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Assessment of Service Quality Performance in Global Seaborne Trade of Agro-Commodities Using a Hybrid DEMATEL and Fuzzy Evidential Reasoning Approach

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ABSTRACT

The uncertainty of information supporting rational decision analysis complicates the assessment of service quality delivery among various stakeholders within a transport logistics chain. As global seaborne agro-commodity trade continues to grow, it has become increasingly vital to analyze the risks associated with this uncertainty to support rational decisions regarding service delivery. In this paper, a framework consisting of multiple service Quality Dimension Indicators (QDIs) is developed. By integrating a Decision-Making Trial and Evaluation Laboratory (DEMATEL) model with an Evidential Reasoning (ER) algorithm, an innovative rational decision analysis tool is established. This study leverages the foundational elements of the DEMATEL technique to compute the direct weighted relationship among the identified service QDIs based on their level of influence. The evaluation of these QDIs is conducted through the application of an ER algorithm. Moreover, the study introduces a novel scheme for weight normalization and probability assignment to enable the aggregated assessments of both quantitative and qualitative variables, offering a robust approach to dealing with imprecise, incomplete, or vague data in a transport and logistics chain. An empirical study is conducted using raw data from Vietnam, China, and Thailand, focusing on key players in the agro-food markets supplying products to the global market. The findings indicate that among the identified causal indicators influencing the service quality in the agro-food transport logistics (AFTL) chain, the core drivers include: openness in information exchange, company ethical image, social responsiveness, equipment efficiency, order correctness, and the application of IT and electronic data interfaces, which function as net drivers that positively influence other risk-related variables affecting service quality. The proposed evaluation model provides strong decision-support capability for improving service quality across the transport chain. Furthermore, it will enable stakeholders to develop targeted strategies to mitigate factors contributing to service quality deterioration. Overall, the study not only enhances operational efficiency but also fosters better collaboration among stakeholders in the logistics sector.

Keywords: DEMATEL, AFTL, QDIs.

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1 INTRODUCTION

Transport and logistics service providers form a significant part of the global supply networks in the seaborne trade (Erdem et al., 2012). For instance, in the agro-food industry, products after production need to be transported to the right place, at the right time, and in the right condition. However, global stakeholders in the agro-food supply network attempt to instill a transport logistic service quality performance that will enable continuous improvement in service delivery. The term "Service quality," according to the International Organization for Standardization (ISO), is the totality of features and characteristics of a product or service that bear its ability to satisfy the stated or implied needs (International Organization for Standardization, 2015). Similarly, in the academic literature, "Service quality" has been defined by two approaches: (1) a subjective approach, proposing service quality as an adaptation to service specification predefined by the service provider, and (2) an objective approach, proposing "Service quality" as perception and evaluation of customer satisfaction when their expectations are met (Thai, 2013). Moreover, the majority of academic literature adopts the subjective definition of service quality. For instance, Mellat-Parast (2013) defines service quality as a group of practices that enables continuous process and improvement among the stakeholders; this definition is in line with the definition proposed by Siddh et al. (2017). These authors all incorporate the improvement of performance and the attainment of customer satisfaction in their definition. In this study, service quality is defined as the extent to which coordinated practices, processes, and stakeholder interactions within the transport chain consistently meet service specifications and fulfil customer expectations, thereby improving overall performance and customer satisfaction.

Service quality is unquestionably of paramount importance to service delivery. It measures how an organization's service delivery meets customer and stakeholder expectations. (Nakhai & Neves, 2009). However, a drawback highlighted in the literature is that transport and logistics service providers in the agro-food sector face challenges related to service quality, revealed by minimal studies in the existing literature. To overcome these challenges, this study aims to develop a novel service quality model for evaluating the performance of agro-food transport logistics (AFTL) service quality indicators. To achieve its objectives, the study is structured as follows: Section 1 consists of an overview of the proposed service quality evaluation models; Section 2 describes the identification of the service quality attributes used to measure performance; Section 3 describes the methodology used in the study, including the computation of the attributes' weighting with DEMATEL applications and the probability assignment of multilayer attributes assessment grades; Section 4 presents the integration of an ER approach and the empirical assessment of twenty-six global agro-food supply chain companies to demonstrate the feasibility of the proposed model; lastly, Section 5 concludes this study by addressing its limitations and proposing further research directions.

2 MODELING AFTL SERVICE QUALITY PERFORMANCE

Based on the general understanding of the attributes in the service industries and a review of the modeling frameworks in the literature, it is evident that there is no standard framework in the academic literature designed to measure the quality performance of the cargo-transport industry, all frameworks are industry-specific with a general focus on the organization features and purpose (Rafiq & Jaafar, 2007, Ladhari, 2008, Emari et al., 2011).

Over the last twenty years, various industry-specific attributes have been published in the literature to measure the organizations' service quality performance, such as the attributes to measure service quality in campus career service centers (Engelland et al., 2000), historic house service centers (Frochot & Hughes, 2000), manufacturing industries (Franceschini & Rafele, 2000), banking industry (Emari et al., 2011), the health care industry, and others. Hence, no study has yet attempted to integrate this plethora of research on service quality in the agro-commodities transport and logistics industry, thereby creating a knowledge gap. The AFTL sector operates under a set of constraints that make service quality management particularly challenging. Unlike many other service contexts, agro-food logistics involves perishable and quality-sensitive products whose condition can deteriorate rapidly if transport, storage, handling, and delivery are not properly coordinated (Yang et al., 2024). The sector is also characterized by strict food safety and traceability requirements, seasonal fluctuations in supply, variable demand patterns, and high dependence on timely information exchange among multiple actors, including producers, distributors, logistics providers, retailers, and regulators. In such a context, service failure is not limited to late delivery or poor customer experience, but may also result in spoilage, quality degradation, documentation errors, non-compliance, and financial loss across the supply chain. These sector-specific challenges suggest that service quality in AFTL should be assessed through a broader and more integrated framework.

Recent research has extensively examined the application of digital technologies in food and agro-product logistics, suggesting that the evolution of this field is being increasingly shaped by digitalization. In particular, Internet of Things (IoT) technologies have been widely adopted in agro-product logistics to address challenges such as limited real-time data capture, information asymmetry, and inadequate data security in cold-chain transport (Gao et al., 2021). For instance, Yu et al. (2025) developed an IoT-enabled cold-chain logistics supervision system to enhance the efficiency and quality of cold-chain oversight. At the same time, blockchain has been progressively introduced into agro-product supply and circulation processes to strengthen information transparency and source traceability. Zhao et al. (2026) applied blockchain technology to the supply of premium origin-based agro-products to combat adulteration and examined its role in enabling origin traceability, thereby offering an effective solution for improving the transparency and traceability of modern agricultural supply chains. Beyond traceability, blockchain has also been employed to mitigate supply-demand mismatches, deficiencies in quality and safety management, and price volatility in agro-product circulation (Hu, 2022; Li et al., 2023; Lv et al., 2023; Zheng & Zhou, 2023). Moreover, Han (2021) developed an intelligent cold-chain logistics system using RFID, sensing devices, and GPS technologies in response to the development needs of cold-chain logistics, thereby strengthening condition monitoring, shipment tracking, and process control throughout logistics operations. As this research stream has advanced, intelligent analytical methods such as machine learning have also begun to be applied in the agro-product domain, for example, in price forecasting and trend analysis based on logistics information (Chen & Li, 2019). Taken together, these studies show that digital technologies are steadily advancing food and agro-product logistics toward real-time monitoring, information transparency, end-to-end traceability, and intelligent decision support. They also provide further support for the indicator system developed in this study, demonstrating that embedding digital capabilities into the AFTL service quality evaluation framework, on the basis of traditional service quality dimensions, is both practically necessary and theoretically justified.

Although various service quality measuring attributes presented in the literature reflect the objectives, competencies, and performance of AFTL service providers, some of the attributes act as service descriptors (e.g., reliability, responsiveness, empathy) while others act as a proxy to evaluate service outcomes (i.e., tangibles) (Brady & Cronin, 2001). It must also be remarked that some of these attributes represent customer perceptions of service provision (e.g., reliability, tangibles, responsiveness, empathy, assurance, and lead time) while others represent the internal management of service provision (e.g., productivity, competence). It is also noted that some attributes are similar with different interpretations, and some are split as sub-indicators or grouped based on the quality that influences the delivery of the services to meet stakeholders' needs and/or firm objectives (Emari et al., 2011). For instance, reliability, the ability of a firm to perform the promised service dependably and accurately, is measured as a sub-indicator of correctness, completeness, and on-time delivery. It is also used independently as a modeling factor to measure the quality of performance (Franceschini & Refele, 2000; Thai, 2013). It is also noted in the literature that several authors classify the quality-measuring attributes into various dimensions of a construct, as seen in the studies by Emari et al. (2011), and Thai (2013).

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Based on this research, this study identified thirty-five lower-level multi-criteria service quality attributes relevant to the AFTL chain. These attributes were classified into four cluster groups following a brainstorming session with domain experts supported by an EU food supply chain project (European Commission, 2024), each with more than fifteen years of experience in the AFTL chain, as illustrated in Figure 1. It should be noted that, although the conceptual foundation of the proposed framework draws on the established service quality literature, the operationalization of the indicators was updated to reflect the digital transformation of contemporary logistics systems. In particular, the model does not treat digitalization as a detached or stand-alone dimension, but embeds it within the existing service quality structure. This is especially evident in the resource quality cluster, where IT and electronic data exchange are further specified through product shipment and trace systems, temperature monitoring, humidity monitoring, IoT, RFID technology, and AI/machine learning applications. These elements reflect the growing role of smart logistics in enabling real-time visibility, condition monitoring, traceability, and predictive decision support. In addition, digital capabilities are also reflected in management and relational dimensions through openness in information exchange, responsiveness, reliability of order information, and convenience of order placement. Therefore, the framework remains contemporary not because it replaces foundational service quality dimensions, but because it incorporates current digital service mechanisms within them. This clustering also reflects the major challenges faced by the AFTL sector, namely the need to manage service coordination, operational accuracy, resource adequacy, and inter-organizational reliability in the handling of perishable agro-food products.

The **Management cluster group** encompasses the attributes that define management activities, such as responsiveness to customer needs, understanding customer requirements, staff efficiency, tangible aspects of service, corporate social responsibility, commitment to human safety, company ethical image, openness to information sharing, and collaboration with external partners. In the context of increasingly digitalized logistics systems, these attributes also reflect an organization's ability to respond to customers and coordinate with supply chain partners in a timely, transparent, and data-supported manner. **The Operational cluster group** focuses on the attributes that reflect an organization's attitude and behavior in meeting customer needs. This includes flexibility and completeness of orders, accuracy of orders, and consistency in order handling. These attributes remain central to service quality assessment because, even in highly automated logistics environments, digital technologies primarily serve to enhance the precision, consistency, and responsiveness with which such operational requirements are fulfilled rather than replace them. **The Resources cluster group** pertains to the attributes related to the resources available for service delivery. This includes the condition and availability of equipment and facilities, the application of IT and electronic data interfaces in customer service, and consistency in storage, warehousing, and shipment tracing. Importantly, this cluster captures the digital transformation of contemporary logistics systems through indicators such as product shipment and traceability systems, temperature and humidity monitoring, IoT technology, RFID technology, and AI/machine learning applications. These elements reflect the growing role of smart logistics in enabling real-time visibility, condition monitoring, traceability, and predictive decision support, all of which are particularly important in agro-food transport and logistics. Lastly, **the Relational cluster group** defines the speed, security, and reliability of the services provided. Key attributes in this group are the reliability of order information, safety of service delivery, availability of services, reliability of documentation, security during service delivery, convenience of order placement, accessibility of order information, consistency in order handling, timeliness of shipments, pick-up, delivery, and competitive pricing of services. In a digitalized logistics environment, these attributes also reflect the extent to which service providers can ensure reliable information flows, accessible service interfaces, secure transactions, and timely delivery performance. Therefore, the framework remains contemporary not because it replaces foundational service quality dimensions, but because it incorporates current digital service mechanisms within them. The attributes' interpretation and unit measurements are shown in Table 1. Some attributes are assessed subjectively (qualitatively) or with numeric values (quantitatively).

