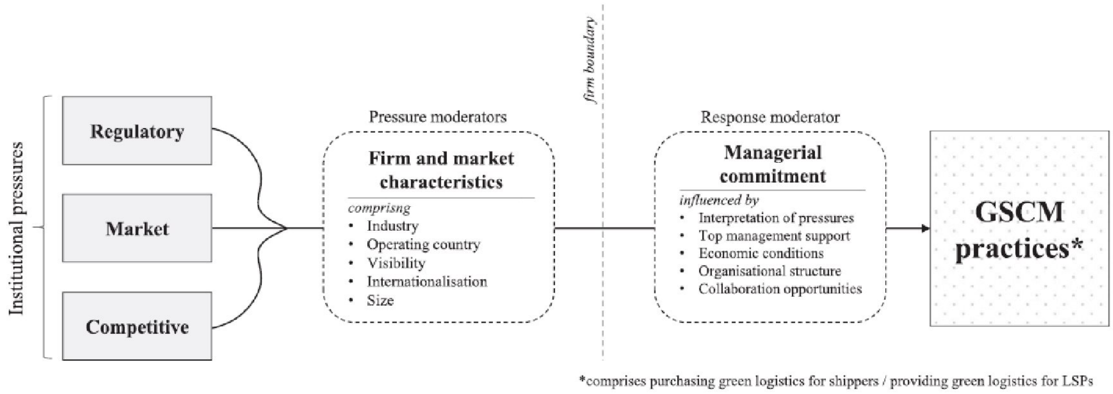

Figure 2. Institutional pressures and pressure/response moderators for GSCM practices [3]

Data was mostly gathered through interviews, and four experts with extensive experience in supply chain management and contract logistics were requested to select the key questions. As a result, it was asserted that what motivates shippers to engage in GSCM activities is closely related to their need for green logistics services from LSPs. Additionally, it was stated that regulatory, market, and competitive pressures are what motivate both players to engage in green behavior. The fact that empirical data for this study came from a relatively small number of cases involving a constrained range of businesses and that every single example was located in either Sweden or Germany was one of its key limitations. [3]

Evangelista (2014) examined LSPs' environmental sustainability initiatives and the elements that influence them both favorably and unfavorably [12]. The used method was based on a two-phase strategy. Two research phases were established following the first phase's thorough literature analysis on the adoption of green initiatives by third-party logistics providers (3PLs) about green initiatives and the primary reasons and challenges that prevent 3PLs from adopting green initiatives. In the second phase, a case study analysis on 13 Italian transport and logistics service providers was done in order to answer the research questions. Three groups of businesses have been identified with slightly distinct environmental profiles in terms of the green activities they have adopted as well as the key motivators and restraints. Due to differences in the scope of services provided and the weight given to environmental issues, the surveyed companies demonstrated varying degrees of involvement in green efforts. The study argued that LSPs anticipate environmental sustainability being a selection criterion in the near future; This trend was mostly caused by two factors. The first was the goal to strengthen client connections by assisting them with their environmental sustainability initiatives. The opportunity to lower expenses (by improving energy efficiency, getting access to subsidies, and lowering taxes) and improve sales (for example, by enhancing brand perception, increasing consumer demand for green products, and attracting new clients) was the second justification. Interview tool mostly consisted of open-ended questions on the general business information, the adoption of green initiatives and the place of sustainability in the corporate strategy, as well as the factors that facilitate and impediment to the adoption of green initiatives has been used. Finally results and discussion on adopted green initiatives, drivers, and barriers were divided into three sections. The first group was interested in going green when operating their vehicles but was more focused on cost effectiveness than sustainability. They viewed environmental sustainability as a source of extra expenses rather than as a chance to strategically differentiate their company. They contended that fierce competition places significant pressure on prices and profit margins in the industry of transportation. Customers have little impact on a company's attempts to go green; instead, investments in sustainability are dependent on the availability of financial incentives and a supporting legislative framework. "Wait and see" strategy. The second team carried out a variety of projects with a larger supply chain participation. Both a driver and a barrier might be the customer. The LSP viewed low customer perceptions of environmental sustainability as a roadblock that prevented the growth of green initiatives. and the LSPs took it into account as a driver when it is deemed to be high. Businesses employed a "reactive" strategy for preserving the environment. The third group was more cooperative and took a "proactive" stance on environmental issues. Their market-focused solution was geared for clients who outsource a sizable portion of their logistics operations and views environmental sustainability as a key component of a LSP service offering. They thought of their customers as partners in their sustainability efforts. These businesses made targeted investments in this field to expressly integrate environmental sustainability into their service offerings. They had the staff members who dedicated themselves to sustainability and routinely measure CO2 savings. Although in conclusion the case study companies under investigation showed little interest in environmental sustainability and this demonstrated how young the Italian LSP market was in 2014 [12].

Roy et.al (2020), investigated to choose the best LSPs from a pool of six viable logistic providers in India for a firm that manufactures food [13]. The selection of sustainability metrics for LSP evaluation, their prioritization, and the best option for a sustainable collaboration partner were the three main research questions. They argued that thorough literature, the goals of sustainability identified as economic, environmental, and social.

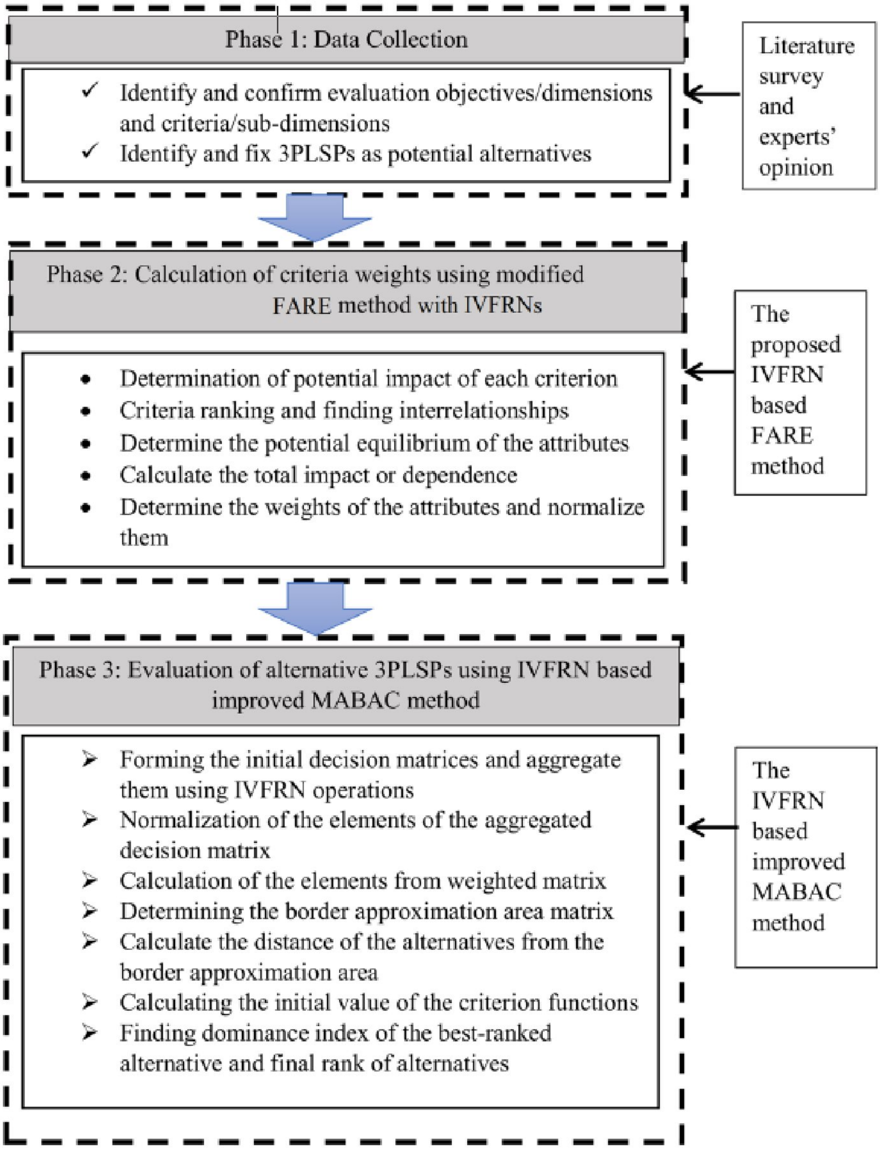

Figure 3 Flow diagram of the research framework [13]

The work process of this study is presented in Figure 3. The key economic, environmental, and social viewpoints on sustainability were classified into fifteen categories. Cost of services, brand and market position, technological know-how, geographic location, resource consumption, adherence to International Organization for Standardization (ISO), green distribution strategies, waste generation, emission, effluents, and health and safety practices, staff training, equitable labor sources, local community influence. They developed a new multi criteria decision making (MCDM) model and combined the factor relationship (FARE) and multi-attributive border approximation area comparison (MABAC) models based on the interval-valued fuzzy-rough number (IVFRN). The method was used in this case because it benefits from both fuzzy sets theory and rough sets theory, two of the greatest methods for dealing with uncertain data. Using this in mind, they first enhanced the IVFRN-MABAC by including the dominance index of alternatives and changed the FARE model using IVFRNs. A hybrid evaluation framework was also presented as result. They argued that benefits include: 1) The straightforward idea and use of a tried-and-true method based on relative evaluations of the criteria, which enables decision-makers to quickly ascertain the weight coefficients of the criteria through comparative comparisons; 2) A mathematical framework that is reliable and easy to adapt to various decision problems depending on the hierarchical structure of the problem itself; and 3) Improvement to each method separately [13].

ORŠIČ et. al. (2019), created a model that illustrates the Third-Party Logistics Green Innovative Framework named (3PL GIF) based on chosen environmental, economic, and social indicators [14]. They argued that the model demonstrated the objective comparability of the current condition and progress in sustainable development between various enterprises engaged in the distribution of commodities which is described in Figure 4. A (Plan-Do-Check-Act) PDCA cycle system of continuous improvement and the use of quality measurement criteria were incorporated into the model's indicators. They compared the success of sustainable operations across several Slovenian logistics companies based on their size, areas of specialization, and places in the supply chain using this model. As result they concluded that the model offers supply chain operators, logistics firms, and the general public that is interested comparisons of sustainable operation. Additionally, it helps supply chain management firms to assess, enhance, and communicate their performance in a sustainable area, as well as to advance toward goals set by the firm with its cycle of ongoing improvement. This enables a fair comparison of corporate progress toward sustainable development.

	Business policy	Performance measurement
Environment	Success of environmental standard use Reduction of energy consumption Reduction of the scope of recycling Reduction of environmental incident	Measuring and reporting on environmental performance Reduction of emissions into the air Reduction of water pollution and consumption Reduction of solid waste
Social	Improvement of employee social security Improvement of logistical production safety Improvement of working conditions	Improvement of work environment quality Increase of preventive measures Reduction of accidents Increase of education
Economy	Market share increase Income and profitability increase Operation by code of conduct Economic effort to ensure green production	Cost reduction due to lean logistics Cost reduction per Stock Keeping Unit(SKU) Improvement of transportation economic efficiency Reduction of energy, waste water, waste costs

Figure 4 Structure of 3PL GIF indicators [14]

ORŠIČ et. al. (2019), surveyed and interviewed the main Slovenian enterprises to determine the significance of sustainable regions [14]. The 3PL GIF model was argued that it could be a tool that gives businesses and the entire supply chain information on the effectiveness of the implementation of logistics services and the development of the most crucial sustainability components, with straightforward comparisons between various businesses and a successful system for structured and simple reporting. As a result, they categorized four types of stakeholders who are interested in the data from the 3PL GIF: Managers of certain logistics businesses who want to run more productively. Managers of the entire supply chain who have the ability to select better performers in the sustainable industry. Clients of logistical services provided by outside contractors. Final purchasers of goods so they may learn which businesses a certain product interacted with along the supply chain [14].

Gupta et.al. (2021) suggested a strategy for choosing the best LSP based on sustainable service quality [10]. On the basis of a literature review and subsequent focused group discussions, a total of seventeen characteristics related to sustainable service quality were finalized. A questionnaire-based survey was used to gather information from 150 LSP clients. Data was analyzed using factor analysis, and five factors—Commitment, Competence, Communication, Creativity & Customization, and Coordination and Collaboration—were identified from the seventeen sustainable service quality criteria. This framework was also used to show how to choose the best LSP based on long-term service quality. Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Fuzzy Analytic Hierarchy Process (AHP) approaches were combined to analyze the above features. Finally, an actual case study was used to explain this framework for making decisions. To verify the robustness of the suggested framework Figure 5, sensitivity analysis was also performed. As result they reached to a conclusion that the focus area for LSPs should be the development of capabilities for the implementation of sustainable practices. Their findings showed that in order to win over clients, logistics providers should put a greater emphasis on communication with all stakeholders, with fast pace, providing dependable green services with high flexibility, and optimizing sustainable networks. They claimed that LSPs will be able to design their strategies for providing sustainable service quality to clients with the use of the study's insights. Their results also suggested that logistics service providers should work to enhance their capabilities, including green warehousing, an environmentally friendly fleet, and cost optimization, for the proper implementation of sustainable practices [10].

