“Assessment of logistics service quality based on the application of fuzzy methods modeling”

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ASSESSMENT OF LOGISTICS SERVICE QUALITY BASED ON THE APPLICATION OF FUZZY METHODS MODELING

Abstract

Improving the logistics service quality (LSQ) requires its assessment to identify appropriate reserves, which actualizes the scientific task of improving the appropriate methodological support for LSQ assessment. The purpose of this paper is to develop a model for assessing the quality of logistics services based on a specified list of criteria, their grouping, and the application of the mathematical apparatus of the fuzzy sets theory.

The study substantiates the expediency of using the fuzzy set method to assess the quality of logistics service and builds an LSQ assessment model that includes 12 criteria grouped into four groups: company reputation, product availability/quality, reliability/flexibility, and consumer service.

As a result of assessing the quality of logistics service, an integral indicator was obtained, which made it possible to determine the evaluations of its components: product availability/quality is rated high; reliability/flexibility – average; consumer service – good; and company reputation – poor. The obtained results indicate that such an aspect of logistics service quality assessment as company reputation needs particular attention, which confirms the modern trend of prioritizing the perception of the quality of logistics service, personal service/contact, and empathy by customers. Therefore, customers' perception of the quality of logistics service becomes a decisive factor in the competitive struggle in the logistics services market. Moreover, it is a bottleneck in the process of increasing LSQ, which requires further research to develop appropriate management mechanisms.

Keywords logistics, service, quality, logistics company, logistics services, customs logistics, fuzzy set method

JEL Classification L87, L14, D81, L91

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INTRODUCTION

Considering the globalization of logistics processes, the creation of digital supply chains, and the widespread use of innovative logistics technologies in international practice, fundamentally new requirements are put forward for logistics services. In a certain way, this affects the development of logistics service providers and must be considered in the relevant management mechanisms in assessing the quality of logistics service. Furthermore, the urgency of improving logistics management mechanisms of companies operating on the world market has increased due to the aggravation of all problems associated with the Russian Federation's war against Ukraine. Thus, it has led to a significant increase in cargo delivery prices, increased risks, and limited the range of logistics providers, which survived in the difficult conditions of the breakdown of global logistics chains and political and customs restrictions.

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It is necessary to note the significant evolution of companies providing logistics services on the world market in the last 10 years. Logistics service, which on the international market was usually provided by 3PL level logistics providers, gradually rose to a higher level of complexity and integrability, which 4 PL level providers provide. The multi-functionality of 3PL level logistics operators and their tactical nature gave way to the integrated multi-functionality and complexity of the strategic services of 4 PL level operators. The trend of the development of electronic commerce is toward the emergence of electronic logistics operators-providers of the fifth level (5PL). These objective processes caused a change in the emphasis of logistics services from optimizing individual business processes to informatization, automation, transparency, and communication with consumers. Traditional logistics services, such as transportation, warehousing, customs clearance, inventory management and order processing, were supplemented with the latest services of strategic network planning, effective management of product sales (revenue management), provision of information and computing resources and services (application service providing), documentation support (electronic, paper), search and provision of personnel for hire (personnel leasing), financial services, and consulting. Transportation planning was supplemented by tracking the route and information about the origin of the cargo (tracking and tracing), tracking the status of the order, and the geographical location of the cargo (order tracking). All this has led to the fact that logistics service has changed significantly in the content and structure of processes and acquired new properties, which actualizes the requirements for developing adequate methodical approaches to assessing its quality.

1. THEORETICAL BACKGROUND

The methodological toolkit for evaluating the logistics service quality is rather broad and includes deterministic, stochastic, heuristic methods, methods of fuzzy sets and fuzzy logic, and their combination. In addition, most logistic service quality assessment models are hybrid and based on multi-factor analysis of quantitative and qualitative indicators.

Some methods for assessing the logistic service quality are based on the quantitative assessment of partial indicators followed by the determination of an integral indicator. For example, Smolyaga (2012) suggests using an integrated index for assessing the logistics service quality (Integrated Index of Assessing the Quality of Logistics Service (IIAQLS)). It combines critical indicators of the quality of logistics service that affect the level of logistics service into a single indicator, the value of which can range from 0 to 1 and is calculated by:

$$\mathrm{IIAQLS} = \sqrt[7]{R \times \mathrm{N} \times \mathrm{S} \times \mathrm{E} \times \mathrm{C} \times \mathrm{F} \times \mathrm{L}} \qquad (1)$$

where R is non-deficit demand; N – demand saturation rate; S – completeness of orders coverage; E – efficiency of order fulfillment; C – uninterrupted performance of logistics services; F – flexibility of logistics service; L – satisfaction level of customer requests.

The given approach considers only quantitative evaluations of the logistics service and assumes the use of deterministic methods of evaluating each key indicator and a significant amount of input information. This makes it time-consuming and limits the possibilities of its use in conditions of uncertainty and instability of the quality of the services provided.