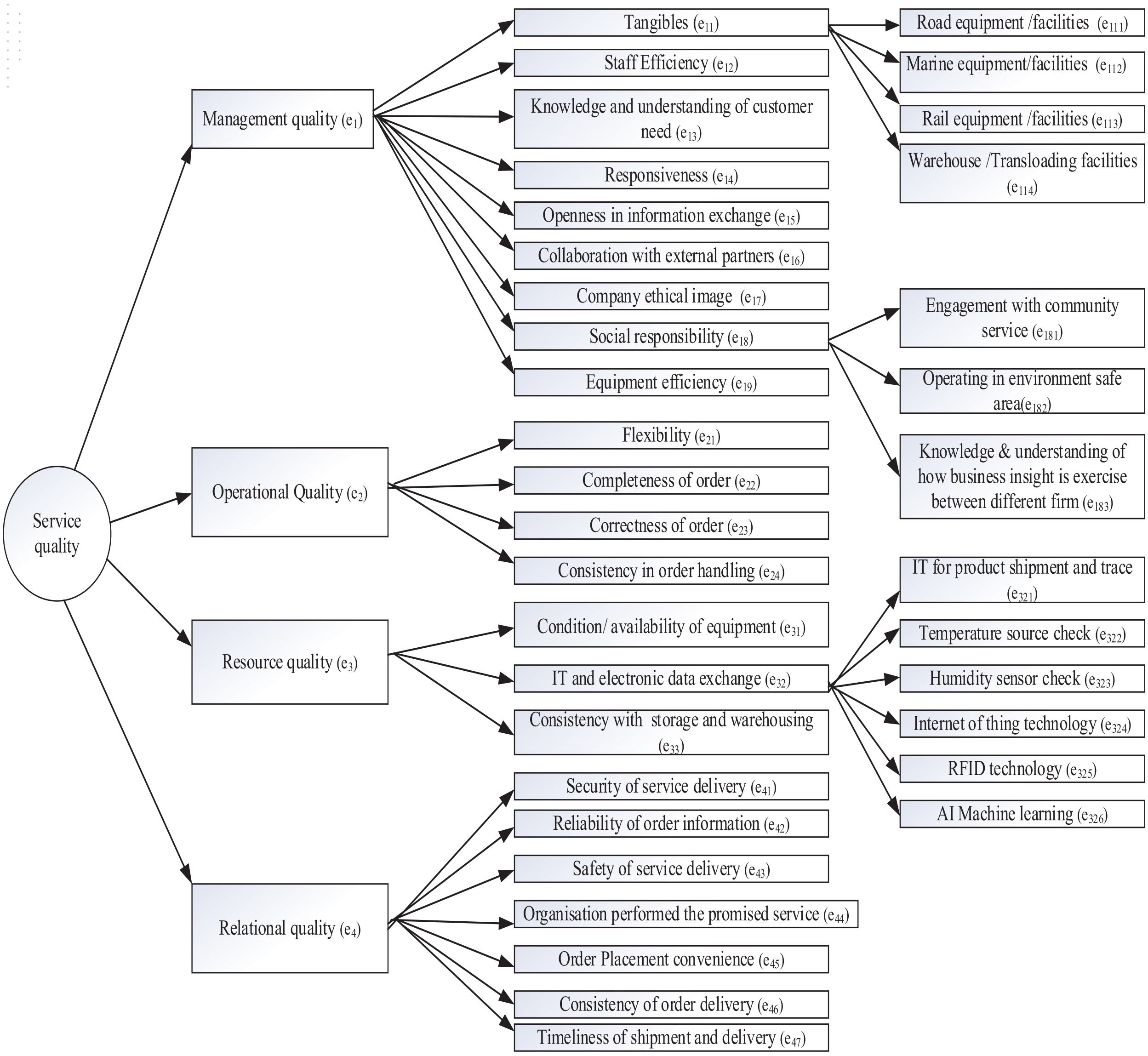

Figure 1. Service quality dimension indicators framework.

Table 1. Service quality attributes' interpretation and unit measurements.

Dimension	Principal-QDI	QDIs interpretation	Reference	Notes
Management-cluster group	Staff efficiency	Reflects the ability of the staff to contribute to service delivery	Rafele (2004)	QT: Measured by the maximum order per unit load/the number of personnel working in that given period (month)
	Responsiveness	Reflects the ability to respond to customer orders and provide prompt service	Yoon and Suh (2004), Markovic (2006), Kilibarda et al. (2016), Kataike et al. (2019)	QT: Measured as the percentage of the number of orders delivered on time divided by the total number of orders delivered in the same period
	Equipment efficiency	Reflects the ability of the equipment to contribute to service delivery	Rafele (2004)	QT: Measured as the maximum order per unit load/period
	Tangibles	Reflects how visually appealing the company facility, equipment, personnel, and communication materials are associated with the service provided	Akbaba (2006), Markovic (2006), Kilibarda et al. (2016)	QL: Evaluated on a five-point scale ranging from 1: much worse than competitors to 5: much better than competitors
	Knowledge and understanding of customer needs and requirements	Reflects the ability to understand customer needs and requirements	Thai (2013)	

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Dimension	Principal-QDI	QDIs interpretation	Reference	Notes
	Openness in information exchange	Reflects the degree of openness in the information exchange between all parties in the transport logistics system regarding the "Plan," "Source," and "Deliver" processes	Sower et al. (2001), Janda et al. (2002), Rafiq & Jaafar (2007)	
	Collaboration with external partners	Reflects the degree to which the firm collaborates with its partners, including major competitors	Thai (2013)	
	Company ethical image	Reflects how the organization's ethical culture is perceived by customers, particularly in comparison to major competitors	Akbaba (2006), Thai (2013)	
	Social responsible behavior and concern for human safety	Reflects the perception the customer has of the service delivered as requiring adherence to social responsibility norms, especially when compared with major competitors	Handgraaf et al. (2008), Thai (2013)	

Dimension	Principal-QDI	QDIs interpretation	Reference	Notes
Operation-cluster group	Flexibility	Reflects the degree to which organizations adapt to the changing demands of the users	Rafele (2004)	QT: It is measured as the percentage of special, urgent, or unexpected orders confirmed to the customer out of the total number of special, urgent, or unexpected orders requested by the customer in a given period
	Completeness of order	Reflects the completeness and accuracy of the order information	Mesquita and Brush (2008)	QT: It is measured as the percentage of complete orders delivered to the total number of orders placed in each period
	Correctness of order	Reflects the number of incorrect orders	Rafele (2004)	QT: It is measured as the percentage of incorrect orders dispatched in a given period, divided by the total number of orders dispatched during that same period
	Consistency in order handling	Reflects consistency in order handling	Rafele (2004)	QT: It is calculated as the percentage of orders processed to those delivered within the same period
Resource group	Consistency in storage and warehousing	Reflects the consistency in storage and warehousing	Rafele (2004)	QT: This is calculated as the percentage of the used volume of storage or warehousing compared to the total available volume of storage or warehousing

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Dimension	Principal-QDI	QDIs interpretation	Reference	Notes
	Condition and availability of equipment and facilities	Reflects the customer's expectations of the equipment and facilities of the firm	Handgraaf et al. (2008), Thai (2013)	QL: Evaluated on a five-point scale, where one point represents the maximum value that is physically realizable (Very High), and zero points correspond to the minimum value (Very Low)
	Application of IT and electronic data interfaces in customer service	Reflects the degree to which the IT and electronic data interfaces are used		
	Shipment tracing capacity	The availability of information about the shipment		
	Product tracing and tracking capacity	The availability of information about the product during transit		
Relational group	Security of service delivery	Reflects the number of recorded threats to transport logistics activities	Rafele (2004)	QT: It is measured as the percentage of recorded security threats divided by the total number of journeys during a specific period
	Safety of service delivery	Reflects the number of accidents occurring during the product transportation journey in a certain period	Rafele (2004)	QT: It is measured as the percentage of damage accidents divided by the number of journeys over a specific period
	Timeliness of shipment, pickup, and delivery	Reflects the duration of the delivery activities	Kilibarda et al. (2016) Kataike et al. (2019)	QT: It is measured as the time taken for the customer to receive their goods after ordering

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Dimension	Principal-QDI	QDIs interpretation	Reference	Notes
	Reliability of order information	Reflects how dependably and accurately the firm performs the promised service	Handgraaf et al. (2008), Thai (2013)	QL: Responses were evaluated on a five-point scale, where 1 indicates "strongly disagree" and 5 indicates "strongly agree"
	Reliability of available service			
	Reliability of documentation			
	Speed of service performance	Reflects the service performance speed		
	Order placement convenience	Reflects the convenience of placing an order		
	Consistency of order handling	Reflects the consistency of order handling		

[a] Note: QT: Quantitative attributes; QL: Qualitative attributes.

3 METHODOLOGY

The following steps are established to evaluate the aggregated assessment of the AFTL service quality measuring attributes.

Step 1. Estimating the relationship matrix and normalized weight of the multi-criteria attributes in the hierarchy structure.

Step 2. Developing a set of evaluation grades to evaluate the attributes and transform the quantitative attributes into a belief grade using a fuzzy membership function.

Step 3. Applying an ER algorithm in the aggregated assessment of multi-criteria attributes in the hierarchy structure.

Step 4. Conducting an empirical study on the applicability of the ER model using raw data collected from leading players in the agro-food market and supplying agro-food products to the global market.

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3.1 Attribute Relationship Matrix and Normalized Weight Estimation

The DEMATEL technique is utilized to compute the direct relationship matrix of the QDIs based on their levels of influence. This is accomplished using a comparison scale of influence that ranges from 0 to 4, where "0" signifies no influence and "4" indicates very high influence. The influencer relationships of the QDIs, as determined by the opinions of fifty domain experts, guide the weighting of these indicators (Tadic et al., 2014). The expert panel comprised 30% industry practitioners, 40% academics, and 20% government policy experts, thereby ensuring diversity in professional perspectives. Further details are presented in Appendix 1. The DEMATEL methodology was applied to analyze these relationships and compute indicator weights (Najmi & Makui, 2010). The local normalized weight of each indicator is calculated using the weighted arithmetic mean based on its assessed level of importance within a specific group and is calculated as the ratio of the indicator's unit weight to the total weight of all indicators in the same group. This relationship is expressed as:

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

where:

- w_{ij} is the normalized local weight of the indicator j in group i;
- W_{ij} is the unit (unnormalized) weight of the indicator j in group i; and
- $\sum_{j=1}^{n} W_{ij}$ is the total weight of all indicators within the group i.

The global weight of each bottom-level attribute is derived from the local weights of both upper-level and bottom-level attributes and is derived by multiplying its local weight by the overall weight of its corresponding group, thereby reflecting both within group and across group influence.

The domain experts are assumed to possess comparable and sufficient knowledge, and their relative weights are equally assigned during the computation of their judgments. The normalized local and global weighted values of the indicators are presented in Table 2. The findings indicate that the attributes within the management and operation groups have the highest weights, each with a value of 0.253. This is followed by the attributes in the resources and relational groups, as shown in Figure 2. Within the management group, the most critical attribute is staff efficiency, which has a local weighted value of 0.120. In the operation group, completeness of order is identified as the most important attribute, with a local weighted value of 0.255. The normalized weighted values for all the attributes are significant in the application of the proposed ER algorithm in this study.

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Table 2. Normalized weighted value of the attributes.

Upper-level attributes	Bottom-level attributes		Local weight	Global weight
Management attribute e_1 0.253	e_{11}	e_{111}	0.0285	0.007
		e_{112}	0.0285	0.007
		e_{113}	0.0285	0.007
		e_{114}	0.0285	0.007
	e_{12}		0.120	0.031
	e_{13}		0.116	0.029
	e_{14}		0.111	0.028
	e_{15}		0.109	0.028
	e_{16}		0.110	0.028
	e_{17}		0.108	0.027
	e_{18}	e_{181}	0.035	0.009
		e_{182}	0.035	0.009
		e_{183}	0.035	0.009
	e_{19}		0.108	0.027
Operation attribute e_2 0.253	e_{21}		0.243	0.061
	e_{22}		0.255	0.064
	e_{23}		0.253	0.064
	e_{24}		0.249	0.063
Resource attribute e_3 0.250	e_{31}		0.197	0.050
	e_{32}	e_{321}	0.205	0.051
		e_{322}	0.196	0.049
		e_{323}	0.200	0.050
		e_{324}	0.067	0.017
		e_{325}	0.067	0.017
		e_{326}	0.067	0.017
Relation attribute e_4 0.244	e_{41}		0.148	0.036
	e_{42}		0.148	0.036
	e_{43}		0.148	0.036
	e_{44}		0.120	0.029
	e_{45}		0.145	0.035
	e_{46}		0.147	0.036
	e_{47}		0.144	0.035

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Figure 2. Computed weight of the main group.

3.2 Membership Degree of Evaluation of the Bottom-Level Attributes

In this study, a set of five evaluation grades was employed to assess the lower-level attributes within the hierarchical structure illustrated in Figure 1. Each grade was designed to assign one point to the maximum value that can be physically realized, while zero points were allocated to the minimum value. Evaluation grades such as ["Excellent," "Good," "Average," "Poor," and "Worst"] (Yang et al., 2001), ["Very High," "High," "Medium," "Low," and "Very Low"], ["Strongly Agree," "Agree," "Indifferent," "Disagree," and "Strongly Disagree"] (Thai, 2013) were used for their assessment. For a detailed understanding of the qualitative features of these attributes, please refer to Table 3. For the quantitative attributes, a detailed discussion was conducted with industry experts to establish a grading scale for attributes with quantitative features, as no standardized grading scale exists in the existing academic literature. The experts reached a consensus that quantitative attributes should be evaluated using a transformation of the data gathered from the industry. Specifically, the maximum (max) and minimum (min) values that can be realistically achieved from an industrial perspective will serve as the starting and endpoint values for each attribute. Subsequently, fuzzy triangular and trapezoidal distribution functions will be applied to distribute the values into five uniform evaluation grades. For instance, if max and min are the two ending values, the average of these values can be used to define the middle level linguistic terms; the linguistic term between the lowest and middle is defined by the average of the min and the middle level terms while the linguistic term between the average and max is defined by the average value of the middle level and max term.

Each of the quantitative attributes x is evaluated on five linguistic grades:

$$G = \{g_1, g_2, g_3, g_4, g_5\}$$

Where $g_1 =$ Excellent, $g_2 =$ Good, $g_3 =$ Average, $g_4 =$ Poor, $g_5 =$ Worst and each grade is associated with a fuzzy membership degree in the interval $[0, 1]$.

Hence, $x_{\min}$: minimum realistically achievable value and $x_{\max}$: maximum realistically achievable value. The midpoint value is defined as:

$$x_3 = \frac{x_{\min} + x_{\max}}{2} \tag{2a}$$

and intermediate grading points are defined as:

$$x_2 = \frac{x_{\min} + x_3}{2} \tag{2b}$$

$$x_4 = \frac{x_3 + x_{\max}}{2} \tag{2c}$$

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Thus, the five reference points are:

$$x_1 = x_{\min}, x_2, x_3, x_4, x_5 = x_{\max}$$

Triangular and trapezoidal fuzzy membership functions are used to map quantitative values to the five evaluation grades.