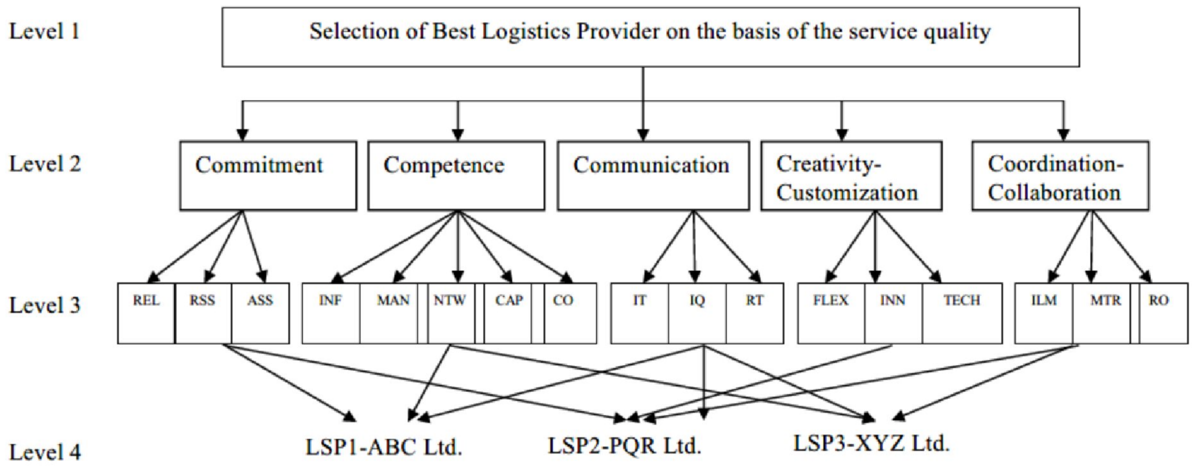

Figure 5 Proposed Framework for Selecting Best Logistics Provider [10]

Numerous authors have identified various facets of logistics and connected them to sustainability. Logistics providers can increase their profitability and competitiveness by incorporating green practices. [15] Several authors have investigated the connection between the adoption of sustainable practices, superior customer service, and business excellence in the literature. Results typically indicated a favorable effect of using green practices on service excellence and business excellence. [16] Few authors have also discussed the difficulties and dangers involved in achieving sustainability goals, despite the majority of research highlighting the benefits of include sustainability in logistics performance. The crucial success elements for achieving sustainable service quality by logistics providers have been identified and highlighted. Some authors have discovered that logistics companies in poor nations have started implementing green practices after realizing their significance and contribution to cost savings and environmental protection. [10] From the review, it can be shown that while many writers emphasize the need for logistics providers to deliver high-quality service, most studies neglect to include a sustainability element. When choosing logistics service providers, it is imperative to consider sustainability factors in addition to other service quality factors. The absence of frameworks incorporating sustainability factors in service quality when choosing logistics service providers is one of the key research gaps found in the literature evaluation. This offers plenty of room for framework development that helps clients choose a suitable logistics supplier based on long-term service quality. Therefore, by completing the research objectives outlined in section 3, the study will add to the body of literature already in existence.

5. Thesis objectives

I. Preparing a long list of sustainable service quality parameters important for logistic industry through literature review, then shortlist the parameters using the questionnaire filled by experts in sustainability and logistics of Aker Solutions AS Company.

II. Using literature review and focus group discussion to categorize the shortlisted sustainable service quality attributes into main criteria.

III. Applying fuzzy AHP for ranking the sustainable service quality attributes and proposing a framework to rank the logistics service providers with consideration of sustainability qualities.

6. Methodology

6.1 AHP Hierarchy

AHP models can be used in both individual and group decision-making settings and can take into consideration the decision-makers' experience as well as some consistency that is normal in human judgment. AHP consists of the following four basic steps: organizing and developing the hierarchy, identifying priorities, defining consistencies, and evaluating and rating. It uses pair-wise comparison matrices to produce ratio scales for both qualitative and quantitative inputs. With a stepping increment of 2, Saaty [7] employed a discrete paired scale with a bottom bound of 1 and an upper bound of 9. To put it another way, the values of the pairwise comparison can range from [1/9: C_1 is of little importance relative to C_2] to [9: C_1 is extremely important relative to C_2, 7: C_1 is very important relative to C_2,...] when two criteria, C_1 and C_2, are compared in terms of their relative importance to one another, from the perspective of a decision maker. The AHP relative judgment scale is shown in Table 1 describe the pairwise comparisons that are considered to be more important, and Table 2 identify pairwise comparisons that are less important.

Table 1 Weighting Scale of Pairwise Comparison: More Important [7]

Relative importance of a factor compared with any other factor	Scale
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate judgments	2,4,6,8

Table 2 Weighting Scale of Pairwise Comparison: Less Important [7]

Relative Importance of a factor compared with any other factor	Scale
Equally important	1
Moderately less important	1/3
Strongly less important	1/5
Very strongly less important	1/7
Extremely less important	1/9
Intermediate judgment levels	1/2,1/4,1/6,1/8

In order to describe it more clearly, any two characteristics such as F_x and F_y can be considered. According to Table 1, the relative importance of F_y as compared to F_x is equal to 5 if F_y is significantly more important than F_x. On the other hand, the reciprocal of 5, or 1/5, represents the relative importance of F_x in relation to F_y. This implies the existence of Table 2, which shows the less important pairwise comparison scale.

According to studies, the human brain divides behavioral components into hierarchically organized sequences [17]. Saaty [7] said that our brains work like a step-by-step ladder, where we break big problems into smaller pieces. This helps us understand complex problems better. Building a hierarchy that shows the hierarchical link between various system variables and components is the first stage in creating an AHP model. The best way to describe the AHP technique is as a hierarchical structure of criteria and options. This is how a four-level structure would be constructed: Level 1: The objective of the analysis, Level 2: The criteria considered in achieving the objective, Level 3: The sub-criteria and Level 4: Alternatives. Figure 6 indicates a hierarchy with four levels where each criteria has two sub-criteria. The multi-attribute analysis of this structure will follow the following steps [18]:

Step 1: Consider the relative weight of each criterion in accomplishing the goal.

Step 2: Give each sub-relative criteria's importance to the main criterion it belongs to weighting.

Step 3: Consider how much each choice contributes to each criterion and its sub-criterion. Using the information from stages 1, 2, and 3, pick the best option.

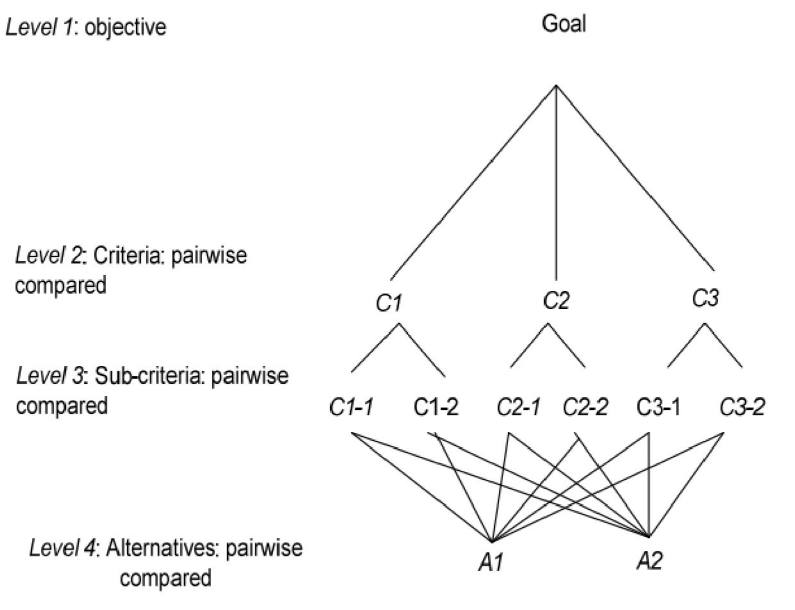

Figure 6 AHP hierarchy with sub criteria [18]

6.2 AHP Judgment Matrix

Saaty et al. (1980) carried out the examination of comparison scaling and weighting by means of the judgment matrix [7]. A judgment matrix is made for each criterion, sub-criterion, and alternative. Using the scales provided in Table 1 and Table 2, the entries in these matrices represent the relative weights of the elements (criteria, sub-criteria, or alternatives) in relation to one another. Since each criterion or alternative is equally important to itself, start by placing 1s in the diagonal table where rows and columns match. The remaining values in the matrix are then filled in by the decision-makers, experts, or whoever is tasked with grading the criteria, sub-criteria, and alternatives using the pairwise scale. The following numerical example illustrates this idea. There are n criteria are considered, $C_1, C_2, \ldots, C_n$. Every matrix's diagonal, which represents the comparison of an element to itself, should have a value of 1.

X	C_1	C_2	C_3	………	C_n
C_1	1	a_{12}	a_{13}		a_{1n}
C_2	$\frac{1}{a_{12}}$	1	a_{23}		a_{2n}
C_3	$\frac{1}{a_{13}}$	$\frac{1}{a_{23}}$	1		a_{3n}
⋮					
C_n	$\frac{1}{a_{1n}}$	$\frac{1}{a_{2n}}$	$\frac{1}{a_{3n}}$		1

where $a_{ii} = 1$, $a_{ji} = \frac{1}{a_{ij}}$, and $i, j = 1, 2, 3 \ldots, n$

In order to obtain the priority weights (W_i), the matrix will need to be first normalized. The value in each cell in a column is divided by the sum of all the values in that column:

$$W_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

The eigenvector of the normalized matrix is then computed and becomes the relative weight of each sub-factor (W_i):

$$W_i = \frac{\sum_{j=1}^{n} W_{ij}}{n}$$

Since the pair-wise comparison process is in part based on input containing human judgment, the consistency of the values derived from the pair-wise comparison requires validation. The validation process ensures that the priority values have an acceptable margin of error. In this work, consistency check was performed by the Consistency Ratio which is calculated as the ratio of Consistency Index (CI) to the Random Index (RI): (CR) test.

$$CR = \frac{CI}{RI}$$

CI is then calculated by:

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

where n is the number of factors and X, max is the maximum eigenvalue of the matrix. An acceptable consistency ratio should be less than 10%. λ_{max} is the sum of the product of the priority vectors by the column totals. The RI value is directly related to the size of the matrix and is shown in Table 3 below:

Table 3 Random Index [18]

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

6.3 Theory of Probability and Uncertainty

The theory of fuzzy and its valuation with its many variations is the mathematical tool to deal with uncertainty, while the theory of probabilities is the theory used relative to chance [18]. Uncertainty and chance do not coincide to the same level of information. This leads to the conclusion that uncertainty is deficiently structured and it is subjectively explained. On the other hand, the concept of probability is linked to chance which is like a measurement based on repeated observations in time and/or space. Thus, probability constitutes an evaluation that, if desired, can be as objective as possible.

According to Gil-Aluja (2004), the classification of models intended to solve problems can fall into one of the following categories ranging from the uncertain to the known [19]:

1. Nondeterministic with unknown situations.
2. Nondeterministic with known possible situations but the assignment of an objective scale of value to them is not known.
3. Nondeterministic with situations and events that can be evaluated but not measured.
4. Nondeterministic with known situations and with measurable probability events.
5. Deterministic model in which the situations are known, and a hypothesis can be considered that the event of a specific situation is known.

From an optimum point of view, one should build a model based on category 5 in which all parameters of the decision are predetermined. The cost in this case may inhibit such action and force researchers to stop at category 3. In this case the model deals with the most general of theories that can describe an uncertain environment, namely the theory of fuzzy logic.

6.4 Fuzzy Logic

Dr. Lotfy Zadeh, in 1965, proposed a theory called fuzzy sets [18]. According to Zadeh's definition, a fuzzy set is a class of elements or objects that lack definite 58 boundaries between them. The fuzzy logic is useful to define objects which are characterized by vagueness and uncertainty. Fuzzy logic is a multivalued theory where intermediate values are expressed in a range, such as high, moderate, or low, instead of yes or no, true, or false as in the classical crisp logic theory [18]. The fuzzy sets are defined by the membership functions. The fuzzy sets represent the grade of any element x of space X that have partial membership in A (where A is a fuzzy set). The degree to which an element belongs to a set is defined by the value between 0 and 1. An element x really belongs to A if $\mu(A(x) = 1$, and clearly not if $\mu(A(x) = 0$. As the value of $\mu(A(x)$ moves toward 1, the degree of membership of an element x increases in a fuzzy set A. Therefore, if $\mu(A(x) = 0.5$, then we can say x somewhat belongs to A. On the other hand, if $\mu(A(x) = 0.8$, then we can say x has a strong membership in A.

6.4.1 Fuzzy Numbers and Linguistic Variables

In this section, some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from Buckley (1985), Kaufmann and Gupta (1991), Negi (1989), and Zadeh (1975). The basic definitions and notations below will be used throughout this research unless otherwise stated [18].

Dubois and Prade (1980) defined a triangle fuzzy number (TFN) as a special class of fuzzy number whose membership defined by three real numbers, expresses as (l, m, u) with the following properties:

$$\mu A(x) = \begin{cases} x - l / m - l, & l \leq x \leq m, \\ u - x / u - m, & m \leq x \leq u, \\ 0, & otherwise. \end{cases}$$

Where m is the most possible value of a fuzzy number A, also known as the modal [20], l and u are the lower and upper bound, respectively. If the element falls before or beyond them, it will have no membership to the set. Note that $\mu A(x) = 0$, if $x < l$ and $x > u$. This is shown in Figure 7 , $x < l$ and $x > u$ will have no membership in the fuzzy number A = (l, m, u).

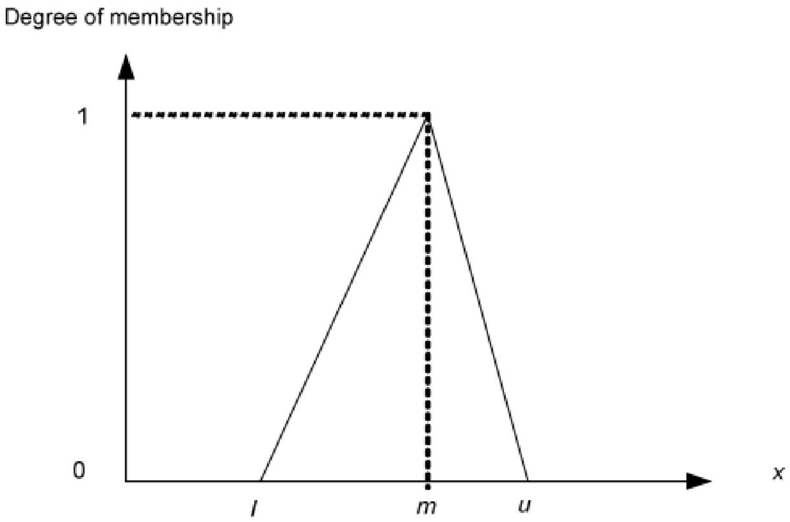

Figure 7 Graphical representation of triangular fuzzy number [20]

Operations on Triangular Fuzzy Numbers Here are some of the fuzzy arithmetic operations on triangular fuzzy numbers. Let A and B be two triangular fuzzy numbers where A = (la, ma, ua) and B = (lb , mb , ub), where l, u are the lower and upper bounds of each of the triangular fuzzy number and m represents the middle value. Addition: A + B = (la + lb , ma + mb , ua+ ,ub). Subtraction: A - B = (la - lb , ma - mb , ua - ub). Multiplication: A.B = (la. lb , ma. mb , ua ub): Scalar multiplication: ∀k greater than ,0 k ∈ R, kA = (kla, kma, kua) This mathematical formulation reads: for every scalar value k greater than 0 and k belong to the set of real numbers R. If k is multiplied by a fuzzy number A = (la, ma, ua), then the result is a new fuzzy number that is equal to (kla, kma, kua). Division:

$$\frac{A}{B} = \left\langle \frac{la}{ub}, \frac{ma}{mb}, \frac{ua}{lb} \right\rangle$$

Inverse:

$$A^{-1} = \left\langle \frac{1}{ua}, \frac{1}{ma}, \frac{1}{la} \right\rangle$$

6.5 Fuzzy AHP

Using the use of triangular fuzzy numbers for the pairwise comparison scale of fuzzy AHP and the extent analysis method for the synthetic extent values of the pairwise comparisons, Chang (1996) presents a new method for handling fuzzy AHP [21]. The fuzzy analytical hierarchy method, which Cheng (1997) provides, is a new technique for evaluating naval tactical missile systems based on the grade value of the membership function [22]. The steps of the Fuzzy AHP method have been applied for ranking the attributes and factors as discussed in the proposed framework. Pair-wise comparison of all the factors at each level is done based on the linguistic scale as shown in Table 4 [10].

Table 4 Linguistic scale for importance weight of each factor [10]

Linguistic variable	Triangular fuzzy numbers
Equally Important	(1,1,1)
Weakly Important	(2/3, 1, 3/2)
Fairly Important	(3/2, 2, 5/2)
Strongly Important	(5/2, 3, 7/2)
Absolutely Important	(7/2, 4, 9/2)

This is a pair-wise comparison matrix based on the linguistic scale in Fuzzy AHP:

$$\tilde{A} = [\tilde{a}_{ij}] = \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ n \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & \dots & n \end{array} \\ \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{a}_{nn} \end{bmatrix} \end{array}$$

In the following, first the outlines of the extent analysis method on fuzzy AHP are given and then the method is applied to rank the sustainable logistics provider attributes.

Let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set $U = \{u_1, u_2, \ldots, u_m\}$ and be a goal set. According to the method of Chang's (1992) extent analysis, each object is taken and extent analysis for each goal, g_i; is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs [22]:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m, \quad i = 1, 2, \ldots, n,$$

Step 1: The value of fuzzy synthetic extent with respect to the i_{th} object is defined as:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}.$$

To obtain summation; perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=i}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right)$$

and to $[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j]^{-1}$ obtain; perform the fuzzy addition $M_{g_i}^j \ (j = 1, 2, \ldots, m)$ operation of

values such that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right)$$

and then compute the inverse of the vector in the previous Equation such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right).$$

Step 2: The degree of possibility of $M_2=(l_2,m_2,u_2) \geq M_1=(l_1,m_1,u_1)$ is defined as:

$$V(M_2 \geqslant M_1) = \sup_{y \geqslant x} \left\lfloor \min(\mu_{M_1}(x), \mu_{M_2}(y)) \right\rfloor$$

And can be equivalently expressed as follows:

$$V(M_2 \geqslant M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1, & \text{if } m_2 \geqslant m_1, \\ 0, & \text{if } l_1 \geqslant u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise}, \end{cases}$$

where d is the ordinate of the highest intersection point D between µM1 and µM2 (see Figure 8).

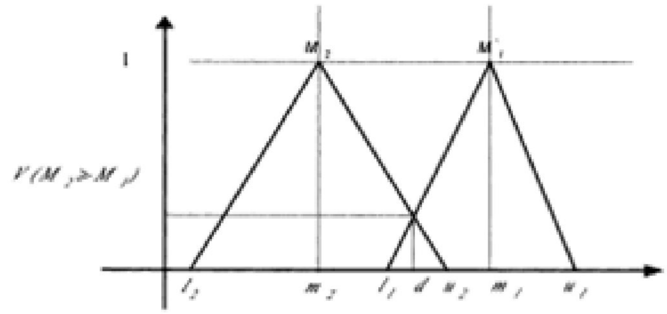

Figure 8 The Intersection between M1 and M2

To compare M_1 and M_2; we need both the values of $V(M_1 \geqslant M_2)$ and $V(M_2 \geqslant M_1)$.

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i(i=1,2,\ldots,k)$ can be defined by

$$\begin{aligned} V(M \geqslant M_1, M_2, \ldots, M_k) &= V[(M \geqslant M_1) \text{ and } (M \geqslant M_2) \text{ and } \ldots \text{ and } (M \geqslant M_k)] \\ &= \min V(M \geqslant M_i), \; i = 1, 2, 3, \ldots, k. \end{aligned}$$

Assume that:

$$d'(A_i) = \min V(S_i \geqslant S_k).$$

For k=1,2,…,n; k ≠ i. Then the weight vector is given by:

$$W' = (d'(A_1), d'(A'_2), \ldots, d'(A_n))^{\mathrm{T}},$$

Where A_i (i=1,2,…,n) are n elements.

Step 4: Via normalization, the normalized weight vectors are:

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^{\mathrm{T}},$$

Where W is a nonfuzzy number.

6.6 Inconsistency Ratio in Fuzzy AHP

Inconsistency rate is an index that measures the consistency of experts' responses to evaluations and pairwise comparisons. In other words, with the help of the inconsistency rate index, it is possible to find out whether there is consistency between two-by-two and pairwise comparisons in our questionnaires. Gogus and Boucher (1998) developed a method for calculating the inconsistency ratio of fuzzy pairwise comparison matrices, which its steps are given as follows [23].

STEP 1: Transform a triangular fuzzy matrix into two independent matrices. At this step, a triangular fuzzy matrix is divided into two matrices, assuming that the triangular fuzzy number is presented as follows.

$$A_i = (l_i, m_i, u_i)$$

Then, we will get,

The first matrix can be created by middle numbers of the triangular fuzzy matrix, that is:

$$A_m = [a_{ijm}]$$

The second matrix can be created by the geometric mean (GM) of the upper and lower bounds of the triangular fuzzy matrix, that is:

$$A_g = [\sqrt{a_{iju} a_{ijl}}]$$

STEP 2: Compute the weight vector based on the saaty method and calculation of ƛ (max)

STEP 3: Calculate the consistency index (CI): for each matrix, the CI can be calculated based on the following equation:

$$CI_m = \frac{\lambda^m_{max} - n}{n - 1}$$

$$CI_g = \frac{\lambda^g_{max} - n}{n - 1}$$

STEP 4: Calculate the consistency ratio (CR) of the matrices in Problem. In order to compute the CR, the consistency index (CI) of each matrix is divided by its random index (RI).

$$CR_m = \frac{CI_m}{RI_m}$$

$$CR_g = \frac{CI_g}{RI_g}$$

If the values of CR_m and CR_g are less than 0.1, the matrices are consistent.

The values of the RI given by Gogus and Boucher method are different from those in the saaty method. Gogus and Boucher redeveloped the random indices (RI) Table for fuzzy pairwise comparison matrices with creating 400 random matrices. The following table presents the values of the RI for each matrix of Gogus and Boucher method [23].

Table 5 The Values of the RI_m and RI_g [23]

n	RI_m	RI_g
1	0	1
2	0	2
3	0.4890	0.1796
4	0.7937	0.2627
5	1.0720	0.3597
6	1.1996	0.3818
7	1.2874	0.4090
8	1.3410	0.4164
9	1.3793	0.4348
10	1.4095	0.4455
11	1.4181	0.4536
12	1.4462	0.4776
13	1.4555	0.4691
14	1.4913	0.4804
15	1.4986	0.4880

7. Results and Discussion

7.1 Shortlisting and Categorization of Sustainability Attributes

In this study a thorough literature research was used to identify 37 sustainable service quality attributes of logistics providers with the focus and relevancy to the energy industry requirements. The literature chosen for this study covered a wide range of industrial specialties and geographical regions and some additional items also have been added in the focus group discussions. Focused Group Discussions (FGD) have therefore been conducted to understand the needs of logistic provider customer experts in the Aker Solutions AS organization in order to prioritize the crucial elements of the service quality that must be provided. Six industry professionals with extensive knowledge of supply chain management logistics and sustainability and environment were taken into consideration for this study. The experts were specifically chosen from supply chain management in order for the findings to be applicable to the choice of logistics service providers supplying the business. In order to complete a short list of sustainable service quality attributes based on their significance and relevance, rounds of conversations and questionnaires were conducted with experts and they have identified and valued the attributes (see Appendix A the questionnaires). Many of the traits, in the opinion of experts, are redundant and overlap. All attributes have been reviewed and discussed in the meetings and then ranked based on the relevancy and importance for energy industry. After receiving the responses from the questionnaires, the higher ranked attributes have been extracted and shortlisted. We have chosen 19 sustainable service quality attributes, which are presented in Table 6, based on expert input.

After shortlisting the attributes, an extensive review of literature has been conducted in order to categorize the attributes and the results have been discussed in the meetings with FDG from company SCM and sustainability department. Based on the expert opinions a categorization system has been developed. In this new categorization, the company`s existing evaluation categories for logistic service providers have been enhanced by the addition of sustainability evaluation, marking a positive and necessary advancement in the field. The newly integrated sustainability assessment comprises all crucial aspects, including analyzing the provider's environmental impact through carbon footprint reduction, eco-friendly operational practices, and emissions management. Furthermore, it involves examining their commitment to schedule, keeping the quality while ensuring the green processes and cost optimization policies. Supply chain sustainability is also evaluated, considering partnerships with eco-conscious LSPs, sustainable sourcing efforts, and adherence to international standards. Additionally, the logistic service provider's adoption of innovative and sustainable technologies, such as renewable energy utilization and intelligent routing systems, can be assessed. The incorporation of green certifications and accreditations, and transparent reporting further strengthens the comprehensive evaluation process. By embracing interdisciplinary perspectives and real-time data-driven decision-making, the categorization system enhances organizational resilience and competitive advantage. Aligned with sustainability principles, it reflects the company's commitment to long-term success in an ever-changing business environment.