(i) Excellent (g_1) – Trapezoidal

$$\mu_{g_1}(x) = \begin{cases} 1, & x \leq x_1 \\ \frac{x_2 - x}{x_2 - x_1}, & x_1 < x \leq x_2 \\ 0, & x > x_2 \end{cases} \tag{3a}$$

(ii) Good (g_2) – Triangular

$$\mu_{g_2}(x) = \begin{cases} 0, & x \leq x_1 \text{ or } x \geq x_3 \\ \frac{x - x_1}{x_2 - x_1}, & x_1 < x \leq x_2 \\ \frac{x_3 - x}{x_3 - x_2}, & x_2 < x < x_3 \end{cases} \tag{3b}$$

(iii) Average (g_3) – Triangular

$$\mu_{g_3}(x) = \begin{cases} 0, & x \leq x_2 \text{ or } x \geq x_4 \\ \frac{x - x_2}{x_3 - x_2}, & x_2 < x \leq x_3 \\ \frac{x_4 - x}{x_4 - x_3}, & x_3 < x < x_4 \end{cases} \tag{3c}$$

(iv) Poor (g_4) – Triangular

$$\mu_{g_4}(x) = \begin{cases} 0, & x \leq x_3 \text{ or } x \geq x_5 \\ \frac{x - x_3}{x_4 - x_3}, & x_3 < x \leq x_4 \\ \frac{x_5 - x}{x_5 - x_4}, & x_4 < x < x_5 \end{cases} \tag{3d}$$

(v) Worst (g_5) – Trapezoidal

$$\mu_{g_5}(x) = \begin{cases} 0, & x \leq x_4 \\ \frac{x - x_4}{x_5 - x_4}, & x_4 < x < x_5 \\ 1, & x \geq x_5 \end{cases} \tag{3e}$$

For example, the attribute "staff efficiency" is measured as the ratio of total orders received to the number of personnel handling those orders. The highest value achieved (Excellent) is 5 units of order per person, while the lowest value (Worst) is 340 units of order per person. The midpoint value (Average) is calculated to be 172.5 units of order per person. A value considered better than average (Good) is calculated at 88.8 units of order per person, and a value deemed worse than average (Poor) is 253.3 units of order per person. Similar methods were used to determine the grading value index for all quantitative attributes as shown in Table 4.

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Table 3. Grading for qualitative index.

Qualitative dimensions	Definition of scale				
	A. Worst	**B. Poor**	**C. Average**	**D. Good**	**E. Excellent**
Tangibles	The company's equipment and facilities are not appealing to the quality of service provided (A and B are the same, need to review)	The company's equipment and facilities are not appealing to the quality of service provided	The company's equipment and facilities are partially appealing due to the quality of service provided	The company's equipment and facilities are appealing due to the quality of service provided	The company's equipment and facilities are very appealing to the quality of service provided
Knowledge and understanding of customer needs and requirements	Staff lack knowledge and understanding of the customer's needs and requirements	Staff have poor knowledge and understanding of the customer's needs and requirements	Staff have partial knowledge and understanding of the customer's needs and requirements	Staff have good knowledge and understanding of the customer's needs and requirements	Staff have a very good knowledge and understanding of the customer's needs and requirements
Openness in information exchange	Lack of openness to information exchange	Below average openness to information exchange	Average openness to information exchange	Good openness to information exchange	Excellent openness to information exchange
Collaboration with external partners	Completely lacking collaborative qualities	A poor collaborator	A partial good collaborator	A good collaborator	An excellent collaborator
Company ethical image	An uncommitted ethical culture	An inconsistent ethical culture	An average ethical culture	A good ethical culture	An excellent ethical culture
Social responsible behavior and concern for human safety	Services delivered have poor social responsibility values	Services delivered have a different social responsibility value	Services delivered have an improved social responsibility value	Services delivered have good social responsibility values	Services delivered have a world-class social responsibility value
Condition and availability of equipment and facilities	Equipment and facilities are severely degraded and largely non functional	Equipment and facilities are frequently unavailable and unreliable	Equipment and facilities are functional but show noticeable wear	Equipment and facilities are generally reliable and suitable for operation with minor wear	Equipment and facilities are modern, fully functional, well - maintained, and always available when required
	Very low	Low	Medium	High	E. Very High
Application of IT, tracing, tracking, and electronic data interfaces on customer products and in customer service	IT and electronic data interfaces are not adequate	IT and electronic data interfaces are sometimes adequate	IT and electronic data interfaces are partially adequate	IT and electronic data interfaces are adequate	IT and electronic data interfaces are exceptionally adequate
Shipment tracing capacity	Shipment information is consistently unavailable	Shipment information is frequently not available	Shipment information is partially available	Availability of shipment information is good	Availability of shipment information is excellent
Product tracing and tracking capacity	The availability of product information during transit is not always available	The availability of product information during transit is sometimes not available	The availability of product information during transit is partially available	The availability of product information during transit is available	The availability of product information during transit is always available
	A. Strongly Disagree	B. Disagree	C. Indifferent	D. Agree	E. Strongly Agree
Reliability of order information	Order information is not always reliable	Order information is sometimes not reliable	Order information is partially reliable	Reliability of order information is good	Reliability of order information is excellent
Reliability of available service	Service availability is not always reliable	Service availability is sometimes not reliable	Service availability is partially reliable	Reliability of service availability is good	Reliability of service availability is excellent
Reliability of documentation	Documentation is not reliable	Documentation is sometimes not reliable	Documentation is partially reliable	Documentation reliability is good	Documentation reliability is excellent
Speed of service performance	Overall speed of service performance is poor	Overall speed of service performance is improving	Overall speed of service performance is average	Overall speed of service performance is good	Overall speed of service performance is excellent
Order placement convenience	Order placement is not convenient	The placing of an order is the least convenient	Convenience in placing an order is average	Convenience in placing an order is good	Convenience in placing an order is excellent
Consistency of order handling	Customer orders are not handled correctly	Customer orders are not well handled	Customer orders are partially handled	Good handling of customer orders	World-class handling of customer orders
Timeliness of shipment and delivery	Shipment and delivery of customer products are always delayed	Shipment and delivery of customer products are sometimes delayed	Average timing in the shipment and delivery of customer products	Good timing in the shipment and delivery of customer products	Excellent timing in the shipment and delivery of customer products

Source: (Yang et al., 2001; Handgraaf et al., 2008; Thai, 2013)

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Table 4. Grading for quantitative index.

Quantitative criteria	Worst	Poor	Average	Good	Best
Staff efficiency (Orders/Persons)	340.0	256.3	172.5	88.8	5.0
Responsiveness (%)	75.0	81.3	87.5	93.8	100.0
Equipment efficiency (Equipment/Order)	0.0	20.83	41.67	62.50	83.33
Flexibility (%)	5.0	28.8	52.5	76.3	100.0
Completeness of order (%)	15.0	36.3	57.5	78.8	100.0
Correctness of order (%)	50.0	62.5	75.0	87.5	100.0
Consistency in order handling (%)	75.0	81.3	87.5	93.8	100.0
Consistency in storage and warehousing (%)	0.0	25.0	50.0	75.0	100.0
Security of service delivery (Threat/Month)	26.7	20.0	13.3	6.7	0.0
Safety of service delivery (%)	50.0	62.5	75.0	87.5	100.0
Timeliness of shipment, pickup, and delivery (%)	10.0	32.5	55.0	77.5	100.0

3.3 Evidential Reasoning Algorithm

An ER approach was developed in 1994 to address multi-criteria problems that involve both qualitative and quantitative aspects, particularly when the information is imprecise, incomplete, or vague (Yang & Xu, 2002). The ER model integrates decision theory and Dempster-Shafer (D-S) theory within a distributed modeling framework. This allows it to manage both precise data and subjective judgments under conditions of uncertainty in a unified manner (Yang et al., 2001). The model's applications are extensive in academic literature, including areas such as marine safety analysis and system safety (Wang et al., 1995), organizational quality management self-assessment (Yang et al., 2001), performance evaluation (Yang & Xu, 2002), risk assessment (Liu et al., 2013), and green port development (Wan et al., 2018). This study utilizes the ER algorithm to assess the organization's service quality performance within the agro-product chain. The results of this analysis will provide a valuable risk mitigation tool that can be used to evaluate and benchmark quality performance standards in the AFTL network.

The ER algorithm is based on a distributed assessment framework that incorporates a variety of evaluation grades, each reflecting different levels of confidence. For example, let L represent the number of basic attributes defined as $E = \{e_1, e_2, \dots e_i \dots e_L\}$ and let their corresponding estimated weights, based on the relative importance of each attribute, be represented as $W = \{w_1, w_2, \dots w_i \dots w_L\}$. These attributes are assessed using N distinct evaluation grades, denoted as $H = \{H_1, H_2, \dots H_n \dots HN\}$. With a degree of belief of βn, I (where n = 1,…N), the assessment of each attribute ei, represented as $S_{(ei)}$, can be expressed using Equations (4) and (5).

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$$S_{(ei)} = \{(H_n, \boldsymbol{\beta}_{n}, _{I}), \; \boldsymbol{n = 1 \ldots \ldots \ldots \ldots \ldots \ldots . N}\} \qquad \boldsymbol{i = 1, \ldots \ldots, L}\} \tag{4}$$

$$\boldsymbol{\beta}_{n}, = M_n, \; \boldsymbol{I\,(L)}, \; \boldsymbol{n = 1, \ldots \ldots, N}\}$$

$$\boldsymbol{\beta}_{H}, \boldsymbol{I\,(L)} = \mathbf{1}\text{-}\; \textstyle\sum_{n=1}^{N}. \; \beta_{n}, \; \boldsymbol{n = 1 \ldots n} \tag{5}$$

Where w_I is the relative weight of the $\boldsymbol{\beta}_H$ ith attribute of (e_I), with $0 \leq w_I \leq 1$, $\boldsymbol{\beta}_{n,I} \geq \sum_{n=1}^{N}. \; \boldsymbol{\beta}_{n,I} \leq$ and $\boldsymbol{\beta}_{n,I}$ denote a degree of belief. Thus, Equation (1) denotes that attribute e_I is assessed to the grade of H_n, with a degree of belief of $\beta_{n,I}$ (n=1). The assessment of $S(e_i)$ is complete if $\sum_{n=1}^{N}. \; \boldsymbol{\beta}_{n,I}$=1, and incomplete if, $\sum_{n=1}^{N}. \; \boldsymbol{\beta}_{ni}$ is < 1, and $\sum_{n=1}^{N}. \; \boldsymbol{\beta}_{n,i} = 0$ when there is a complete lack of information on $\boldsymbol{e}_i$. To aggregate the combined degree of belief of all basic attributes, $\boldsymbol{E}_n$, is first defined as the subset of the first $\boldsymbol{I}$ basic attributes as shown in Equation (6). Where the basic probability mass $\boldsymbol{m}_{n,\;I}$ represents the degree to which the ith basic attribute $\boldsymbol{e}_i$ supports the hypothesis that the attribute y is assessed to the nth grade $\boldsymbol{H}_n$ and the remaining probability mass unassigned to an individual grade after assessing all the basic attributes in $\boldsymbol{E}_i$ is $M_n, I(i)$, **and** $M_H, I(i)$ **are** then generated by combining the basic probability masses M_n, j and M_H, j for all n = 1…….N, j=1………I as shown in Equations (7a) to (7c). Where $K_{I\,(i+1)}$ is a normalizing factor so that $\sum_{n=1}^{N}.$ $M_n, I(i+1) + M_H, I(i+1)$=1. After all the attribute assessments have been aggregated, the combined degree of belief of all the basic attributes for the assessment of criterion E is calculated using Equations (8) and (9).

$$E_{I\,(i)} = \{e_1, e_2, \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots e_i\} \tag{6}$$

$$M_n, I(i+1) = K_{I\,(i+1)} \quad (m_n, I(i)\, m_n, i+1, + m_n, I(i)\, MH_{i+1} + MH_{,1(i)} \quad M_n, (i+1) \tag{7a}$$

$$M_H, I(i+1) = K_{I\,(i+1)} \; MH_{,1(i)} \quad , MH(i+1) \tag{7b}$$

$$K_{I\,(i+1)} = \left[1 - \textstyle\sum_{=1}^{N} \; \sum_{J=1}^{N} m_t\, I_{(i)}\, m_{j,i+1}\right]\dot{-}1 \tag{7c}$$

$$\{H_n\}: \frac{\beta_n = M_n, I\;(L)}{1 - \overline{M}_{H,I\,(L)}} \qquad n = 1,\, 2,\, \ldots\ldots,\, N \tag{8}$$

$$\{H\}: \frac{\beta_H \; = \quad \widehat{M}_{H,I\,(L)}}{1 - \widehat{M}H_{,I\,(L)}} \tag{9}$$

Ranking attributes based on their distributed assessments can be challenging, as it is often difficult to differentiate between the assessments of various attributes using their degree of belief in linguistic grades. To address this, the study employs the concept of expected utility to produce a numerical value that corresponds to the distributed assessment (Yang & Xu, 2002). Hence, suppose u (H_n) is the utility of the grade H_n such that u (H_{n+1}) is greater than u (H_n), If u (H_{n+1}) is preferred to H_n then u (H_n) is calculated using a linear distribution (Yang et al., 2001) as shown in Equation (10).

$$u\,(H_n) = \frac{n-1}{N-1}, \quad n = 1,2 \ldots\ldots N \tag{10}$$

where N denotes the number of the linguistic term. For a complete and precise assessment, β_n will be equal to zero, and the expected utility of the attribute y is used to rank the alternatives using Equation (11)

$$u\,(y) = \textstyle\sum_{n=1}^{N} \beta n \;\; u\,(H_n) \tag{11}$$

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4 AN EMPIRICAL STUDY ON THE APPLICABILITY OF THE ER MODEL

This section applies the ER algorithm technique to evaluate and rank the overall performance quality of various AFTL firms in a chosen agro-products supply chain. This assessment is based on verified service quality attributes outlined in the hierarchical structure presented in Figure 1. The following three processes were followed: (1) data collection from the case company through a questionnaire survey; (2) application of the proposed ER model; and (3) analysis and discussion of the results. Details for each of these processes are discussed below.