The results are shown in Table 7. These six main factors that categorize all the attributes, are named as Schedule, Cost, Quality, Infrastructure, Digitalization and Innovation and Health, Security, Safety and the Environment (HSSE). From Table 7, it can be observed that under schedule, three sustainable service quality attributes Integrated Sustainable Logistics Management, responsiveness towards green practices, and On-time Delivery are grouped. Logistics companies must fulfill their pledges to implement sustainability by providing their promised deliveries with integration, responsiveness, and on-time [24]. Integrated Sustainable Logistics Management shows incorporation of sustainable practices whereas responsiveness towards green practices and on-time delivery fulfills LSP dedication to schedule by delivering shipments on promised time through green processes.

The second factor Cost comprises of Cost optimization, Effective Shipment Planning and Combine and Consolidate Cargo. In existing evaluation frameworks LSPs majorly compete on their costs and this feature usually act as differentiating factors among service providers and affect the selection decision [25]. One of the challenges that LSPs are facing is to optimize the costs using green resources and use green practices to become more competitive. To optimize the costs two of the most effective ways are effective planning and combining the cargos. The shipment planning optimization or capability of LSPs to consolidate the volume of tasks efficiently can create an additional value for the service providers and reduce the carbon footprint significantly. With growing environmental concern, shipment consolidation has emerged as a key strategy among logistics service providers to minimize CO_2 emissions and transportation costs [26]. Green and sustainable logistics is always defined with well-planned shipments using modern logistics technology and environmental management with the goal of lowering pollutant emissions and increasing logistics efficiency [27].

Table 6 Shortlisted Sustainability Attributes

S. No.	Attributes	Meaning/Definition
1	Responsiveness	Ability to use green practices and provide prompt service to react to customers more quickly
2	Safety	Handling Packages Safely
3	Green infrastructure	A sufficient number of environmentally friendly vehicles and green storage facilities are available
4	Alternative Fuels	Ability to use alternative fuels such as Biofuel, Biogass, Electric, Amonia, Hydrogen as part of their fuel
5	Accuracy	Ability to deliver the right product to the right location and to the right client using sustainable methods
6	Green Assurance	Ability to transport goods using sustainable methods and ensuring that deliveries are made using environmentally friendly methods
7	On-time Delivery	Delivering products on time and using sustainable methods
8	Green Manpower	Having a sufficient number of trained staff available to adopt and execute green practices
9	Cost optimization	Make the cost of their green services as affordable as possible
10	Emission Requirement	Ability to audit the emissions for each activity in the logistic processes and provide Type III Environmental Product Declaration (EPD) based on standard
11	Reliability	Capability to execute promised services using sustainable methods with high reliability
12	IT support	Equipped with sufficient IT resources to encourage the use of green projects
13	Optimization of information quality	The regularity, excellence, and accuracy with which the customer is provided with information
14	Integrated Sustainable Logistics Management	Coordinating and incorporating sustainable practices with all participants in the supplier chain Including other supply chain partners and working together to execute sustainably
15	Mutual Trust and Relationship	Supply chain partners must have mutual understanding and trust in one another
16	Effective Shipment Planning	All cargoes' effective route plans and all shipments' effective route plans
17	Innovation capability	Providing customers with innovative, personalized services in a way that is sustainable for the climate and advances green supply chain management
18	Attitude towards customer green requirements	Attitudes toward customers' sustainable requirements and uphold honesty and desire to help in those
19	Combine and Consolidate Cargo	Ability to Combine and Consolidate Cargo between different client to reduce emissions and make ready the infrastructure for that

Table 7 Categories of Sustainable Service Quality Attributes

Category	Sustainability Attributes
Schedule of Services (1):	Integrated Sustainable Logistics Management
	Responsiveness towards green practices
	On-time Delivery
Cost of Services (2):	Cost optimization
	Effective Shipment Planning
	Combine and Consolidate Cargo
Quality of Services (3):	Reliability for green services
	Accuracy in delivering goods through green operations
	Assurance for green operations
Infrastructure (4):	Green infrastructure
	Manpower for implementing green operations
	Using Alternative Fuels
Digitalization and Innovation (5):	IT support for green practices
	Optimization of information quality
	Emission Auditing Service Infrastructure
	Innovation capability
HSSE (6):	Safety in handling shipments
	Mutual Trust and Relationship
	Attitude towards customer green requirements

The third factor, quality, is also considered an important part of the evaluation of logistics services by customers. It consists of Reliability for green services, Accuracy in delivering goods through green operations and Assurance for green operations. Reliability for green services demonstrates logistics firms' commitment to delivering cargo without fail by using sustainable methods. Assurance for green operations denotes the assurance of delivering damage-free shipments using environmentally friendly resources and methods.

The fourth Infrastructure factor is summarizing green infrastructure, Manpower for implementing green operations and Using Alternative Fuels. In reality, logistics companies compete primarily on the availability of green assets and resources for implementing sustainable practices. Competitive features are typically used to differentiate service providers and influence selection decisions [25]. Logistics providers' green infrastructure includes a dedicated and eco-friendly fleet as well as green facilities outfitted with sustainable and natural resources to service customers in an eco-friendly manner. Manpower is also trained to make the best use of green resources and to employ green practices in order to be more competitive. As the transportation sector moves toward incorporating cleaner fuels to meet with increasing environmental requirements, the need for alternative fuels will continue to rise. Subsequently, the demand for shipping companies and port operators to modify their vessels to run on cleaner fuels will not only rise over time, but it will also yield significant commercial benefits for those willing to make an early transition [28].

The fifth factor Digitalization and Innovation include IT support for green practices, Optimization of information quality, Emission Auditing Service, and Innovation capability. Quality communication between source and destination via digital processes can save time, money, and resources. Furthermore, the use of information, communication, and technology (ICT) has improved the accuracy and effectiveness of coordination among all parties involved and has a direct impact on the efficiency of supply chain performance by allowing for easy tracing and tracking of shipments [29]. The quality, frequency, and accuracy of information distribution via digital techniques have a significant impact on the total service quality given. The time spent by logistics providers to handle enquiries and respond to customer issues with appropriate solutions might make a difference in logistics providers' long-term service quality [30]. When it comes to measuring sustainability performance, most companies are not transparent regarding the emissions generated by their whole supply chain or how they intend to reduce overall emissions. The lack of transparency in sharing the entire carbon emissions or impact caused by a company's actions is a key flaw in current sustainability reporting. Companies should offer a comprehensive picture of the emissions generated by their internal operations as well as the activities of their suppliers, including year-on-year changes in Scope 3 emissions. This will be critical in determining the future viability of coordinated decarbonization activities. This will also enable for proper sustainability evaluations based on precise data [31]. Greening procedures and service innovation work together to help logistics companies' management with increased globalization and unknown market risks. In today's world, logistics companies must deliver customized and innovative services by leveraging

cutting-edge technology and changing manual operations into digital ones. The use of digital platforms such as e-invoicing, e-way bills, GPS tracking, and warehouse management software, among others, improves paper-less procedures while also saving money and time [32].
The Sixth factor HSSE include Safety in handling shipments, Mutual Trust and Relationship, and Attitude towards customer green requirements. A solid relationship between intermediaries and mutual trust can lead to resource sharing, effective decision making, and long-term collaboration. Logistics providers maximize available resources by encouraging the use of natural and renewable resources [33]. Safety is crucial because it protects human life, especially in areas like logistics where a deadly mistake can be disastrous. Safety reduces risks to people, and processes and reviewing the HSSE reports should be one of key elements of evaluation.

7.2 Fuzzy AHP based Analysis

Following the identification of six criteria from the preceding investigation, a 6-factor framework is provided to comprehend the hierarchy of logistics provider selection. Customers also want a ranking of features and attributes when selecting the best logistics service provider. Several academics have used analytical approaches to rate the components in the literature. Vendor selection is a significant and difficult business subject addressed by numerous writers using a variety of analytical methodologies. Researchers have weighed the advantages of one analytical instrument over another, and fuzzy AHP has become popular due to its superiority over other methodologies. Fuzzy AHP was used in this thesis to rank the sustainable service quality features and associated determinants. The benefit of Fuzzy AHP over other approaches is that it captures experts' uncertain imprecise judgment in pair-wise comparisons. Its straightforward and easy techniques make it more generally applicable than other MCDM tools, however it does have some limits. The biggest limitation of utilizing Fuzzy AHP is that it does not account for factor correlation. It also does not provide a solution when two or more alternatives provide the same result. When there are a large number of choices, managing pairwise comparisons becomes problematic [34]. Despite its shortcomings, it has been determined to be the best way for dealing with minor concerns such as personal or business preferences.
The AHP's primary premise is to do pair-wise comparisons to determine accurate ratio scale priorities. This is the technique for determining the priorities of two factors by comparing their relative importance to another factor at the next higher level of the hierarchy. Because a group interactive session to select priorities was ruled out, it was decided that individual judgements

would be gathered by sending questionnaires to those with relevant experience. The mean of the individual weights can then be used to calculate group weights. To get priority weights for the factors stated in Appendix B, a questionnaire was created. The questionnaire contains 36 questions that are made up of redundant pair-wise comparisons designed to assess respondents' opinions on the importance of the items being compared. For the questionnaire, the pair-wise comparison method was used because to its capacity to precisely define participants' perceptions, quantify alternatives, and indicate preference for all alternatives.

In April 2023, a comprehensive questionnaire was distributed to professionals in Environmental Specialists and Supply Chain Management & Logistic Specialists at Aker Solutions AS in Norway, seeking their opinions on the importance ratios among various factors. The survey aimed to gain insights into critical aspects impacting environmental practices and supply chain operations within the company. By analyzing the responses from diverse roles and departments, the survey aimed to inform decision-making processes, prioritize key factors, which are aligned with the organization's strategies for sustainability and efficiency improvement. The survey findings are expected to serve as a valuable reference point for Aker Solutions AS, contributing to a more environmentally responsible and robust supply chain, setting an example for the industry. The focus of this initiative is on individuals possessing over a decade of project experience in supply chain management and a demonstrated track record of overseeing and monitoring their respective company's progress towards sustainability. By targeting such seasoned professionals, the aim is to leverage their wealth of expertise and industry insights to propel the organization closer to its sustainability goals outlined in the company roadmap. Through their strategic guidance and in-depth knowledge of supply chain dynamics, these adept individuals will play a pivotal role in driving sustainable practices, fostering environmentally responsible decisions, and ultimately ensuring the company's commitment to a greener, more responsible future. The cover page of the questionnaire explained the rating scale and the nature of the comparison and asked the experts to indicate their job position. Participants were asked to compare the importance of pairs of factors and assign a weight to the importance based on a 1-9 scale of importance.

The questionnaire was set up with seven sets of questions. The first set compared comparing the categories in selection of the best sustainable Logistic Service Provider. The second to seventh part is to compare pair categories attributes with each other.

Based on the expert’s view, comparison of main and sub-criteria is assessed and included in Table 8.

Table 8 Pair Wise Comparisons of main criteria Using Linguistic Terms

	Schedule	Cost	Quality	Infrastructure	Digitalization and Innovation	HSSE
Schedule	Equally important	Equally important	Reverse comparison to Strongly important	Weakly important	Weakly important	Equally important
Cost	Reverse comparison to Equally important	Equally important	Equally important	Reverse comparison to Weakly Important	Weakly important	Equally important
Quality	Strongly important	Reverse comparison to Equally important	Equally important	Equally important	strongly important	Equally important
Infrastructure	Reverse comparison to Weakly important	Weakly Important	Reverse comparison to Equally important	Equally important	Weakly important	Equally important
Digitalization and Innovation	Reverse comparison to Weakly important	Reverse comparison to Weakly important	Reverse comparison to strongly important	Reverse comparison to Weakly important	Equally important	Reverse comparison to Weakly important
HSSE	Reverse comparison to Equally important	Reverse comparison to Equally important	Reverse comparison to Equally important	Reverse comparison to Equally important	Weakly important	Equally important

Table 9 Triangular Fuzzy Numbers

Linguistic variable	Triangular fuzzy numbers
Equally Important	(1,1,1)
Weakly Important	(2/3, 1, 3/2)
Fairly Important	(3/2, 2, 5/2)
Strongly Important	(5/2, 3, 7/2)
Absolutely Important	(7/2, 4, 9/2)

In the next step, each variable in the scale is mapped to a triangular fuzzy number. Table 10 shows assessment of fuzzy evaluation matrix with respect to the criteria by the triangular fuzzy number stated in the Table 9:

Table 10 Assessment of fuzzy evaluation matrix

	Schedule	Cost	Quality	Infrastructure	Digitalization and Innovation	HSSE
Schedule	(1,1,1)	(1,1,1)	(2/7,1/3,2/5)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)
Cost	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)
Quality	(5/2,3,7/2)	(1,1,1)	(1,1,1)	(1,1,1)	(5/2,3,7/2)	(1,1,1)
Infrastructure	(2/3,1,3/2)	(2/3,1,3/2)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)
Digitalization and Innovation	(2/3,1,3/2)	(2/3,1,3/2)	(2/7,1/3,2/5)	(2/3,1,3/2)	(1,1,1)	(2/3,1,3/2)
HSSE	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(2/3,1,3/2)	(1,1,1)

Due to the fact that the questionnaire related to pairwise comparisons was distributed among 6 experts, in order to check the opinions of all experts, a matrix is formed Table 11, whose numbers are composed of the geometric mean of fuzzy numbers Table 12.

Table 11 Expert Opinions

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Criteria	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Criteria
Q1	Schedule			1	1	3					Cost
Q2	Schedule					1			4		Quality
Q3	Schedule				4		1				Infrastructure
Q4	Schedule			1	3		1				Digitalization and Innovation
Q5	Schedule					2	2	1			HSSE
Q6	Cost					2	1	2			Quality
Q7	Cost			1	1		2	1			Infrastructure
Q8	Cost			1	2		2				Digitalization and Innovation
Q9	Cost					2		3			HSSE
Q10	Quality		1	2		2					Infrastructure
Q11	Quality		4	1							Digitalization and Innovation
Q12	Quality					2	1	2			HSSE
Q13	Infrastructure			1	3	1					Digitalization and Innovation
Q14	Infrastructure					2		3			HSSE
Q15	Digitalization and Innovation						2	3			HSSE

Table 12 Opinions Experts based on Fuzzy Numbers

	Schedule	Cost	Quality	Infrastructure	Digitalization and Innovation	HSSE
Schedule	(1,1,1)	(1,1.15,1.3)	(0.37,0.42,0.48)	(0.67,1,1.5)	(0.78,1.15,1.66)	(0.71,0.87,1.08)
Cost	(0.77,0.87,1)	(1,1,1)	(0.64,0.76,0.92)	(0.78,1,1.41)	(0.78,1.15,1.66)	(0.58,0.66,0.78)
Quality	(2.08,2.38,2.70)	(1.08,1.32,1.56)	(1,1,1)	(1.41,1.52,1.85)	(2.25,2.76,3.27)	(0.64,0.76,0.92)
Infrastructure	(0.67,1,1.5)	(0.71,1,1.28)	(0.54,0.66,0.71)	(1,1,1)	(0.85,1.15,1.53)	(0.58,0.66,0.78)
Digitalization and Innovation	(0.60,0.87,1.28)	(0.60,0.87,1.28)	(0.31,0.36,0.44)	(0.65,0.87,1.18)	(1,1,1)	(0.49,0.65,0.92)
HSSE	(0.93,1.15,1.41)	(1.28,1.51,1.72)	(1.09,1.52,1.72)	(1.28,1.52,1.72)	(1.09,1.54,2.04)	(1,1,1)

All the matrices of pairwise comparisons related to the sub-criteria are formed in the same way in the form of fuzzy numbers and their inconsistency ratio is also checked. To calculate the ratio, as mentioned, two methods have been used, one using the matrix of middle numbers of the triangular fuzzy matrix and the other matrix with the geometric mean of the first and third fuzzy numbers. The matrixes and calculations are shown below Table 13.

Table 13 matrix of middle numbers of the triangular fuzzy matrix

A_m	Schedule	Cost	Quality	Infrastructure	Digitalization and Innovation	HSSE	Sum A_i	W_i	A*W
Schedule	1	1.15	0.42	1	1.15	0.87	5.59	0.1426	0.8674
Cost	0.87	1	0.76	1.1	1.15	0.66	5.54	0.1413	0.8820
Quality	2.38	1.32	1	1.52	2.76	0.76	9.74	0.2485	1.4716
Infrastructure	1	1	0.66	1	1.15	0.66	5.47	0.1395	0.8617
Digitalization and Innovation	0.87	0.87	0.36	0.87	1	0.65	4.62	0.1179	0.7124
HSSE	1.15	1.51	1.52	1.52	1.54	1	8.24	0.2102	1.3589
Sum							39.2		

Landa values are obtained in the following order:

λ1	λ2	λ3	λ4	λ5	λ6	λ^{m}_{max}= Average (λ1,.., λ6)= 6.1551
6.0829	6.2408	5.9225	6.1755	6.0442	6.4646	

$$CI_m = \frac{\lambda\max - n}{n-1} = 0.0310$$

$$CR_m = \frac{CI\ m}{RI\ m} = \frac{0{,}0310}{1{,}1996} = 0{,}0259$$

The second matrix can be created by the geometric mean (GM) of the upper and lower bounds of the triangular fuzzy matrix, that is Table 14:

Table 14 **geometric mean of the first and third fuzzy numbers**

A_g	Schedule	Cost	Quality	Infrastructure	Digitalization and Innovation	HSSE	sum	W	A*W
Schedule	1	1.14	0.42	1	1.14	0.88	5.58	0.1436	0.8662
Cost	0.88	1	0.77	1.05	1.14	0.67	5.51	0.1418	0.8814
Quality	2.38	1.30	1	1.62	2.71	0.77	9.78	0.2518	1.4859
Infrastructure	1	0.95	0.62	1	1.14	0.67	5.38	0.1385	0.8469
Digitalization and Innovation	0.88	0.88	0.37	0.88	1	0.67	4.68	0.1205	0.7233
HSSE	1.14	1.49	1.30	1.49	1.49	1	7.91	0.2036	1.2920
sum							38.84		

Landa values are obtained in the following order:

λ1	λ2	λ3	λ4	λ5	λ6	$\lambda^g{}_{max}$= Average (λ1,.., λ6)= 6.1008
6.0296	6.2132	5.9011	6.1139	6.0025	6.3444	

$$CI_g = \frac{\lambda \max - n}{n-1} = 0.0202$$

$$CR_g = \frac{\text{CI g}}{\text{RI g}} = \frac{0,0202}{0,3818} = 0.0528$$

The values of CR_m and CR_g are less than 0.1, then the matrices are consistent.

Inconsistency ratio is done in the same way for all the matrix of pairwise comparisons. In the following Table 15, the stages of fuzzy hierarchical analysis are shown on each category of criteria.

Table 15 **Matrix of pairwise comparisons**

	Schedule	Cost	Quality	Infrastructure	Digitalization and Innovation	HSSE	$\sum_{j=1}^{m} M\ kl$
Schedule	(1,1,1)	(1,1.15,1.3)	(0.37,0.42,0.48)	(0.67,1,1.5)	(0.78,1.15,1.66)	(0.71,0.87,1.08)	(4.53,5.59,7.02)
Cost	(0.77,0.87,1)	(1,1,1)	(0.64,0.76,0.92)	(0.78,1,1.41)	(0.78,1.15,1.66)	(0.58,0.66,0.78)	(4.55,5.44,6.77)
Quality	(2.08,2.38,2.70)	(1.08,1.32,1.56)	(1,1,1)	(1.41,1.52,1.85)	(2.25,2.76,3.27)	(0.64,0.76,0.92)	(8.46,9.74,11.30)
Infrastructure	(0.67,1,1.5)	(0.71,1,1.28)	(0.54,0.66,0.71)	(1,1,1)	(0.85,1.15,1.53)	(0.58,0.66,0.78)	(4.35,5.47,6.80)
Digitalization and Innovation	(0.60,0.87,1.28)	(0.60,0.87,1.28)	(0.31,0.36,0.44)	(0.65,0.87,1.18)	(1,1,1)	(0.49,0.65,0.92)	(3.65,4.62,6.10)
HSSE	(0.93,1.15,1.41)	(1.28,1.51,1.72)	(1.09,1.52,1.72)	(1.28,1.52,1.72)	(1.09,1.54,2.04)	(1,1,1)	(6.67,8.24,9.61)

$\sum_{i=1}^{n}\sum_{j=1}^{m} M\ kl$= (32.21,39.10,47.60)
$[\sum_{i=1}^{n}\sum_{j=1}^{m} M\ kl]^{-1}$ = (0.021,0.026,0.031)

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1}.$$

S_1= (4.53,5.59,7.02) ⊗ (0.021,0.026,0.031) = (0.0952,0.1430,0.2179)
S_2= (4.55,5.44,6.77) ⊗ (0.021,0.026,0.031) = (0.0956,0.1391,0.2102)
S_3= (8.46,9.74,11.30) ⊗(0.021,0.026,0.031) = (0.1777,0.2491,0.3508)
S_4= (4.35,5.47,6.80) ⊗(0.021,0.026,0.031) = (0.0914,0.1399,0.211)
S_5= (3.65,4.62,6.10) ⊗(0.021,0.026,0.031) = (0.0767,0.1182,0.1894)
S_6= (6.67,8.24,9.61) ⊗(0.021,0.026,0.031) = (0.1401,0.2107,0.2984)

The degree of possibility of $M_2=(l_2,m_2,u_2) \geq M_1=(l_1,m_1,u_1)$ is defined as:

$$V(M_2 \geqslant M_1) = \begin{cases} 1, & \text{if } m_2 \geqslant m_1, \\ 0, & \text{if } l_1 \geqslant u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise,} \end{cases}$$

Then we can calculate the degree of possibility of $S_i \geq S_j$.

	S_1	S_2	S_3	S_4	S_5	S_6
S_1		1.000	0.275	1.000	1.000	0.534
S_2	0.968		0.228	0.994	1.000	0.495
S_3	1.000	1.000		1.000	1.000	1.000
S_4	0.974	1.000	0.234		1.000	0.501
S_5	0.792	0.817	0.082	0.818		0.347
S_6	1.000	1.000	0.759	1.000	1.000	

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i(i=1,2,\ldots,k)$ can be defined by:

$$= \min V(M \geqslant M_i),\ i = 1, 2, 3, \ldots, k.$$

S_i	Degree of Possibility (S_i)	Normalization
S_1	0.275	0.1066
S_2	0.228	0.0884
S_3	1.000	0.3880
S_4	0.234	0.0908
S_5	0.082	0.0317
S_6	0.759	0.2944
Sum	2.577	1

The weight of the 6 main criteria can be seen in the Table 16 below:

Table 16 The weight and ranks of main criteria

Criteria	Normalized Weight	Rank
Schedule	0.107	3
Cost	0.088	5
Quality	0.388	1
Infrastructure	0.091	4
Digitalization and Innovation	0.032	6
HSSE	0.294	2

Fuzzy hierarchy analysis is also performed on the sub-criteria of each criterion with opinions obtained from experts.

Sub-criteria of Schedule

The first criteria, schedule, is crucial in determining project efficiency and success. For this criterion 3 sub criteria are defined and compared with each other in pair comparison. Below Table 17 shows the experts opinion about each attribute in schedule category.

Table 17 Experts Opinions about Schedule Attributes

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Sub-criteria (Schedule)	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-criteria (Schedule)
Q16	Integrated Sustainable Logistics Management				1	2	1	1			Responsiveness
Q17	Integrated Sustainable Logistics Management					2	1	1	1		On-time Delivery
Q18	Responsiveness					2	2	1			On-time Delivery

In the following Table 18, the stages of fuzzy hierarchical analysis are shown on schedule sub criteria.

Table 18 Matrix of pairwise comparisons - Schedule

	Integrated Sustainable Logistics Management	Responsiveness	On-time Delivery	$\sum_{j=1}^{m} M\,kl$
Integrated Sustainable Logistics Management	(1,1,1)	(0.708,0.871,1.084)	(0.598,0.699,0.833)	(2.3060,2.5700,2.9170)
Responsiveness	(0.923,1.148, 1.412)	(1,1,1)	(0.708,0.871,1.084)	(2.6310,3.0190,3.4960)
On-time Delivery	(1.200, 1.430, 1.672)	(0.923,1.148, 1.412)	(1,1,1)	(3.1230,3.5780,4.0840)

$CR_m = \frac{CI\ m}{RI\ m} = 0{,}0006$, $CR_g = \frac{CI\ g}{RI\ g} = 0.0021$

	S_1	S_2	S_3	Degree of Possibility (S_i)
S_1		0.694	0.369	0.369
S_2	1		0.691	0.691
S_3	1	1		1

The weight of the 3 sub- criteria of Schedule can be seen in the Table 19 below:

Table 19 The weight and ranks of Schedule Sub criteria

Criteria	Normalized Weight	Rank
Integrated Sustainable Logistics Management	0.179	3
Responsiveness	0.335	2
On-time Delivery	0.485	1

Sub-criteria of Cost

For this criterion 3 sub criteria are defined and compared with each other in pair comparison. Below Table 20 shows the experts opinion about each attribute in cost category.

Table 20 Experts Opinions about Cost Attributes

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Sub-criteria (Cost)	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-criteria (Cost)
Q19	Cost optimization			3			2				Effective Shipment Planning
Q20	Cost optimization			3		1	1				Combine and Consolidate Cargo
Q21	Effective Shipment Planning			1	2		2				Combine and Consolidate Cargo

In the following Table 21, the stages of fuzzy hierarchical analysis are shown on cost sub criteria.