4.1 Questionnaire Survey for Primary Data Collection

The survey questionnaire was developed to collect raw data from respondents regarding verified service quality measuring attributes. The initial questionnaire version was designed based on the attribute unit of measure and was pilot tested with three academic experts. They provided feedback on the questionnaire's rationality, structure, and reliability, leading to a few suggested changes. After implementing the recommended modifications, the validated questionnaires were translated into Chinese, Vietnamese, and Thai. Ethical approval was obtained to ensure the questionnaire contents were appropriate, and participant consent was secured before the questionnaires were distributed to participants in China, Thailand, and Vietnam via mail.

The questionnaire is divided into two parts. Part A collects demographic and company information from the respondents, while Part B focuses on measuring various quality attributes using multiple criteria. Some of these attributes are assessed using numerical units (quantitative), while others depend on the respondents' subjective judgments (qualitative). A total of 150 questionnaires were sent to AFTL companies to participate in the study. Three weeks later, a reminder email was sent to the companies. By the end of the two-month cutoff period, 26 questionnaires had been returned, resulting in a response rate of 17.3%. The respondents represent the top three countries supplying food products to the global market, which helps minimise bias in the survey. Table 5 presents the profile and location of the respondents who participated in the survey.

Table 5. Respondent profile.

Company food product	Position	Location
General fruit	Purchasing manager	China
Grains, beans, and nuts	General manager	China
Grains, beans, and nuts	Deputy manager	China
Fish and seafood	Logistic manager	China
Grains, beans, and nuts	Area manager	China
Meat and poultry	Area manager	Thailand
General consumer food	Supply chain manager	Thailand
General consumer food	Supply chain manager	Thailand
General consumer food	Shipping export manager	Thailand
Dried food products	Logistic manager	Thailand
Fish and seafood	Customer experience manager	Thailand
Dried food products	Supply chain manager	Thailand

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Company food product	Position	Location
Grains, beans, and nuts	Marketing manager	Thailand
Grains, beans, and nuts	Quality assurance manager	Thailand
Grains, beans, and nuts	Assistant managing director	Thailand
Dried food products	Supply chain manager	Thailand
Fish and seafood	Director	Vietnam
Fish and seafood	Vice president	Vietnam
Grains, beans, and nuts	Supply chain manager	Vietnam
Vegetable products	Area manager	Vietnam
Grains, beans, and nuts	Director	Vietnam
Vegetable products	Assistant managing director	Vietnam
Vegetable products	Area manager	Vietnam
Grains, beans, and nuts	Supply chain manager	Vietnam
Grains, beans, and nuts	Supply chain manager	Vietnam
Grains, beans, and nuts	Supply chain manager	Vietnam

Out of the 26 global food supply chain companies that took part in the survey, 40% were based in Thailand, 38% in Vietnam, and 19% in China, as shown in Figure 3. These companies specialize in the transportation and logistics of various agro-products. Specifically, 42% are involved in transporting grains, beans, and nuts; 19% handle fish and seafood; 12% manage vegetables, dried foods, and general consumer goods; and 4% focus on fruits, as illustrated in Figure 4.

The survey questionnaire is specifically designed for participants in managerial positions or higher due to the sensitive nature of the data required for this study. As shown in Figure 5, 30% of the respondents are supply chain managers, while 15% are area managers. The remaining participants include senior company leaders such as assistant directors, directors, general managers, deputy managers, shipping export managers, quality assurance managers, and vice presidents. The high caliber of these domain experts enhances the validity and reliability of the study's data.

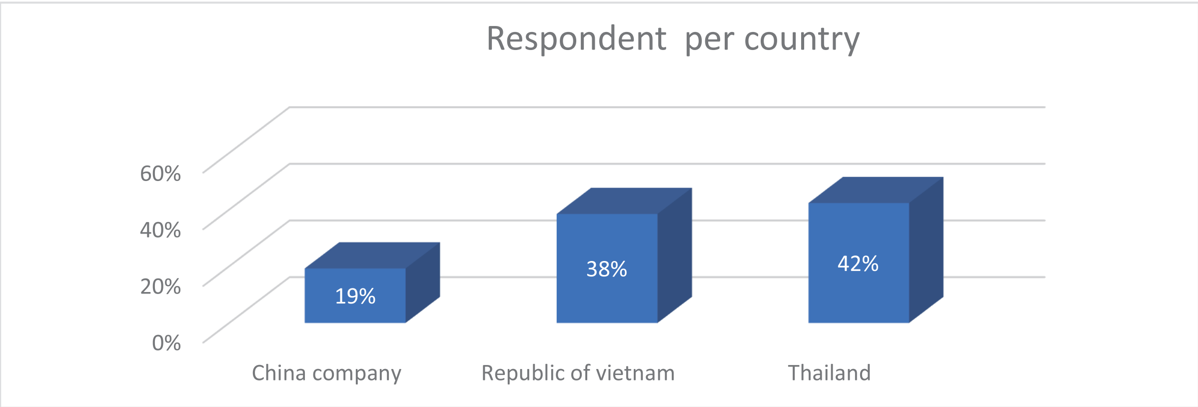

Figure 3. Respondents as per country.

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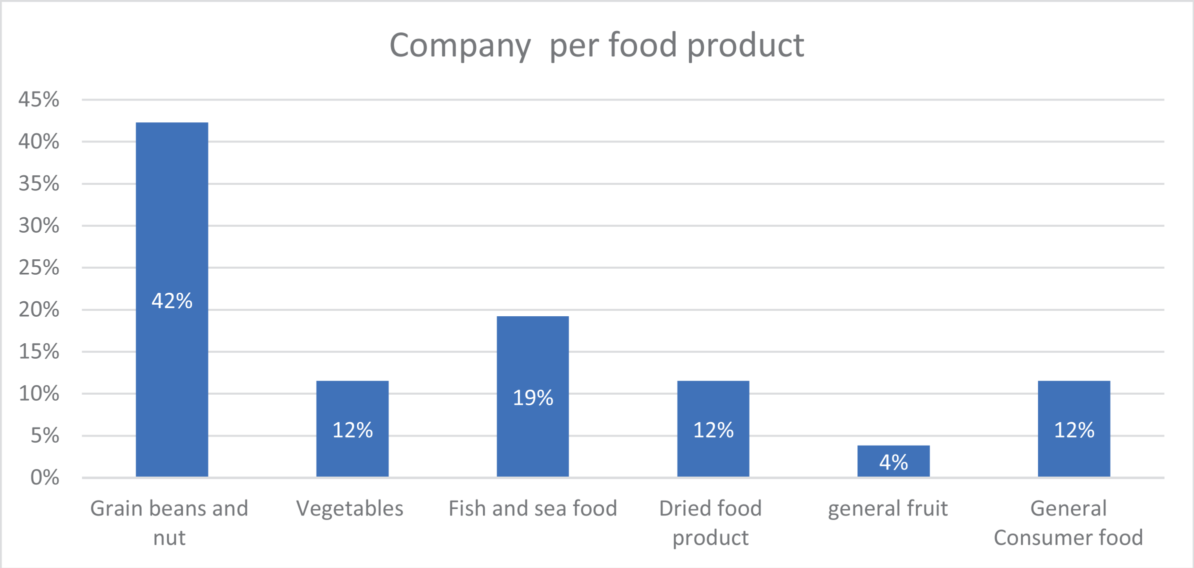

Figure 4. Respondent company as per agro-products.

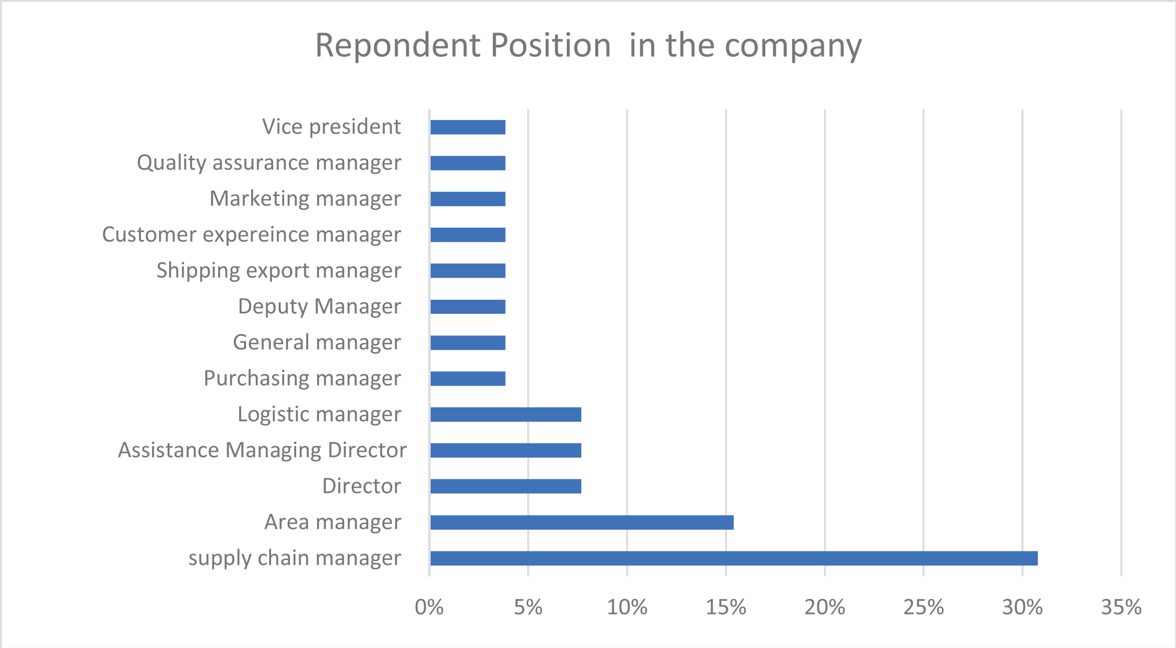

Figure 5. Respondents' position in the company.

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4.2 Application of the Proposed Methodology on Service Quality Performance

In this section, we assessed the quality performance index of agro-product transport and logistics companies to determine the individual quality performance value of each company, as well as an overall benchmark performance value for the AFTL industry. The qualitative attribute data were established based on expert judgment using the grading scale outlined in Table 3, while the quantitative attribute data were converted into numeric values according to the measurement formulas provided in Table 1. The quantitative attribute data for the first five companies are presented as an illustration in Table 6, and a linear distribution as explained above is employed on all the attributes; in addition, the overall aggregation assessment of these attributes was obtained by following the ER process discussed in Section 3.3. To minimize the lengthy and tedious calculation involved with the ER algorithm, a window-based intelligent decision system (IDS) software developed to implement the ER approach was used (Yang & Xu, 2002).

Figure 6 displays the main window of the IDS software, which includes all the functional menus necessary for inputting both numerical and qualitative information required to conduct a Multi-Criteria Decision-Making (MCDM) assessment. For example, the comprehensive assessment of company A's service quality performance, as determined by the software, is categorized as follows: 5.33% rated as worst, 6.04% as poor, 30.82% as average, 29.39% as good, and 28.41% as best, as illustrated in Figure 7. Similarly, the service quality performance assessments of all participating companies have been compiled, and the results are presented in Table 7. To rank these companies based on their service quality performance, Equations (7) and (8) are applied to calculate their utility values. Consequently, the utility value for company A is calculated to be 0.6738, or 67.38%, and the calculated utility values for the other companies are shown in Figure 8.

The highest-ranked company has a service quality performance utility value of 0.8742 (87.42%), while the lowest-ranked company has a utility value of 0.4538 (45.38%). This results in an average utility value of 0.664 (66.4%), which serves as a benchmark for measuring the service quality performance of seaborne AFTL companies in future studies (Yang et al., 2001). In this context, the value of 0.664 is established as a cut-off point to benchmark the service quality performance score of AFTL service providers in China, Vietnam, and Thailand.

Table 6. Value of the quantitative attributes.

Quantitative attributes	EX 1	EX 2	EX 3	EX 4	EX 5
AB (Order/Personnel)	5.0	10.0	300.0	20.0	15.0
AD (%)	80	100	83	80	90
AI (Equipment/Order)	6.67	0.00	0.03	0.00	3.33
BA (%)	100	50	63	75	40
BB (%)	100	90	100	75	100
BC (%)	93	89	100	73	100
BD (%)	80	100	83	80	90
CA (%)	100	80	30	100	70
DE (Threat/Month)	0.00	8.00	0.00	26.67	0.00
DA (%)	100	100	100	100	100
DI (%)	80	90	83	60	90