Table 21 Matrix of pairwise comparisons - Cost

	Cost optimization	Effective Shipment Planning	Combine and Consolidate Cargo	$\sum_{j=1}^{m} M\ kl$
Cost optimization	(1,1,1)	(1.084,1.516,2.038)	(1.084,1.516,1.879)	(3.168,4.032,4.917)
Effective Shipment planning	(0.491,0.659,0.922)	(1,1,1)	(0.784,1.149,1.661)	(2.275,2.808,3.583)
Combine and Consolidate Cargo	(0.532,0.659,0.922)	(0.602,0.870,1.275)	(1,1,1)	(2.134,2.529,3.197)

$CR_m = \frac{CI\ m}{RI\ m} = 0{,}0014$, $CR_g = \frac{CI\ g}{RI\ g} = 0.0086$

	S_1	S_2	S_3	Degree of Possibility (S_i)
S_1		1	1	1
S_2	0.607		1	0.607
S_3	0.485	0.884		0.485

The weight of the 3 sub- criteria of Cost can be seen in the Table 22 below:

Table 22 The weight and ranks of Cost Sub criteria

Criteria	Normalized Weight	Rank
Cost optimization	0.478	1
Effective Shipment Planning	0.290	2
Combine and Consolidate Cargo	0.232	3

Sub-criteria of Quality

For this criterion 3 sub criteria are defined and compared with each other in pair comparison. Below

Table 23 shows the experts opinion about each attribute in quality category.

Table 23 Experts Opinions about Quality Attributes

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Sub-criteria (Quality)	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-criteria (Quality)
Q22	Reliability			1	1	1	2				Accuracy
Q23	Reliability			1			4				Green Assurance
Q24	Accuracy				1		4				Green Assurance

In the following Table 24, the stages of fuzzy hierarchical analysis are shown on quality sub criteria.

Table 24 Matrix of pairwise comparisons - Quality

	Reliability	Accuracy	Green Assurance	$\sum_{j=1}^{m} M\ kl$
Reliability	(1,1,1)	(0.850,1.149,1.532)	(0.784,1.149,1.166)	(2.634,3.298,3.698)
Accuracy	(0.653,0.870,1.176)	(1,1,1)	(0.667,1,1.5)	(2.320,2.870,3.676)
Green Assurance	(0.858,0.870,1.276)	(0.667,1,1.5)	(1,1,1)	(2.525,2.870,3.776)

$CR_m = \frac{CI\ m}{RI\ m} = 0,0003$, $CR_g = \frac{CI\ g}{RI\ g} = 0.0105$

	S_1	S_2	S_3	Degree of Possibility (S_i)
S_1		1	1	1
S_2	0.844		1	0.844
S_3	0.850	1		0.850

The weight of the 3 sub- criteria of Quality can be seen in the Table 25 below:

Table 25 The weight and ranks of Quality Sub criteria

Criteria	Normalized Weight	Rank
Reliability	0.371	1
Accuracy	0.313	3
Green Assurance	0.316	2

Sub-criteria4: Infrastructure

For this criterion 3 sub criteria are defined and compared with each other in pair comparison. Below Table 26 shows the experts opinion about each attribute in Infrastructure category.

Table 26 Experts Opinions about Infrastructure Attributes

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Sub-criteria (Infrastructure)	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-criteria (Infrastructure)
Q25	Green infrastructure			1	2	2					Green Manpower
Q26	Green infrastructure				3	1	1				Alternative Fuels
Q27	Green Manpower							5			Alternative Fuels

In the following Table 27, the stages of fuzzy hierarchical analysis are shown on infrastructure sub criteria.

Table 27 Matrix of pairwise comparisons - Infrastructure

	Green infrastructure	Green Manpower	Alternative Fuels	$\sum_{j=1}^{m} M\ kl$
Green infrastructure	(1,1,1)	(1.084,1.149,1.413)	(0.723,1,1.383)	(2.8070,3.149,3.796)
Green Manpower	(0.708,0.870,0.923)	(1,1,1)	(0.4,0.5,0.667)	(2.1080,2.37,2.59)
Alternative Fuels	(0.723,1,1.383)	(1.5,2,2.5)	(1,1,1)	(3.223,4,4.883)

$CR_m = \frac{CI\ m}{RI\ m} = 0,035$, $CR_g = \frac{CI\ g}{RI\ g} = 0.063$

	S_1	S_2	S_3	Degree of Possibility (S_i)
S_1		1	0.669	0.669
S_2	0.458		0.159	0.159
S_3	1	1		1

The weight of the 3 sub- criteria of Infrastructure can be seen in the Table 28 below:

Table 28 The weight and ranks of Infrastructure Sub criteria

Criteria	Normalized Weight	Rank
Green infrastructure	0.366	2
Green Manpower	0.087	3
Alternative Fuels	0.547	1

Sub-criteria of Digitalization and Innovation

For this criterion 4 sub criteria are defined and compared with each other in pair comparison. Below Table 29 shows the experts opinion about each attribute in Digitalization and Innovation category.

Table 29 Experts Opinions about Digitalization and Innovation Attributes

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Sub-criteria	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-criteria
Q28	IT support				3		1	1			Optimization of information quality
Q29	IT support							3	2		Emission Requirement
Q30	IT support				3		1	1			Innovation capability
Q31	Optimization of information quality						1		4		Emission Requirement
Q32	Optimization of information quality					4		1			Innovation capability
Q33	Emission Requirement		2	2	1						Innovation capability

In the following Table 30, the stages of fuzzy hierarchical analysis are shown on Digitalization and Innovation sub criteria.

Table 30 Matrix of pairwise comparisons - Digitalization and Innovation

	IT support	Optimization of information quality	Emission Requirement	Innovation capability	$\sum_{j=1}^{m} M\ kl$
IT support	(1,1,1)	(0.602,0.871,1.275)	(0.349,0.425,0.543)	(0.602,0.871,1.275)	(2.531,3.134,4.041)
Optimization of information quality	(0.784,1.148,1.661)	(1,1,1)	(0.338,0.415,0.521)	(0.833,0.871,0.922)	(2.955,3.434,4.104)
Emission Requirement	(1.841,2.353,2.865)	(1.919,2.409,2.986)	(1,1,1)	(1.201,1.643,2.180)	(5.961,7.405,9.004)
Innovation capability	(0.784,1.148,1.661)	(1.085,1.148,1.20)	(0.458,0.608,0.833)	(1,1,1)	(3.327,3.904,4.694)

$CR_m = \frac{\text{CI m}}{\text{RI m}} = 0{,}004$, $CR_g = \frac{\text{CI g}}{\text{RI g}} = 0.01$

	S_1	S_2	S_3	S_4	Degree of Possibility (S_i)
S_1		0.892	0.003	0.738	0.003
S_2	1		0.022	0.827	0.022
S_3	1	1		1	1
S_4	1	1	0.186		0.186

The weight of the 4 sub- criteria of Digitalization and Innovation can be seen in the Table 31 below:

Table 31 The weight and ranks of Digitalization and Innovation Sub criteria

Criteria	Normalized Weight	Rank
IT support	0.002	4
Optimization of information quality	0.018	3
Emission Requirement	0.826	1
Innovation capability	0.154	2

Sub-criteria of HSSE

For this criterion 3 sub criteria are defined and compared with each other in pair comparison. Below Table 32 shows the experts opinion about each attribute in HSSE category.

Table 32 Experts Opinions about HSSE Attributes

	Left Criteria is Greater						Right Criteria is Greater				
Questions	Sub-Criteria	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-Criteria
Q34	Safety	1	2	2							Mutual Trust and Relationship
Q35	Safety		2	2	1						Attitude towards customer green requirements
Q36	Mutual Trust and Relationship				1	3	1				Attitude towards customer green requirements

In the following Table 33, the stages of fuzzy hierarchical analysis are shown on HSSE sub criteria.

Table 33 Matrix of pairwise comparisons - HSSE

	Safety	Mutual Trust and Relationship	Attitude towards customer green requirements	$\sum_{j=1}^{m} M\ kl$
Safety	(1,1,1)	(1.179,2.702,3.217)	(1.564,2.047,2.582)	(3.743,5.749,6.799)
Mutual Trust and Relationship	(0.311,0.379,0.848)	(1,1,1)	(0.850,1,1.176)	(2.161,2.370,3.0242)
Attitude towards customer green requirements	(0.387,0.488,0.639)	(0.850,1,1.176)	(1,1,1)	(2.237,2.488,2.815)

$CR_m = \frac{CI\ m}{RI\ m} = 0{,}016$, $CR_g = \frac{CI\ g}{RI\ g} = 0.0001$

	S_1	S_2	S_3	Degree of Possibility (S_i)
S_1		1	1	1
S_2	0.192		0.950	0.192
S_3	0.139	1		0.139

The weight of the 3 sub- criteria of HSSE can be seen in the Table 34 below:

Table 34 The weight and ranks of HSSE Sub criteria

Criteria	Normalized Weight	Rank
Safety	0.751	1
Mutual Trust and Relationship	0.144	2
Attitude towards customer green requirements	0.105	3

After successfully conducting the consistency test and verifying the appropriateness of the matrices, the next crucial step is to calculate the overall priority vectors. This is achieved by multiplying the weight of each factor by the weight of its corresponding sub-factors. The resulting overall priorities, also referred to as sub-factors decomposed weights, play a vital role in determining the relative priorities of the sub-factors in the context of the problem at hand. These overall priorities offer valuable insights into the significance of each sub-factor and their respective contributions to the overall decision-making process. By analyzing and interpreting these priorities, decision-makers can gain a comprehensive understanding of the underlying factors that drive the problem, enabling them to make more informed and effective decisions. Thus, this systematic approach ensures a rigorous and well-justified decision-making process, enhancing the overall effectiveness and robustness of the solution.

These overall priorities are presented in the Table 35 below.

Table 35 Weight of the Main and Sub-Factors for Selection of Best Logistics Provider

Level 2 Criteria	Level 3 Sub-Criteria	Weight of Level 2	Weight of Level 3	Final Weight of Sub-Criteria	Rank
Schedule	Integrated Sustainable Logistics Management	0.107	0.179	0.019	15
	Responsiveness		0.335	0.036	9
	On-time Delivery		0.485	0.052	5
Cost	Cost optimization	0.088	0.478	0.0420	8
	Effective Shipment Planning		0.290	0.0255	13
	Combine and Consolidate Cargo		0.232	0.020	14
Quality	Reliability	0.388	0.371	0.144	2
	Accuracy		0.313	0.121	4
	Green Assurance		0.316	0.123	3
Infrastructure	Green infrastructure	0.091	0.366	0.033	10
	Green Manpower		0.087	0.008	16
	Alternative Fuels		0.547	0.049	6
Digitalization and Innovation	IT support	0.032	0.002	0.00006	19
	Optimization of information quality		0.018	0.0006	18
	Emission Requirement		0.826	0.026	12
	Innovation capability		0.154	0.005	17
HSSE	Safety	0.294	0.751	0.221	1
	Mutual Trust and Relationship		0.144	0.0423	7
	Attitude towards customer green requirements		0.105	0.031	11

7.3 Development of the framework

In Appendix C, a framework is proposed for the selection of Aker Solutions AS LSPs based on sustainable service quality in the form of a hierarchical model based on qualities. This hierarchical architecture will be used to extract meaningful results in order to make better business decisions. This framework is broken into four tiers, the first of which is the general purpose of picking the best logistics provider based on service quality. Level 1 is followed by 6 criteria at level 2, which is then followed by 19 service quality qualities at level 3, and finally, the finest logistics providers are chosen from among options at level 4. The following is a brief profile of LSPs considered for illustration of this framework.

The selection of logistics providers is based on the adoption and implementation of sustainable practices in operations to serve the customers. The information about LSPs will be collected from the bid documents received based on the instruction to bidders procedures. LSPs are obligated to submit all required documents such technical and commercial offers including quality, HSSE and sustainability reports for review and evaluation. Afterwards clarification meeting will be held to complete all necessary information needed. After receiving and extracting all necessary information the LSP evaluation framework will be filled by environmental specialist and logistics specialist, and different sustainable service quality indicators considered in the proposed framework will be ranked from 1 to 5 by specialists and the framework will rank the best LSP automatically.

7.4 Conclusion

In the current era of the circular economy, every firm is concerned with the selection of logistics providers based on long-term service quality [35]. Logistics companies are constantly under pressure to deliver sustained service quality in order to enhance operational capabilities. Previous research has not given significant thought to including sustainability indicators in LSP selection frameworks. Most studies in the literature have used generic factors (timeliness, order quality, service quality, timely delivery, IT skills, etc.) to select and evaluate logistics providers. As a result, the goal of this research is to create a framework for selecting logistics providers based on long-term service quality. A sustainable service quality attributes was established through a thorough literature analysis. Industrial experts' advice was also used to make the study relevant in the context of the current business environment.

Based on input from focused group discussions and a questionnaire, nineteen sustainable service quality attributes were selected, and data was collected to categorize all attributes under independent components. As a result, the qualities are divided into six categories. These are schedule, cost, quality, infrastructure, digitization, and innovation, and HSSE. The elements and sustainable service quality qualities are ranked after categorization. To analyze and pick the best logistics provider, a hybrid multi-criteria analytical technique is applied. Fuzzy AHP is used to calculate weights for all components and sub-factors. Quality and HSSE have been identified as the most important considerations in logistics provider selection. These findings show that logistics providers should strive to enhance their quality in areas such as reliability, accuracy while providing the green assurance for better application of sustainable practices. The findings also imply that LSPs needs to maintain health, safety, Security and Environment in terms of optimized Mutual Trust and Relationship and improve their attitude towards customer green requirements. For proper implementation of sustainable practices, logistics providers must develop their capabilities such as green warehousing, eco-friendly fleet, skilled staff for implementing green operations, sustainable capacity optimization, and cost optimization, among others. They should also focus on continual learning and implementation of new IT techniques such as artificial intelligence, big data analytics, machine learning, and so on for real-time data transactions. It is also critical that the logistics supplier agree to using sustainable practices in all logistical activities.