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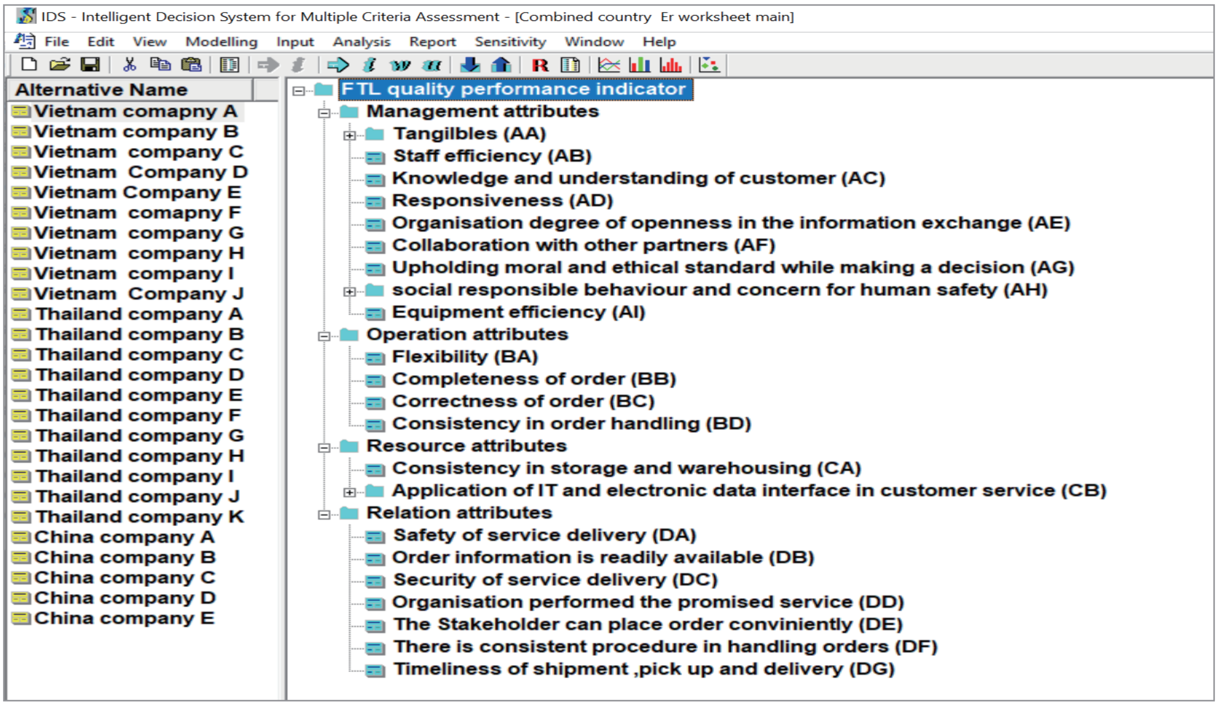
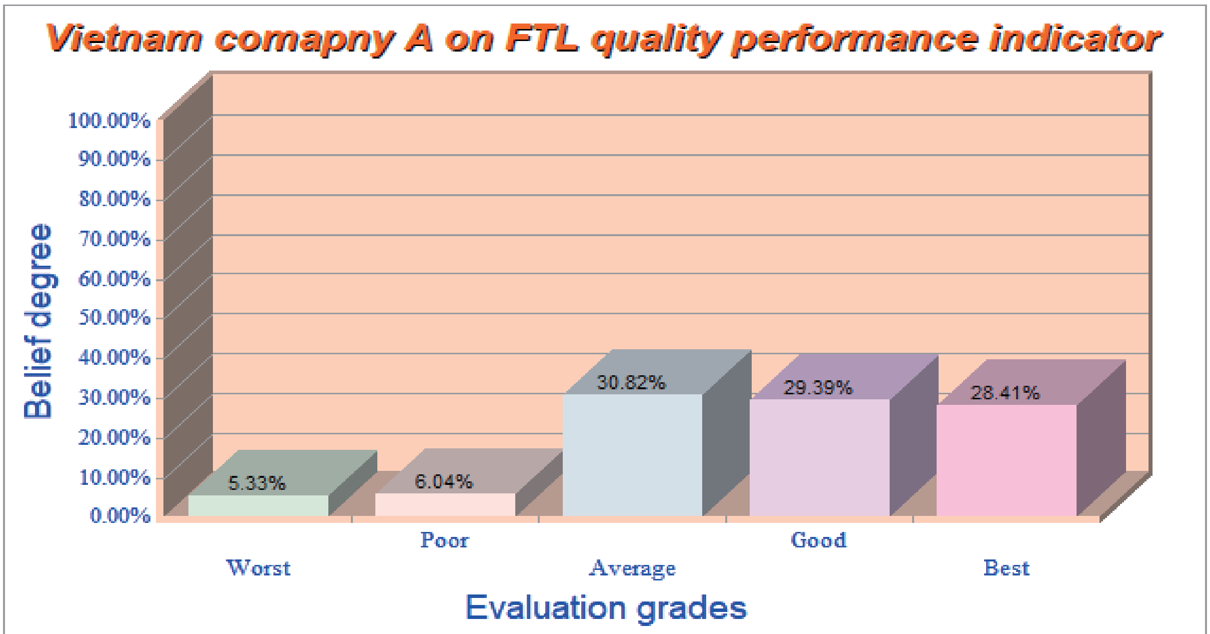


Figure 6. Main window of the IDS software.



	Worst	Poor	Average	Good	Best
Vietnam comapny A	5.33%	6.04%	30.82%	29.39%	28.41%

Figure 7. IDS graphic display of the distributed assessment of the quality performance of company A.

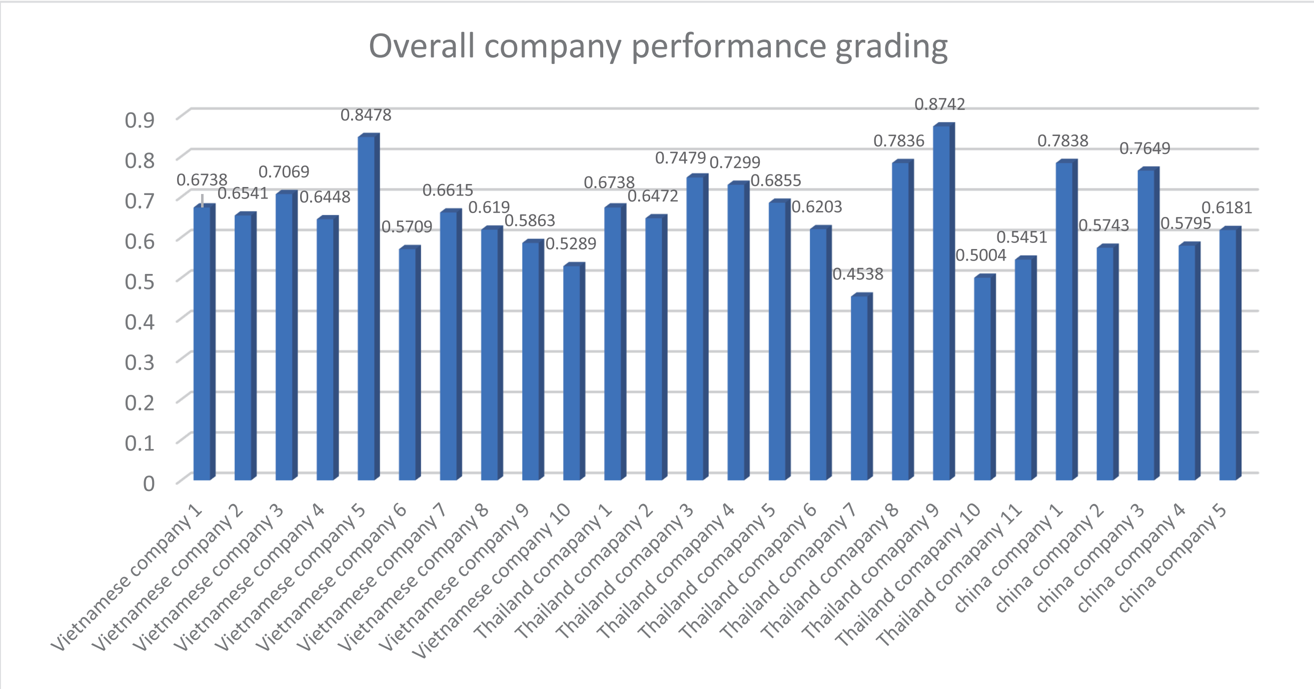


Figure 8. Overall quality performance.

Table 7. Assessment grading/utility value on the quality performance of the participating company.

Companies	Worst	Poor	Average	Good	Best	Utility value	Ranking
Vietnam company 1	5.33%	6.04%	30.82%	29.39%	28.41%	0.6738	10
Vietnam company 2	1.27%	15.69%	23.97%	38.27%	20.80%	0.6541	13
Vietnam company 3	24.30%	1.33%	3.97%	8.13%	62.28%	0.7069	8
Vietnam company 4	18.42%	7.68%	18.12%	9.12%	48.66%	0.6448	15
Vietnam company 5	2.37%	1.21%	22.07%	3.61%	70.73%	0.8478	2
Vietnam company 6	28.82%	3.59%	14.42%	16.74%	36.43%	0.5709	22
Vietnam company 7	10.85%	8.19%	9.59%	48.24%	23.13%	0.6615	12
Vietnam company 8	17.05%	1.32%	27.68%	24.90%	29.06%	0.619	17
Vietnam company 9	20.12%	1.41%	18.75%	43.27%	16.45%	0.5863	19
Vietnam company 10	23.63%	6.95%	29.48%	14.08%	25.86%	0.5289	24
Thailand company 1	5.33%	6.04%	30.82%	29.39%	28.41%	0.6738	10
Thailand company 2	11.44%	10.60%	19.52%	24.53%	33.91%	0.6472	14
Thailand company 3	7.77%	6.17%	15.11%	21.04%	49.92%	0.7479	6
Thailand company 4	3.08%	15.71%	6.42%	35.75%	39.04%	0.7299	7
Thailand company 5	3.15%	4.48%	31.69%	36.37%	24.31%	0.6855	9
Thailand company 6	20.29%	4.07%	8.35%	41.83%	25.46%	0.6203	16

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Companies	Worst	Poor	Average	Good	Best	Utility value	Ranking
Thailand company 7	31.63%	8.97%	18.51%	28.17%	12.73%	0.4538	26
Thailand company 8	1.65%	1.89%	3.08%	68.13%	25.25%	0.7836	4
Thailand company 9	1.76%	0.03%	0%	43.20%	55.01%	0.8742	1
Thailand company 10	33.34%	1.10%	25.33%	2.44%	35.27%	0.5004	25
Thailand company 11	20.55%	11.81%	16.87%	30.61%	20.16%	0.5451	23
China company 1	2.88%	6.38%	11.92%	31.99%	46.83%	0.7838	3
China company 2	15.43%	0.52%	43.95%	19.09%	21.01%	0.5743	21
China company 3	3.20%	7.36%	5.52%	48.12%	35.81%	0.7649	5
China company 4	29.71%	6.84%	8.47%	11.86%	43.11%	0.5795	20
China company 5	19.36%	3.00%	25.14%	16.02%	36.47%	0.6181	18

4.3 Overall Service Quality Performance Assessment

The aggregated quality performance assessment scores of the companies, based on the measured attributes, are shown in Figure 9. The majority of companies attained higher service quality performance scores in the operation and relation groups, with the lowest performance score being 54% in the operation group and 57% in the relation group. In the resource group, over 53.8% of the participating companies reported performance scores below 50%. This shortfall in the resource group attributes, such as consistency in storage and warehousing, condition and availability of equipment and facilities, application of IT and electronic data interfaces in customer services, and shipment and product tracing and tracking capacity, negatively impacts service quality performance. Similarly, in the management group, 15.4% of participating companies had quality performance scores below 50%, with the lowest score being 36%.

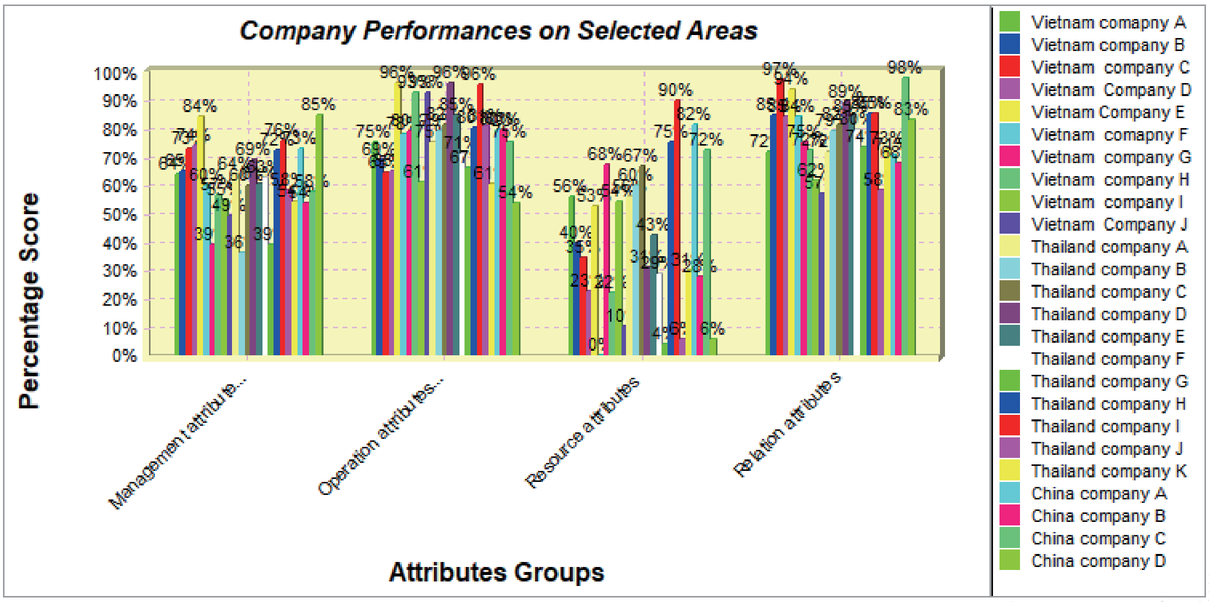

Figure 9. Overall attributes group assessment.

4.3.1 Individual group attributes service quality performance assessment

The analysis of service quality measurement attributes within the management group is illustrated in Figure 10. The findings reveal that equipment efficiency is ranked as the least influential attribute on the service quality performance of organizations, with 96.15% of the participating companies scoring below 50%. Following this, responsiveness to customer orders is associated with 38.5% of the participating companies having performance scores below 50%. Additionally, regarding equipment and infrastructure (tangibles), 30.7% of participating companies have a score below 50%. For the attributes in the operation group, the factors that have the least quality impact on performance include consistency in order handling, the ability to adapt to changing customer demand, and the accuracy and completeness of order information. As shown in Figure 11, 30.7% of the participating companies scored below average on these attributes.

In the resource group, the attributes that significantly affect organizational performance include consistency in storage and warehousing, the absence of an electronic data interfaces, and the lack of temperature and humidity sensors to track and trace products during transit. Additionally, the limited use of artificial intelligence and RFID technology in service represents a performance challenge. More than 50% of the participating companies reported low performance scores on these variables, as shown in Figure 12. For the attributes associated with the relation group, the approach to managing order and order information is identified as the least influential factor in enhancing a firm's service quality performance, as illustrated in Figure 13.

In summary, the findings indicate that attributes within the operation and relational groups—namely flexibility, order completeness, order accuracy, service delivery safety, service delivery security, and shipment timeliness—are the most significant factors contributing to the quality performance of AFTL companies in Thailand, China, and Vietnam. All participating companies from these regions achieved aquality performance assessment score exceeding 75% based on these attributes, as shown in Figures 14 to 16.

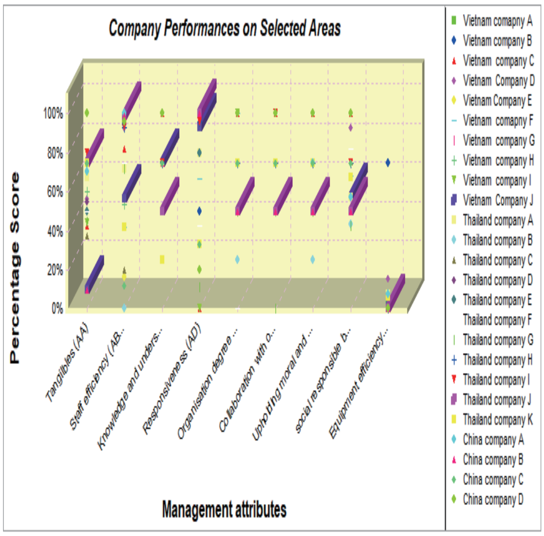

Figure 10. Management attributes assessment.

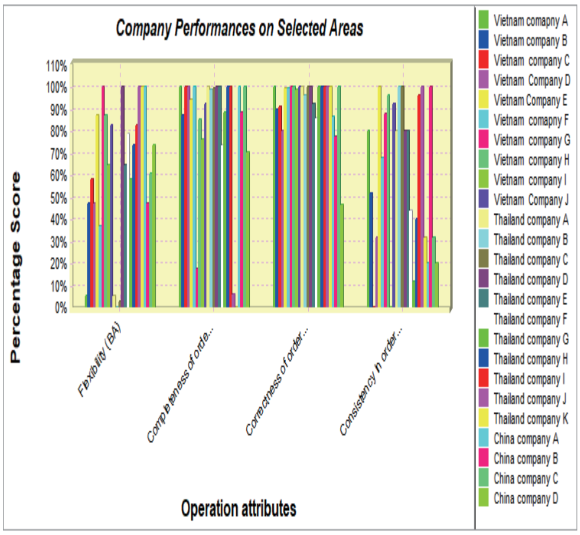

Figure 11. Operation attributes assessment.

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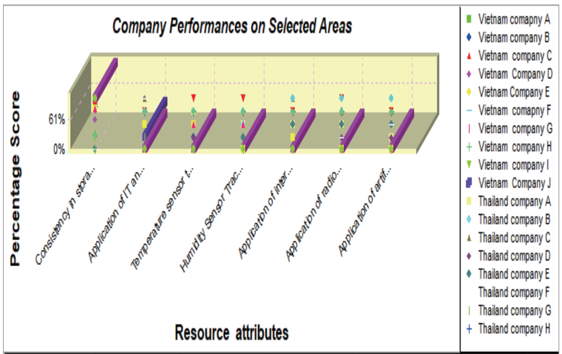

	Temperature sensor t...	Humidity Sensor Trac...	Application of inter...	Application of radio...	Application of artif...
Thailand company E	50%	25%	50%	50%	50%
Thailand company F	0%	0%	75%	25%	50%
Thailand company G	0%	0%	0%	0%	0%
Thailand company H	75%	75%	75%	75%	75%

Figure 12. Resource attributes assessment.

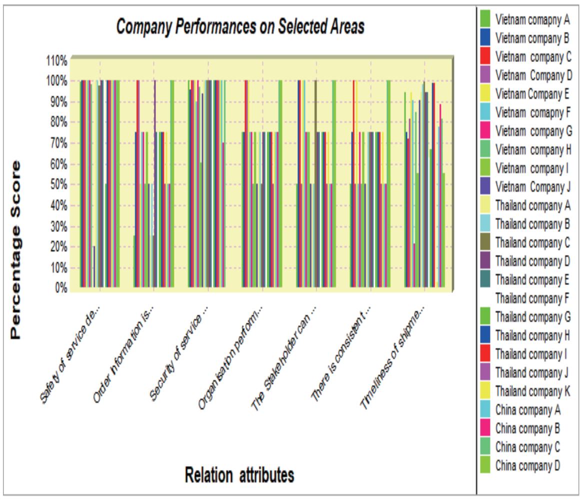

Figure 13. Relation attributes assessment.

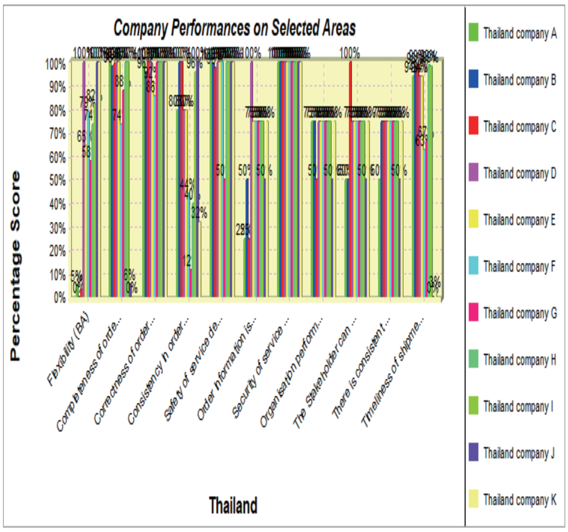

Figure 14. Thailand.

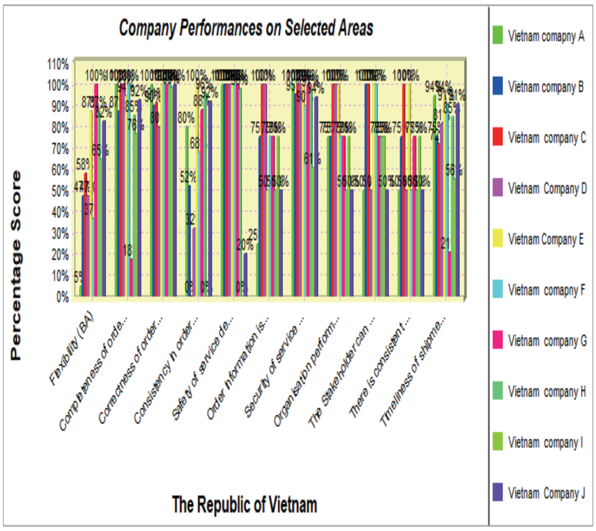

Figure 15. Vietnam.

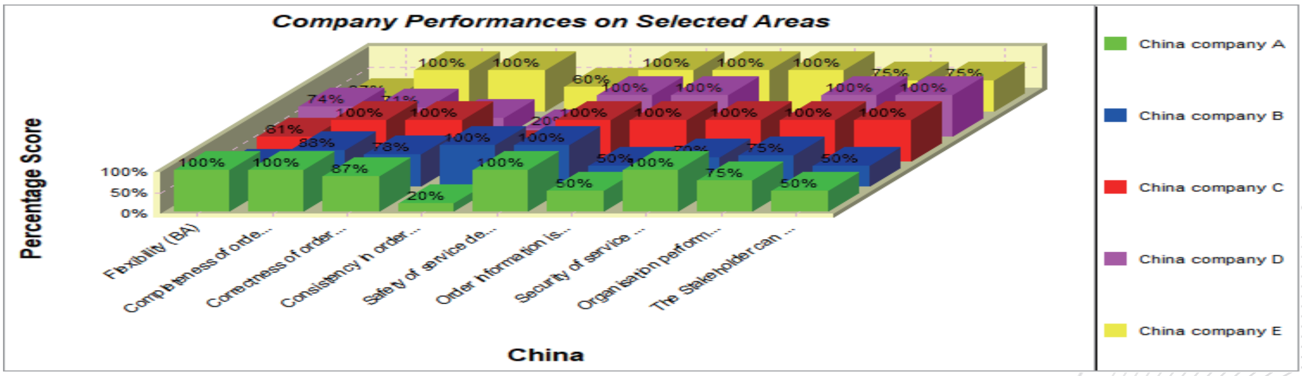

Figure 16. Most influential attributes in China.

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5 EVALUATION OF COMPANIES' SERVICE QUALITY PERFORMANCE BASED ON VARIOUS COMMODITY PRODUCTS

This section assesses the service quality performance of AFTL companies that handle grains, beans, cashew nuts, seafood, and vegetable products. The study utilized survey data from case companies involved in the seaborne trade of these products from Vietnam, China, and Thailand to the global market. The collected survey data were analyzed according to the methodology outlined in Section 3. For attributes with quantitative features, we applied the unit of measurement formula (see Table 1) to convert the raw data into numerical values. The summarized values for the quantitative attributes of the food products are presented in Tables 8-11, while the grading index for evaluating the numerical grades was determined following the process described in Section 3.2. For attributes with qualitative features, the evaluation was based on expert judgments using the proposed grading scale (refer to Table 3). The ER algorithm model was employed to assess the aggregate performance of all lower-level attributes in relation to the upper-level attributes, ultimately determining the overall service quality performance of the firm.

Table 8. Value of the quantitative index of grain, bean, and cashew nut products.

Quantitative index	A	B	C	D	E	F	G	H	I	J	K
AB (Order/Personnel)	10.00	300.00	15.00	29.23	25.71	10.00	66.67	285.71	160.00	16.67	150.00
AD (%)	100	83	90	99	99	100	75	100	99	75	98
AI (Equipment/Order)	0	0	3	0	0	0	3	0	0	2	0
BA (%)	50	63	40	75	83	0	60	88	88	67	83
BB (%)	90	100	100	100	100	10	100	95	88	80	93
BC (%)	89	100	100	100	100	100	96	100	100	99	100
BD (%)	100	83	90	99	99	100	75	100	99	75	98
CA (%)	80	30	70	85	85	100	90	98	90	25	83
DA (%)	100	100	100	100	100	100	100	0	99	50	60
DC (Threat/Month)	8	0	0	0	0	0	0	0	1	11	2
DI (%)	90	83	90	99	99	10	75	95	86	60	92

Table 9. Value of the quantitative index of seafood products.

Quantitative index	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5
AB (Order/Personnel)	20	29.23	25.714	15	22.5
AD (%)	80	99	99	83	88
AI (Equipment/Order)	0	0.003	0.0033	0.83333	0.625
BA (%)	75	75	83	40	50
BB (%)	75	100	100	80	89
BC (%)	73	100	100	50	95
BD (%)	80	99	99	83	88
CA (%)	100	85	85	100	0
DA (%)	100	100	100	100	100
DC (Threat/Month)	0.267	0	0	0	0.0125
DI (%)	60	99	99	67	78

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Table 10. Value of the quantitative index for expert companies handling vegetable products.

Quantitative index	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5
AB (Order/Personnel)	29.23	25.71	30.00	200.00	100.00
AD (%)	99	99	83	92	97
AI (Equipment/Order)	0.003	0.003	0.133	0.0025	0
BA (%)	75	83	50	40	100
BB (%)	100	100	100	100	30
BC (%)	100	100	90	100	100
BD (%)	99	99	83	92	97
CA (%)	85	85	60	80	80
DA (%)	100	100	100	100	100
DC (Threat/Month)	0	0	0	0.0275	0
DI (%)	99	99	83	92	29

Table 11. Value of the quantitative index for expert companies handling consumable products.

Quantitative index	Ex 1	Ex 2	Ex 3	Ex 4	Ex 5	Ex 6	Ex 7	Ex 8
AB (Order/personnel)	5	340	272.7	25	12.5	90	100	200
AD (%)	80	100	100	95	95	86	78	83
AI (Equipment/order)	0.07	0.00	0.00	0.02	0.03	0.00	0.00	0.05
BA (%)	100	5	8	100	67	80	60	100
BB (%)	100	99	100	100	100	78	90	15
BC (%)	93	98	100	100	96	93	100	100
BD (%)	80	100	100	95	95	86	78	83
CA (%)	100	80	33	0	0	0	0	80
DA (%)	100	100	99	100	100	100	75	100
DE (Threat/Month)	0	0	0	0	0	0	0	0
DI (%)	80	98	99	95	95	67	70	13

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5.1 Evaluation of the Quality Performance of AFTL Companies Handling Grains, Beans, and Cashew Nut Products

The IDS software was used to synthesize the aggregate assessment of all lower-level quality measuring attributes and combine them with higher-level attributes to evaluate the overall service quality performance of a company. By analyzing the evaluation grades derived from individual companies, we estimate and present the overall service quality performance assessment for grain, bean, and cashew nut handling companies, as illustrated in Figure 17.

Hence, the final assessment on the quality performance of grain handling company A is evaluated as 22.30% Worst, 1.05% Poor, 5.74% Average, 11.07% Good, and 58.95% Best. Moreover, the evaluation result also shows the degree of incompleteness in the final assessment of company H, i.e., 32.06% Worst, 2.09% Poor, 25.41% Average, 2.29% Good, 35.62% Best, and 2.53% Unknown. This incompleteness arose from an incomplete assessment of the attributes for company H (Yang and Xu, 2002). To rank the service quality performance of the companies, their utility values have been estimated using Equations (7) and (8). The utility value (u) for grain handling company A is 0.7128. The utility values for the other grain handling companies are presented in Figure 18.

The companies are ranked thus: u (company G) = 0.8810 > u (company B) = 0.8518> u (company F) = 0.7940 > u (company J) = 0.7651 > (company A) = 0.7128 > u (company K) = 0.6476 > u (company L) = 0.6273 > u (company D) = .0.6148 > u (company E) = 0.5477 > u (company H) = 0.5309 > u (company I) = 0.5307.