This study's main contribution is that it offered a thorough decision-making framework for evaluating logistics providers based on sustainable service quality in the current business context of the circular economy. The research also attempted to combine statistical analytic tools with FGD and MCDM methodologies. Because this is a hitherto unexplored location, it will considerably contribute to existing understanding. This research will assist all organizations in choosing acceptable logistics providers to satisfy their sustainability goals. In the age of the circular economy, the proposed framework would aid firms in developing strategies for selecting the best service provider for them. In today's economic environment, industries face enormous pressure to protect the environment, as outlined in the United Nations' Sustainable Development Goals (SDGs-7, 12 and 13). As a result, this research can provide a strategic framework for logistics service providers to create sustainable operations. The study would also be useful for LSPs in developing long-term plans to ensure more delighted consumers. The findings of this study can assist LSPs in prioritizing sustainable service quality features and revising their processes to meet shifting requirements.

The main management implication of the results study is that organizations should select LSP based on sustainability parameters in addition to other standard measures. When choosing an LSP, businesses should consider green and flexible operations, long-term network optimization, rapid and accurate information dissemination via digital processes, and client trust. Organizations can greatly improve their business operations by focusing on long-term service quality in addition to key capabilities. The development of these abilities, as well as the smooth flow of quality information, is critical for the integration of green systems in the era of Industry 4.0 and the circular economy. The proposed framework and case illustration for sustainable service quality will be extremely valuable for all enterprises in evaluating potential logistics providers based on sustainable service quality. The proper selection of logistics providers will have a direct impact on customer satisfaction as well as the organization's growth and profitability. Finding would aid in the efficient use of resources with future conservation. The current study has only a few limitations. The first constraint is the amount of service quality attributes, which might be raised to create a more complete framework. Second, case studies on small and medium-sized LSPs might be utilized to validate the proposed paradigm further. Although the majority of the sustainable service quality attributes are considered and grouped into different factors in the current study based on a literature review and experts, empirical testing of the proposed model by structural equation modeling can be done as the study's future scope by collecting more responses from customers. This paradigm can be further changed to include additional features in the context of the circular economy and the Industry 4.0 environment.

8. Appendix A

Questionnaire No.1

Kindly rate each attribute on the scale of 1 to 5 as per their importance for evaluating sustainable service quality of logistics service providers. This activity is a part of vetting the proposed service quality model for identifying and measuring all important attributes which impacts the sustainable service quality of Aker Solutions logistics service providers. Your inputs are highly valuable and will help me in understanding the practical insights on the same. Kindly suggest if you find need to add any new attribute or remove any attribute due to duplicity.

Kindly rate attributes on 1-5 scale

1 Very Unimportant

2. Unimportant

3 Can be considered

4 Important

5. Very Important

S. No.	Attributes	Meaning/Definition	1-5 scale
1	Reliability for green services	Capability to execute promised services using sustainable methods and to perform the promised green services without failing	
2	Responsiveness towards green practices	Ability to use green practices and provide prompt service to react to customers more quickly	
3	Accuracy in delivering goods through green operations	Ability to deliver the right product to the right location and to the right client at the right time using sustainable methods	
4	Assurance for green operations	Ability to transport goods using sustainable methods and ensuring that deliveries are made using environmentally friendly methods	
5	On-time Delivery	Delivering products on time and using sustainable methods, as well as at the appointed time and date	

6	Safety in handling shipments	Handling Packages Safely	
7	Green infrastructure	A sufficient number of environmentally friendly vehicles and green storage facilities are accessible to the logistics supplier	
8	Manpower for implementing green operations	Having a sufficient amount of trained staff available to adopt and execute green practices as well as a skilled and trained workforce in sustainability	
9	Sustainable network optimization	Ability to expand network by promoting green practices and optimize delivery network for geographical reach and sustainability	
10	Capability for sustainable capacity optimization	Ability to successfully manage a high volume of customer business and adequate capacity to maximize inventory controls	
11	Optimizing Inventory Controls	Upkeep and management of client inventory and Give client's inventory management enough importance and attention	
12	Managing Global Sustainable Operations	Globally coordinate operations to achieve sustainability	
13	Product Returns	Coordinating the return of goods, whether they are new or used	
14	Cost optimization	Make the payment to LSPs for their green services as affordable as possible	
15	IT support for green practices	Equipped with sufficient IT resources to encourage the use of green projects	
16	Optimization of information quality	The regularity, excellence, and accuracy with which the customer is provided with information	
17	Access by customers	Ability for customers to readily access and approach the service provider	
18	Response time optimization	Efficiency in handling client orders, questions, and complaints	
19	Efficient Data Handling	Data collection, maintenance of all activities, and client retrieval via digitalization	
20	Integrated Sustainable Logistics Management	Coordinating and incorporating sustainable practices with all participants in the supplier chain Including other supply chain partners and working together to execute sustainably	

21	Mutual Trust and Relationship	For effective operations and the adoption of green practices, supply chain partners must have mutual understanding and trust in one another	
22	Tracking and Tracing of shipments	Using GPS technology to monitor and trace all vehicles, as well as to continue tracking and tracing shipments	
23	Effective Shipment Planning	All cargoes' effective route plans and all shipments' effective route plans	
24	Understanding customer sustainable needs	Recognizing the demand for green products among customers and making an effort to comprehend their requirements	
25	Green and flexible processes	The capability to adapt processes to meet changing or urgent requirements while accommodating green processes	
26	Innovation capability	Providing customers with innovative, personalized services in a way that is sustainable for the climate and advances green supply chain management	
27	Attitude towards customer green requirements	LSPs' attitudes toward customers' sustainable requiremnets and uphold honesty and desire to help in all of their interactions with client	
28	Courtesy towards customers	Respect, comfort level, politeness and friendliness shown to customers and maintains courteous behavior in all transactions	
29	Maintaining confidentiality in customers information	Ability to secure information and uphold values confidentiality in all operations	
30	Empathy towards customer	Ability to consider the client’s problem as their own issue and take appropriate actions to solve it	
31	Concern towards environment	Adopting sustainable practices to make environment safe and Shows concern towards sustainability	
32	Green and flexible processes	The capacity to change processes sustainably in accordance with client’s needs and flexibility in green transition in logistics processes	
33	Technology adoption for sustainable operations	Utilizing technological choices to promote digital processes (paperless) and implementing cutting-edge technology, such as EDI, RFID, VMI, GPS, and WMS, to maximize resources	
34	Use of Warehouse Management Software	IT and software use for managing warehouses and using software for managing warehouses	

35	Using Alternative Fuels	Ability to use alternative fuels such as Biofuel, Biogass, Electric, Amonia, Hydrogen as part of their fuel	
36	Combine and Consolidate Cargo	Ability to Combine and Consolidate Cargo between different client to reduce emissions and make ready the infrastructure for that	
37	Emission Auditing Service Infrastructure	Ability to audit the emissions for each activity in the logistic processes	

Any suggestions related to addition/deletion of any attribute:

Thanks for your time, support, and suggestions.

9. Appendix B

Questionnaire No.2

Please kindly pay attention to complete this questionnaire for comparing criterion A with criterion B, mark the "Equally Important" if the importance of both criteria is the same.

If the criterion on the right was more important, the range on the right should be chosen as much as it is more important, but if the range on the left is more important, mark one of them on the left.

Be careful to only mark the one room of one side, that is, the side of the item that is more important.

Notes to consider:

1. The shortlisted Sustainability Attributes with definition are listed below.
2. Please keep in mind that these are sustainability attributes, and it is necessary to consider each factor in terms of using more sustainable methods instead of current regular methods.

Shortlisted Sustainability Attributes:

S. No.	Attributes	Meaning/Definition
1	Responsiveness	Ability to use green practices and provide prompt service to react to customers more quickly
2	Safety	Handling Packages Safely
3	Green infrastructure	A sufficient number of environmentally friendly vehicles and green storage facilities are available
4	Alternative Fuels	Ability to use alternative fuels such as Biofuel, Biogass, Electric, Amonia, Hydrogen as part of their fuel
5	Accuracy	Ability to deliver the right product to the right location and to the right client using sustainable methods
6	Green Assurance	Ability to transport goods using sustainable methods and ensuring that deliveries are made using environmentally friendly methods
7	On-time Delivery	Delivering products on time and using sustainable methods
8	Green Manpower	Having a sufficient number of trained staff available to adopt and execute green practices
9	Cost optimization	Make the cost of their green services as affordable as possible
10	Emission Requirement	Ability to audit the emissions for each activity in the logistic processes and provide Type III Environmental Product Declaration (EPD) based on standard
11	Reliability	Capability to execute promised services using sustainable methods with high reliability
12	IT support	Equipped with sufficient IT resources to encourage the use of green projects
13	Optimization of information quality	The regularity, excellence, and accuracy with which the customer is provided with information
14	Integrated Sustainable Logistics Management	Coordinating and incorporating sustainable practices with all participants in the supplier chain Including other supply chain partners and working together to execute sustainably
15	Mutual Trust and Relationship	Supply chain partners must have mutual understanding and trust in one another

16	Effective Shipment Planning	All cargoes' effective route plans and all shipments' effective route plans
17	Innovation capability	Providing customers with innovative, personalized services in a way that is sustainable for the climate and advances green supply chain management
18	Attitude towards customer green requirements	Attitudes toward customers' sustainable requirements and uphold honesty and desire to help in those
19	Combine and Consolidate Cargo	Ability to Combine and Consolidate Cargo between different client to reduce emissions and make ready the infrastructure for that

<u>With respect to the overall goal "Selection of the best Sustainable Logistic Service Provider"</u>

Q1. How important is "Schedule" when it is compared with "Cost"?

Q2. How important is "Schedule" when it is compared with "Quality"?

Q3. How important is "Schedule" when it is compared with "Infrastructure"?

Q4. How important is "Schedule" when it is compared with "Digitalization and Innovation"?

Q5. How important is "Schedule" when it is compared with "HSSE"?

Q6. How important is "Cost" when it is compared with "Quality"?

Q7. How important is "Cost" when it is compared with "Infrastructure"?

Q8. How important is "Cost" when it is compared with "Digitalization and Innovation"?

Q9. How important is "Cost" when it is compared with "HSSE"?

Q10. How important is "Quality" when it is compared with "Infrastructure"?

Q11. How important is "Quality" when it is compared with "Digitalization and Innovation"?

Q12. How important is "Quality" when it is compared with "HSSE"?

Q13. How important is "Infrastructure" when it is compared with "Digitalization and Innovation"?

Q14. How important is "Infrastructure" when it is compared with "HSSE"?

Q15. How important is "Digitalization and Innovation" when it is compared with "HSSE"?

	Important (or preference) of one main-attribute over another										
Questions	Attributes	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Attributes
Q1	Schedule										Cost
Q2	Schedule										Quality
Q3	Schedule										Infrastructure
Q4	Schedule										Digitalization and Innovation
Q5	Schedule										HSSE
Q6	Cost										Quality
Q7	Cost										Infrastructure
Q8	Cost										Digitalization and Innovation
Q9	Cost										HSSE
Q10	Quality										Infrastructure
Q11	Quality										Digitalization and Innovation
Q12	Quality										HSSE
Q13	Infrastructure										Digitalization and Innovation
Q14	Infrastructure										HSSE
Q15	Digitalization and Innovation										HSSE

With respect to the main attribute "Schedule"

Q16. How important is "Integrated Sustainable Logistics Management" when it is compared with "Responsiveness towards green practices"?

Q17. How important is "Integrated Sustainable Logistics Management" when it is compared with "On-time Delivery"?

Q18. How important is "Responsiveness towards green practices" when it is compared with "On-time Delivery"?

Questions	Sub-attribute	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-attribute
Q16	Integrated Sustainable Logistics Management										Responsiveness
Q17	Integrated Sustainable Logistics Management										On-time Delivery
Q18	Responsiveness										On-time Delivery

<u>With respect to the main attribute "Cost"</u>

Q19. How important is "Cost optimization" when it is compared with "Effective Shipment Planning"?

Q20. How important is "Cost optimization" when it is compared with "Combine and Consolidate Cargo"?

Q21. How important is "Effective Shipment Planning" when it is compared with "Combine and Consolidate Cargo"?

Questions	Sub-attribute	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-attribute
Q19	Cost optimization										Effective Shipment Planning
Q20	Cost optimization										Combine and Consolidate Cargo
Q21	Effective Shipment Planning										Combine and Consolidate Cargo

<u>With erspect to the main attribute "Quality"</u>

Q22. How important is "Reliability for green services" when it is compared with "Accuracy in delivering goods through green operations"?