A benchmark quality performance value of 0.7058 has been established based on the average range between the highest-performing company's utility value of 0.8810 and the lowest-performing company's utility value of 0.5307. This overall quality performance value for grain and transport logistics companies, derived from the study, can serve as a benchmark for measuring the quality performance of similar companies in future research.

Additionally, the study identifies the key attributes that significantly enhance the quality performance of grain, cashew, and nut handling companies, as illustrated in Figure 19. The assessment results indicate that the most influential attributes within the operational and relational groups include: flexibility, safety of service delivery, availability of order information, security of service delivery, the organization's ability to fulfill promised services, convenience for stakeholders to place orders, consistency in order handling procedures, and timeliness of shipment, pickup, and delivery. Most companies scored above 50% on these attributes, as shown in Figure 19.

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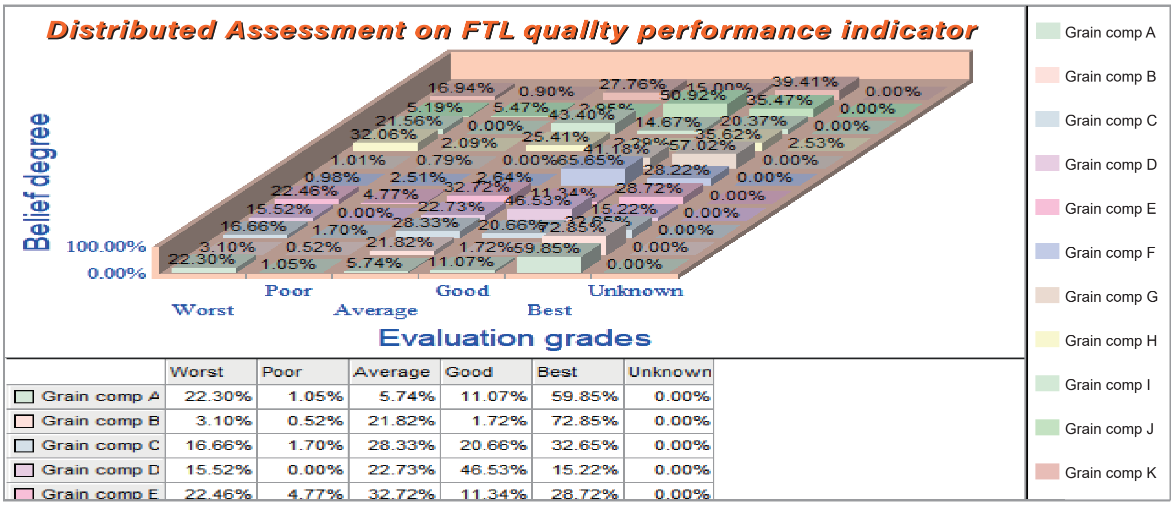

Figure 17. Quality performance of grain, cashew, and nut handling companies.

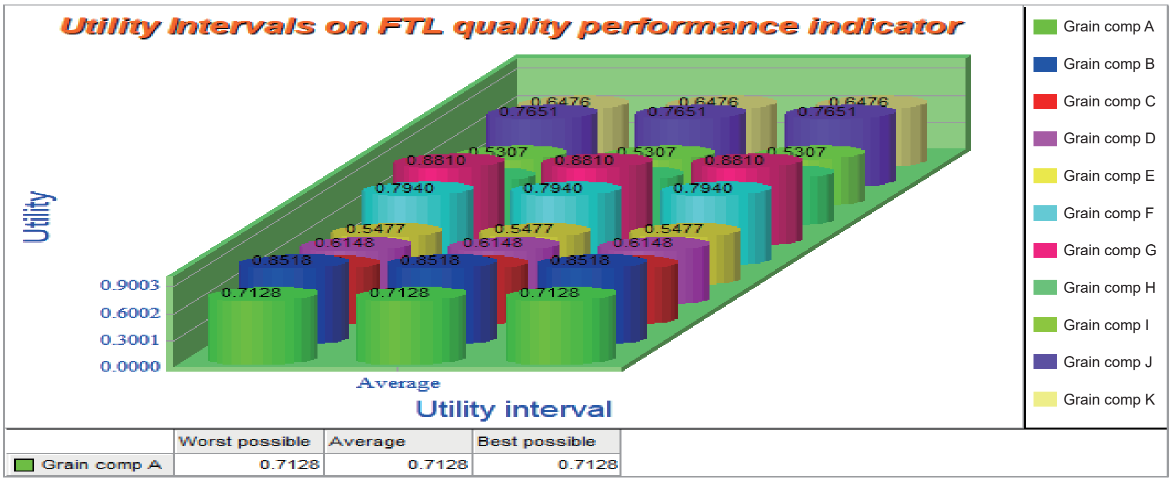

Figure 18. The utility value of the index of grain, cashew, and nut handling companies.

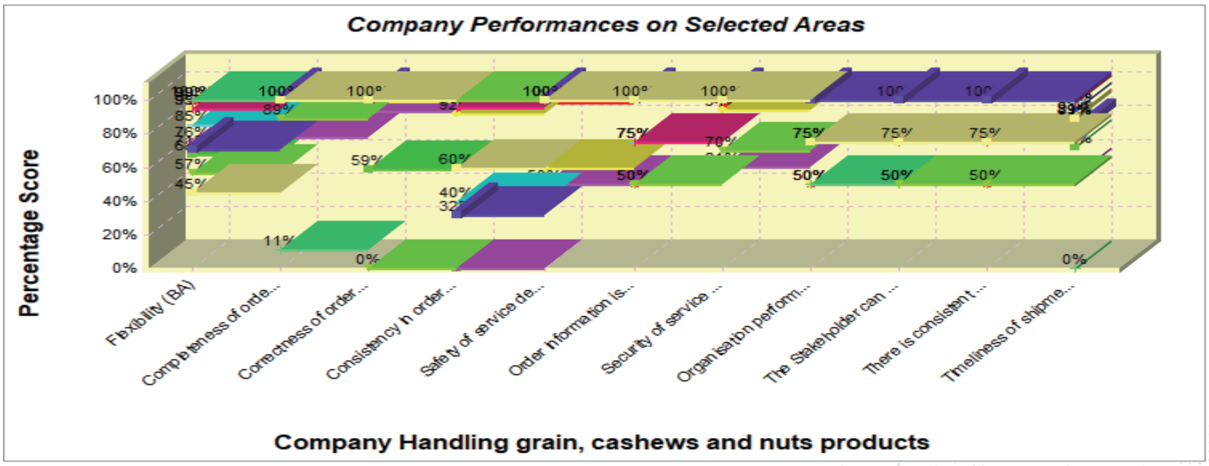

Figure 19. The most influential attributes on the quality performance of companies handling grains, cashews, and nut products.

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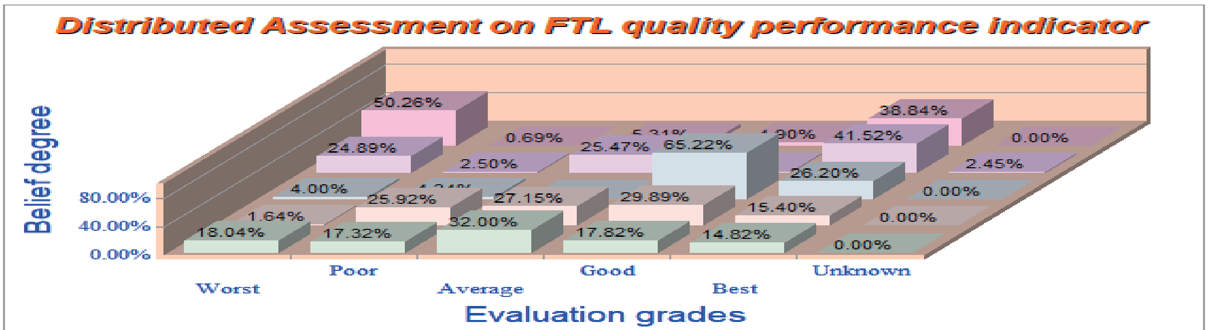
5.2 Evaluation of the Quality Performance of AFTL Companies Handling Seafood Products

Based on the evaluation grades sourced from companies involved in seafood products, the overall quality performance assessment was estimated using the proposed ER algorithm, as illustrated in Figure 20.

Figure 20 indicates that the quality performance assessment for seafood handling company A is as follows: 18.04% rated as Worst, 17.32% as Poor, 32.00% as Average, 17.82% As good, and 14.82% as Best. In comparison, company D has an incomplete assessment, with 2.45% classified as unknown. Its performance breakdown is as follows: 24.89% rated as Worst, 2.50% as Poor, 25.47% as Average, 3.17% as Good, and 41.52% as Best. Equations (7) and (8) were used to calculate the utility values for ranking these companies. Figure 21 presents the utility index of all the seafood handling companies, ranked as u (company E) = 0.4534 < u (company A) = 0.4851 < u (company B) = 0.5787 < u (company D) = 0.5971 < u (company C) = 0.7632. Similarly, A benchmark value of 0.6083 was calculated based on the average range between the utility values of the highest-performing company (0.7632) and the lowest-performing company (0.4534). This benchmark serves as a reference point for measuring the service quality performance of similar seafood handling companies in future studies.

A seafood company is deemed a low performer if its quality performance utility value falls below 0.6083 during the assessment. Conversely, all participating companies achieved a high-performance score exceeding 50%. This score is attributed to factors within the management and resource groups, such as the quality of tangible assets, knowledge and understanding of the customer, the organization's openness in information exchange, collaboration with partner organizations, adherence to moral and ethical standards, the safety of service delivery, fulfilment of promised services, convenient order placement for stakeholders, and a consistent procedure for handling orders. These attributes significantly influence the quality performance standards of companies handling seafood products, as illustrated in Figure 22.



	Worst	Poor	Average	Good	Best	Unknown
Seafood A	18.04%	17.32%	32.00%	17.82%	14.82%	0.00%
Seafood B	1.64%	25.92%	27.15%	29.89%	15.40%	0.00%
Seafood C	4.00%	4.34%	0.24%	65.22%	26.20%	0.00%
Seafood D	24.89%	2.50%	25.47%	3.17%	41.52%	2.45%
Seafood E	50.26%	0.69%	5.31%	4.90%	38.84%	0.00%

Figure 20. Performance assessment of seafood handling companies.

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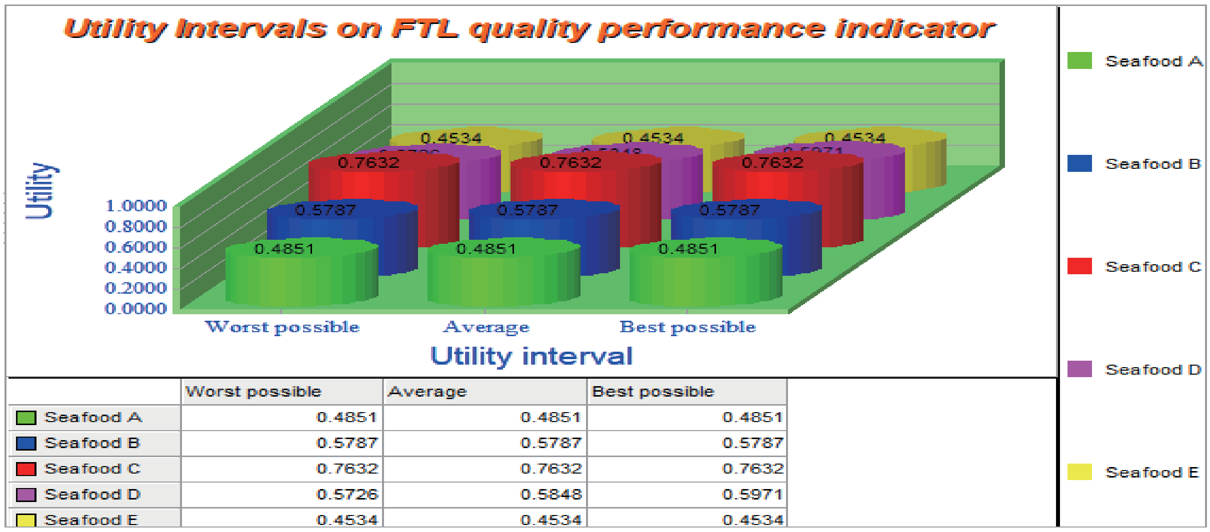

Figure 21. The utility value of the index of seafood handling companies.

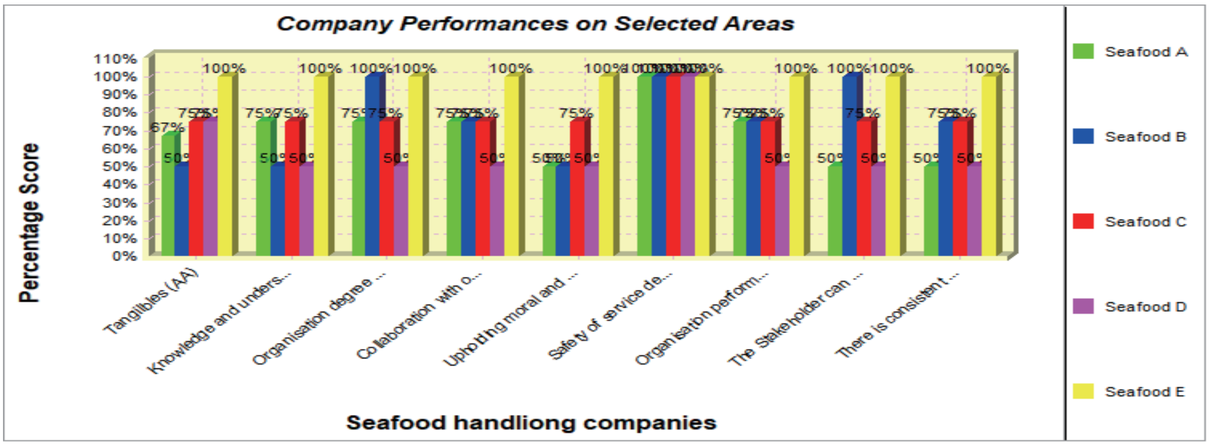

Figure 22. The most influential attributes on the quality performance of the company handling seafood products.