Q23. How important is "Reliability for green services" when it is compared with "Assurance for green operations"?

Q24. How important is "Accuracy in delivering goods through green operations" when it is compared with "Assurance for green operations"?

Questions	Sub-attribute	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-attribute
Q22	Reliability										Accuracy
Q23	Reliability										Green Assurance
Q24	Accuracy										Green Assurance

With erspect to the main attribute "Infrastructure"

Q25. How important is "Green infrastructure" when it is compared with "Manpower for implementing green operations"?

Q26. How important is "Green infrastructure" when it is compared with "Using Alternative Fuels"?

Q27. How important is "Manpower for implementing green operations" when it is compared with "Using Alternative Fuels"?

Questions	Sub-attribute	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-attribute
Q25	Green infrastructure										Green Manpower
Q26	Green infrastructure										Alternative Fuels
Q27	Green Manpower										Alternative Fuels

With erspect to the main attribute "Digitalization and Innovation"

Q28. How important is "IT support for green practices" when it is compared with "Optimization of information quality"?

Q29. How important is "IT support for green practices" when it is compared with "Emission Auditing Service Infrastructure"?

Q30. How important is "IT support for green practices" when it is compared with "Innovation capability"?

Q31. How important is "Optimization of information quality" when it is compared with "Emission Auditing Service Infrastructure"?

Q32. How important is "Optimization of information quality" when it is compared with "Innovation capability"?

Q33. How important is "Emission Auditing Service Infrastructure" when it is compared with "Innovation capability"?

Questions	Sub-attribute	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-attribute
Q28	IT support										Optimization of information quality
Q29	IT support										Emission Requirement
Q30	IT support										Innovation capability
Q31	Optimization of information quality										Emission Requirement
Q32	Optimization of information quality										Innovation capability
Q33	Emission Requirement										Innovation capability

With erspect to the main attribute "HSSE"

Q34. How important is "Safety in handling shipments" when it is compared with "Mutual Trust and Relationship"?

Q35. How important is "Safety in handling shipments" when it is compared with "Attitude towards customer green requirements"?

Q36. How important is "Mutual Trust and Relationship" when it is compared with "Attitude towards customer green requirements"?

Questions	Sub-attribute	Absolutely important	strongly important	Fairly important	Weakly important	Equally important	Weakly important	Fairly important	Strongly important	Absolutely important	Sub-attribute
Q34	Safety										Mutual Trust and Relationship
Q35	Safety										Attitude towards customer green requirements
Q36	Mutual Trust and Relationship										Attitude towards customer green requirements

Thank you.

10. Appendix C

AkerSolutions

Sustainablity Evaluation of Logistic Service Provider

Project		Project Manager	
Project No.		Logistic Specialist	
Package Description		Environmental Specialist	

	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Supplier name				
Evaluation	-	-	-	-

1. Schedule	Applicable: Yes	Weight: 11%	Atribute Description	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Integrated Sustainable Logistics Management		18%	Coordinating and incorporating sustainable practices with all participants in the supplier chain Including other supply chain partners and working together to execute sustainably				
Responsiveness		34%	Ability to use green practices and provide prompt service to react to customers more quickly.				
On-time Delivery		49%	Delivering products on time and using sustainable methods.				
Weighted sub-total | Weighted score				! 0.0 0.00	! 0.0 0.00	! 0.0 0.00	! 0.0 0.00

2. Cost	Applicable: Yes	Weight: 9%	Atribute Description	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Cost optimization		48%	Make the cost of their green services as affordable as possible.				
Effective Shipment Planning		29%	All cargoes' effective route plans and all shipments' effective route plans.				
Combine and Consolidate Cargo		23%	Ability to Combine and Consolidate Cargo between different client to reduce emissions and make ready the infrastructure for that.				
Weighted sub-total | Weighted score				! 0.0 0.00	! 0.0 0.00	! 0.0 0.00	! 0.0 0.00

3. Quality	Applicable: Yes	Weight: 39%	Atribute Description	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Reliability		37%	Capability to execute promised services using sustainable methods with high reliability.				
Accuracy		31%	Ability to deliver the right product to the right location and to the right client using sustainable methods.				
Green Assurance		32%	Ability to transport goods using sustainable methods and ensuring that deliveries are made using environmentally friendly methods.				
Weighted sub-total | Weighted score				! 0.0 0.00	! 0.0 0.00	! 0.0 0.00	! 0.0 0.00

4. Infrastructure	Applicable: Yes	Weight: 9%	Atribute Description	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Green infrastructure		37%	A sufficient number of environmentally friendly vehicles and green storage facilities are available.				
Green Manpower		9%	Having a sufficient number of trained staff available to adopt and execute green practices.				
Alternative Fuels		55%	Ability to use alternative fuels such as Biofuel, Biogass, Electric, Amonia, Hydrogen as part of their fuel.				
Weighted sub-total | Weighted score				! 0.0 0.00	! 0.0 0.00	! 0.0 0.00	! 0.0 0.00

5. Digitalization and Innovation	Applicable: Yes	Weight: 3%	Atribute Description	Bidder 1	Bidder 2	Bidder 3	Bidder 4
IT support		0%	Equipped with sufficient IT resources to encourage the use of green projects.				
Optimization of information quality		2%	The regularity, excellence, and accuracy with which the customer is provided with information.				
Emission Requirement		83%	Ability to audit the emissions for each activity in the logistic processes and provide Type III Environmental Product Declaration (EPD) based on standard.				
Innovation capability		15%	Providing customers with innovative, personalized services in a way that is sustainable for the climate and advances green supply chain management.				
Weighted sub-total | Weighted score				! 0.0 0.00	! 0.0 0.00	! 0.0 0.00	! 0.0 0.00

6. HSSE	Applicable: Yes	Weight: 29%	Atribute Description	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Safety		75%	Handling Packages Safely.				
Mutual Trust and Relationship		14%	Supply chain partners must have mutual understanding and trust in one another.				
Attitude towards customer green requirements		11%	Attitudes toward customers' sustainable requirements and uphold honesty and desire to help in those.				
Weighted sub-total | Weighted score				! 0.0 0.00	! 0.0 0.00	! 0.0 0.00	! 0.0 0.00

	Bidder 1	Bidder 2	Bidder 3	Bidder 4
Overall weigthed technical score	-	-	-	-
Weighted score				
Rank				

Evaluated value	
Disqualified	Not Acceptable
1	Poor
2	Low
3	Neutral
4	Good
5	Excellent

11. References

1. Winkelhaus, S. and E.H. Grosse, *Logistics 4.0: a systematic review towards a new logistics system.* International Journal of Production Research, 2020. **58**(1): p. 18-43.
2. Karaman, A.S., M. Kilic, and A. Uyar, *Green logistics performance and sustainability reporting practices of the logistics sector: The moderating effect of corporate governance.* Journal of Cleaner Production, 2020. **258**: p. 120718.
3. Jazairy, A. and R. von Haartman, *Analysing the institutional pressures on shippers and logistics service providers to implement green supply chain management practices.* International Journal of Logistics Research and Applications, 2020. **23**(1): p. 44-84.
4. Gupta, A., R.K. Singh, and P. Suri, *Prioritizing best practices for logistics service providers*, in *Transforming Organizations Through Flexible Systems Management*. 2020, Springer. p. 257-275.
5. Mishra, A.R., et al., *A hesitant fuzzy combined compromise solution framework-based on discrimination measure for ranking sustainable third-party reverse logistic providers.* Sustainability, 2021. **13**(4): p. 2064.
6. Abudayyeh, O., et al., *Hybrid Prequalification-Based, Innovative Contracting Model Using AHP.* Journal of Management in Engineering, 2007. **23**(2): p. 88-96.
7. Saaty, T.L., *Decision making for leaders.* IEEE Transactions on Systems, Man, and Cybernetics, 1985. **SMC-15**(3): p. 450-452.
8. Noureddine, A.K. *A prioritization system for school rehabilitation projects*. in *Masters Abstracts International*. 2010.
9. Khandelwal, C. and M.K. Barua, *Prioritizing circular supply chain management barriers using fuzzy AHP: case of the Indian plastic industry.* Global Business Review, 2020: p. 0972150920948818.
10. Gupta, A., R.K. Singh, and S.K. Mangla, *Evaluation of logistics providers for sustainable service quality: Analytics based decision making framework.* Annals of Operations Research, 2022. **315**(2): p. 1617-1664.
11. Tan, B.Q., et al., *A blockchain-based framework for green logistics in supply chains.* Sustainability, 2020. **12**(11): p. 4656.
12. Evangelista, P., *Environmental sustainability practices in the transport and logistics service industry: An exploratory case study investigation.* Research in Transportation Business & Management, 2014. **12**: p. 63-72.
13. Roy, J., D. Pamučar, and S. Kar, *Evaluation and selection of third party logistics provider under sustainability perspectives: an interval valued fuzzy-rough approach.* Annals of Operations Research, 2020. **293**(2): p. 669-714.
14. Oršič, J., Rosi, B. and Jereb, B., *Measuring Sustainable Performance among Logistic Service Providers in Supply Chains.* Technical Bulletin, 2019. **26 (5)**: p. 1478-1485.
15. Ansari, Z.N., R. Kant, and R. Shankar, *Prioritizing the performance outcomes due to adoption of critical success factors of supply chain remanufacturing.* Journal of Cleaner Production, 2019. **212**: p. 779-799.
16. Singh, R.K., A. Gunasekaran, and P. Kumar, *Third party logistics (3PL) selection for cold chain management: a fuzzy AHP and fuzzy TOPSIS approach.* Annals of Operations Research, 2018. **267**: p. 531-553.
17. Koechlin, E. and T. Jubault, *Broca's area and the hierarchical organization of human behavior.* Neuron, 2006. **50**(6): p. 963-974.
18. Khader, M., *A fuzzy hierarchical decision model and its application in networking datacenters and in infrastructure acquisitions and design*. 2009, Walden University.
19. Gil-Aluja, J., *Fuzzy sets in the management of uncertainty*. Vol. 145. 2004: Springer Science & Business Media.

20. Tang, Y.-C. and M.J. Beynon, *Application and development of a fuzzy analytic hierarchy process within a capital investment study.* Journal of economics and management, 2005. **1**(2): p. 207-230.
21. Chang, D.-Y., *Applications of the extent analysis method on fuzzy AHP.* European journal of operational research, 1996. **95**(3): p. 649-655.
22. Kahraman, C., U. Cebeci, and D. Ruan, *Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey.* International journal of production economics, 2004. **87**(2): p. 171-184.
23. Gogus, O. and T.O. Boucher, *Strong transitivity, rationality and weak monotonicity in fuzzy pairwise comparisons.* Fuzzy sets and systems, 1998. **94**(1): p. 133-144.
24. Miranda, S., P. Tavares, and R. Queiró, *Perceived service quality and customer satisfaction: A fuzzy set QCA approach in the railway sector.* Journal of Business Research, 2018. **89**: p. 371-377.
25. Gurtu, A., M.Y. Jaber, and C. Searcy, *Impact of fuel price and emissions on inventory policies.* Applied Mathematical Modelling, 2015. **39**(3-4): p. 1202-1216.
26. Kang, K., et al., *Shipment Consolidation Policy under Uncertainty of Customer Order for Sustainable Supply Chain Management.* Sustainability, 2017. **9**(9): p. 1675.
27. Ren, R., et al., *A Systematic Literature Review of Green and Sustainable Logistics: Bibliometric Analysis, Research Trend and Knowledge Taxonomy.* International Journal of Environmental Research and Public Health, 2020. **17**(1): p. 261.
28. Al-Enazi, A., et al., *A review of cleaner alternative fuels for maritime transportation.* Energy Reports, 2021. **7**: p. 1962-1985.
29. Gupta, A., R.K. Singh, and P. Suri, *Sustainable service quality management by logistics service providers: an Indian perspective.* Global business review, 2018. **19**(3_suppl): p. S130-S150.
30. Mathauer, M. and E. Hofmann, *Technology adoption by logistics service providers.* International Journal of Physical Distribution & Logistics Management, 2019. **49**(4): p. 416-434.
31. Wren, B., *Sustainable supply chain management in the fast fashion Industry: A comparative study of current efforts and best practices to address the climate crisis.* Cleaner Logistics and Supply Chain, 2022. **4**: p. 100032.
32. Persdotter Isaksson, M., H. Hulthén, and H. Forslund, *Environmentally sustainable logistics performance management process integration between Buyers and 3PLs.* Sustainability, 2019. **11**(11): p. 3061.
33. Gupta, A. and R.K. Singh, *Managing operations by a logistics company for sustainable service quality: Indian perspective.* Management of Environmental Quality: An International Journal, 2020. **31**(5): p. 1309-1327.
34. Monghasemi, S., et al., *A novel multi criteria decision making model for optimizing time–cost–quality trade-off problems in construction projects.* Expert systems with applications, 2015. **42**(6): p. 3089-3104.
35. Bai, C. and J. Sarkis, *Integrating and extending data and decision tools for sustainable third-party reverse logistics provider selection.* Computers & Operations Research, 2019. **110**: p. 188-207.