5.3 Evaluation of the Quality Performance of AFTL Companies Handling Vegetable Products

Based on the evaluation grades from data received from case companies handling vegetable products, Figure 23 presents their aggregated service quality performance assessments using the proposed ER Algorithm.

Company A's evaluation is as follows: 39.72% Worst, 3.25% Poor, 8.31% Average, 3.40% Good, and 45.32% Best. Company B's evaluation includes: 43.54% Worst, 0.16% Poor, 13.13% Average, 11.39% Good, and 21.78% Best. Company C is assessed as: 15.56% Worst, 1.06% Poor, 11.29% Average, 47.95% Good, and 24.14% Best. Company D's evaluation states: 4.10% Worst, 2.59% Poor, 3.11% Average, 61.34% Good, and 28.87% Best. Company E is assessed as: 1.64% Worst, 0.18% Poor, 0.42% Average, 38.75% Good, and 59.02% Best.

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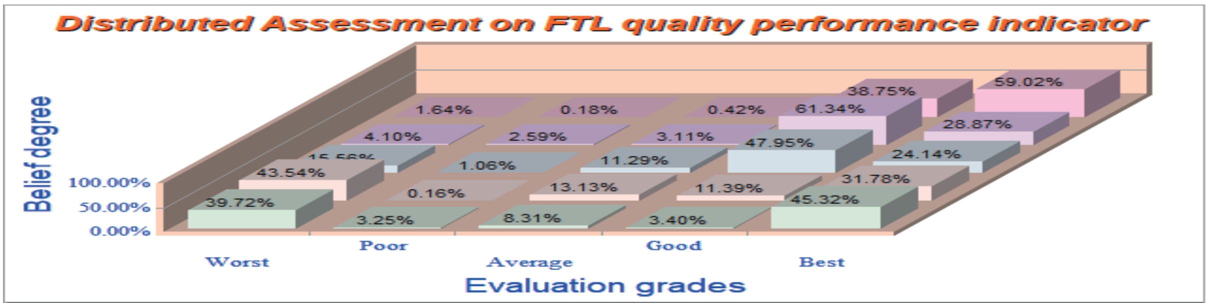
Consequently, the utility index for each company is calculated using Equations (7) and (8), as shown in Figure 24. Vegetable handling company E has the highest utility index value of 0.8833, followed by company D at 0.7707. In contrast, company B has the lowest utility index value of 0.4693.

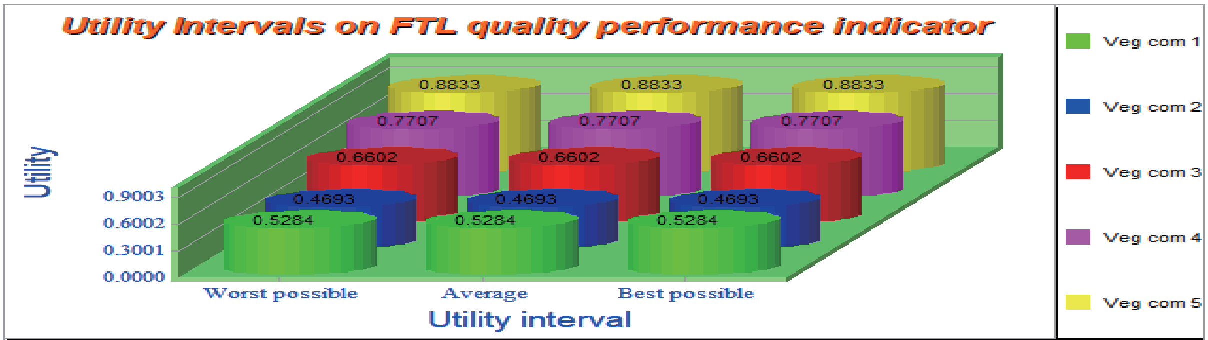
Additionally, an average utility index value of 0.6763 is established based on the range between the highest-performing company and the lowest-performing company. This value serves as a benchmark for assessing the quality performance of similar vegetable handling companies in future studies.

When comparing the quality performance of the companies concerning individual attribute groups, most companies scored higher than 50% in quality performance. However, one company had a quality performance score of 46% in the management group, while two companies scored 16% and 0% in the resource group. One company achieved a quality performance score of 26%, as detailed in Figure 25. This indicates that the quality performance of companies handling vegetable products is predominantly influenced by the attributes in the management and resource groups.



	Worst	Poor	Average	Good	Best
Veg com 1	39.72%	3.25%	8.31%	3.40%	45.32%
Veg com 2	43.54%	0.16%	13.13%	11.39%	31.78%
Veg com 3	15.56%	1.06%	11.29%	47.95%	24.14%
Veg com 4	4.10%	2.59%	3.11%	61.34%	28.87%
Veg com 5	1.64%	0.18%	0.42%	38.75%	59.02%

Figure 23. The most influential attributes on the quality performance of companies handling vegetable products.



	Worst possible	Average	Best possible
Veg com 1	0.5284	0.5284	0.5284
Veg com 2	0.4693	0.4693	0.4693
Veg com 3	0.6602	0.6602	0.6602
Veg com 4	0.7707	0.7707	0.7707
Veg com 5	0.8833	0.8833	0.8833

Figure 24. The utility value of the index of seafood handling companies.

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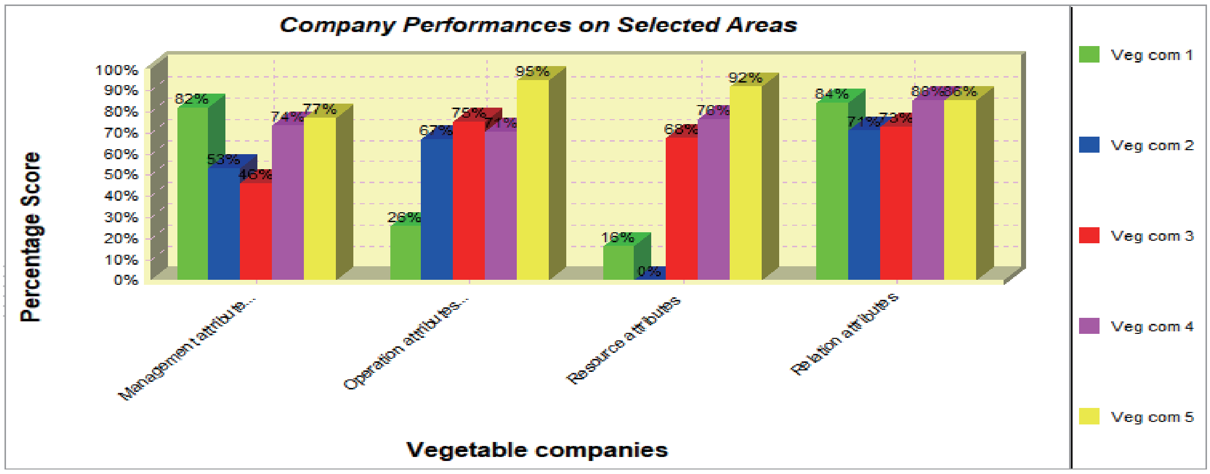

Figure 25. The most influential attributes on the quality performance of companies handling vegetable products.

6 CONCLUSIONS

The study introduces a new framework to evaluate the service quality performance of AFTL companies in the seaborne agro-product commodity trade, consisting of thirty-five lower-level multi-criteria attributes, validated and classified into four main groups. The AHP and ER approaches are integrated into this multi-criteria hierarchy framework to determine the relative weights of the lower-level attributes and to estimate the overall goal of quality performance. Through a comparative analysis of service quality performance among AFTL companies in three major countries involved in the transportation and logistics of the global food supply, the study demonstrates the beauty of the proposed model. This study contributes to the existing literature on the agro-product commodity trade by establishing a standardized method for evaluating quantitative attributes in the AFTL chain. It identifies the most influential attributes for enhancing the quality performance of AFTL service providers, which include flexibility, order completeness, order accuracy, delivery safety, service security, order information availability, consistent order handling procedures, and timeliness of shipments, pickups, and deliveries. Furthermore, this study provides a rational approach for self-assessment and benchmarking the quality performance of logistics companies, based on the estimated benchmark values for AFTL companies handling grain, cashew, seafood, and vegetable products. By addressing the uncertainty stemming from the assessors' lack of experience, this study enables quality audits of AFTL companies by employing both qualitative and quantitative data. The proposed quality performance benchmark will equip audit assessors with a logical framework to justify their quality performance assessment scores within the agro-product commodity trade.

However, this study has some limitations. First, it relied on questionnaire-based data due to the lack of industry-specific risk data. Moreover, data confidentiality within the transport logistics industry limited the sample size and may have introduced response bias. Future research can integrate survey data with archival records, operational data, and interview evidence, or collaborate directly with logistics firms to access more objective and longitudinal datasets. Second, this study focused only on identifying root causes of service quality risk, without evaluating mitigation strategies. Future research can extend the proposed framework by investigating and comparing alternative risk response measures through simulation, comparative case analysis, or decision-support modeling. Third, the analysis was limited to three developing countries (Vietnam, China, and Thailand). Future research should consider larger samples across diverse geographical regions, including developed countries, to further validate and extend the proposed AFTL risk management framework.

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Appendix

Appendix 1. Profile of participating experts.

Category	Number	Percentage
Industry practitioners	15	30%
Academics	20	40%
Government/Policy experts	15	30%
Total	50	100%

Appendix 2. Questionnaire.

Question 1. What is your position in the company?

Question 2. The number of years in your organization:

Question 3. What is the number of employees in your organization?

Question 4. What direction of transport and logistic activities is your organization primarily dealing with? International.

Question 5. What freight mode does your organization typically deal with? Sea.

Question 6. Does your organization have its own freight mode? No.

➢ In a typical month, how many trips does it cover?

Question 7. What kind of products does your organization deal with?

Question 8. Is your organization concerned about the deterioration of quality in the transport logistics chain?

Question 9. Have you had a concern/incident in the past 12 months relating to the quality of services rendered to any stakeholder?

Question 10. Does your organization receive monthly/annual orders from its stakeholders? No.

➢ In a typical month, how many times does your organization receive a full order?

➢ In a typical month, what is the total quantity of orders received?

➢ In a typical month, what quantity of the total order received is delivered? ----------

Question 11. Does your organization allow special/urgent/unexpected orders? No.

➢ In a typical month, how many special/urgent/unexpected orders are allowed?

➢ In a typical month, how many special/urgent/unexpected orders are received?

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Question 12. Does your organization have storage/warehouse facilities? If you answer "yes".

➢ What is the total volume of storage/warehouse that is available? In a typical month, what volume of the storage/warehouse is in use?

Question 13. Does your organization have dedicated personnel to deal with the order? If you answer "yes".

➢ In a typical month, how many personnel members are available?

➢ How many hours are the personnel allowed to work in a day?

Question 14. Does your organization have sufficient equipment to handle the orders? If you answer "yes".

➢ In a typical month, how much of the equipment is in use?

Question 15. In the past 12 months, did your organization encounter any security threat on orders?

➢ How many security threats were recorded?

Question 16. In the past 12 months, did your organization encounter any accidents during product transportation? If you answer "yes".

➢ In a typical month, what is the number of accidents recorded per trip?

Question 17. In the past 12 months, has your organization received complaints of any mistake order during delivery? If you answer "yes".

➢ In a typical month, how many mistake order is delivered?

Question 18. In the past 12 months, did your organization receive a complaint of late order delivery? If you answer "yes".

➢ In a typical month, what quantity from the order received is not delivered on time?

Question 19. Evaluate the physical appearance of the transport-related infrastructure in keeping with the quality of service provided.

	Very Low	Low	Medium	High	Very High
Road infrastructure	○	○	○	○	○
Sea infrastructure	○	○	○	○	○
Rail infrastructure	○	○	○	○	○
Warehousing/Trans-loading facilities	○	○	○	○	○

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Question 20. Evaluate the techniques used in checking and tracking products during transit.

	Very Low	Low	Medium	High	Very High
Application of IT and electronic	○	○	○	○	○
data interchange					
Temperature sensor tracker	○	○	○	○	○
Humidity sensor tracker	○	○	○	○	○
Application of Internet of thing (IoT) technology	○	○	○	○	○
Application of radio frequency identification (RFID) technology	○	○	○	○	○
Application of artificial intelligence (AI) and machine learning	○	○	○	○	○

Question 21. Have the following indicators improved or worsened in your organization?

	Much Worse	Worse	About the Same	Improved	Much Improved
Staff competency in understanding customer requirements	○	○	○	○	○
Organization's degree of openness in the information exchange between all parties in the transport logistic system regarding "Plan" "Source" and "Delivering" processes	○	○	○	○	○
Upholding moral and ethical standards while making a decision	○	○	○	○	○
Collaboration with other partners	○	○	○	○	○
Social responsible behavior and concern for human safety	○	○	○	○	○
Engagement in community activities	○	○	○	○	○
Operating in an environmentally safe area	○	○	○	○	○
Knowing how business insights are used between different divisions in your organization and your client	○	○	○	○	○

Question 22. Based on your experience in transport logistic chain, please select the option that best describes the outcome of services in your organization.

	Strongly Disagree	**Disagree**	**Sometimes**	**Agree**	**Strongly Agree**
The organization performed the promised services dependably and accurately	○	○	○	○	○
Order information is readily available	○	○	○	○	○
Information on customer orders is always accurate	○	○	○	○	○
The stakeholder can place orders conveniently	○	○	○	○	○
There is a consistent procedure in handling orders	○	○	○	○	○

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