Ovcharenko (2020) presented factor-criterion models that determine the quality of logistics service (LSQ) due to its compliance with established goals, standards, and consumer requirements. However, the assessment of logistics parameters is a multifactorial analysis, so it is possible to use a different set of criteria. To do this, it is necessary to justify the goals of assessing logistics service quality and highlight the factors the company wants to evaluate the logistics service level. Moreover, it is vital to estimate the share (specific weight) Pi of each evaluation factor individually, assuming that the sum is equal to 1. Additionally, it is vital to establish interval values for quality indicators of logistics service and formulate conclusions regarding the general level of logistics service quality.

The specified approach involves finding the weight of individual parameters of the logistics service; therefore, in this case, the expert method or the analytical hierarchy method can be used. The Analytic Hierarchy Process (AHP) method is widely used in multi-criteria decision-making tasks and is a theory based on expert evaluations and judgments of individual participants or groups. Analytic Network Process (ANP) is a generalization of ANP.

Kucukaltan et al. (2016) use the Balance Score Card (BSC) decision model, followed by the ANP application of the developed model in the Turkish logistics industry, to evaluate logistics activity. They distinguished 4 perspectives (financial, learning and growth perspective, internal process perspective, and stakeholders' perspective) and 15 final evaluation indicators of efficiency of logistics activities, including logistics service.

Chaohe and Lijie (2010) developed a comprehensive system for assessing the logistics service quality. On the one hand, it allowed assessing the quality of logistics operations/processes. On the other hand, it analyzed the perception of the logistics service quality by the company's customers. Such a system includes 4 main aspects: hard process quality, soft process quality, potential quality, and quality of results. The weight of each indicator included in one or another aspect was established using the AHP method according to the given criteria.

Özispa et al. (2020) used the AHP method to determine the weight of logistics service criteria provided by third-party logistics companies. As a result, 16 criteria (4 main and 12 sub-criteria) were determined, and the cost was determined as the most crucial main criterion.

In addition to deterministic, expert, and multi-criteria methods, questionnaire survey, statistical, and optimization methods are also widely used.

Questionnaire survey methods have gained international recognition thanks to the spread of the SERVQUAL model proposed by Parasuraman et al. (1988). Here, the quality of logistics services is presented through five key dimensions: *D1* – reliability, *D2* – promptness, *D3* – competence, *D4* – empathy, *D5* – tangibility, and Gap models of service quality assessment. The following types of gaps are displayed:

- Gap 1 – The Knowledge Gap – Difference between the target market's expected service and management's perceptions of the target market's expected service;
- Gap 2 – The Standards Gap – Difference between management's perceptions of customer expectations and the translation into service procedures and specifications;
- Gap 3 – The Delivery Gap – Difference between service quality specifications and the service actually delivered;
- Gap 4 – The Communications Gap – Difference between service delivery intentions and what is communicated to the customer; and
- Gap 5 – The Service Quality Gap – Difference between the consumers' expectations and the service received.

This model has been the subject of scientific works for many years and is successfully used by practitioners to assess the quality of logistics services (Kilibarda & Andrejic, 2012). Other service quality assessment models are based on customer expectations (Limbourga et al., 2016), claiming that the formulation of service evaluation criteria with subsequent determination of customer satisfaction is essential.

Arabelen and Kaya (2021) considered the semi-structured interview method more suitable for LSQ assessment. However, despite the wide discussion of this topic, no consensus has been reached either on the definition or the logistics service quality parameters.

It should be noted that the given questionnaire survey methods use only qualitative indicators of the service, making it impossible to take into account quantitative indicators.

Gulc (2017) determined that the development of the definition and concepts of logistics service quality has been built up based on two approach-

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es: subjective and objective quality. The subjective approach employs assessing the quality of the logistics service by the service provider, who determines the adaptation of the service to the specifications defined by him. On the other hand, an objective approach assumes the expediency of adding attributes that reflect consumers' perception of logistics service to the physically observed work attributes. In this aspect, the use of the "service card" is of interest, which is a complex tool for measuring the quality of logistics service both from the side of suppliers and service consumers.

According to Akman and Baynal (2014), many methodological approaches are used to solve the problems of assessing the logistics service quality provided by logistics service providers (Figure 1).

The mathematical apparatus based on the theory of fuzzy sets (highlighted in bold in Figure 1) occupies an important place among techniques and integrative methods of assessing logistics service quality. According to Omelchenko et al. (2018), it allows for obtaining more adequate results than traditional analytical models and management algorithms.

According to Alkhatib et al. (2015), who covered 56 scientific articles related to the evaluation and selection of a logistics service provider, fuzzy logic methods were used in 61% of the integrated methods. This is due to certain advantages of fuzzy set theory methods compared to deterministic and probabilistic methods for assessing the quality of logistics services. However, such advantages are associated with a significant impact of uncertainty, which accompanies the process of evaluating the quality of logistics service:

- firstly, the lack of accurate, formalized information regarding the quality of the provision of certain services by certain specific operators in certain time intervals;
- secondly, the lack of a clearly defined, generally accepted international terminology for the definition of both the logistics services themselves and their structure, content, and characteristics creates a certain linguistic uncertainty;
- thirdly, different opinions of experts regarding the assessment of the importance and quality of logistics services, different degrees of confidence of experts; and
- fourthly, the lack of full access to information regarding the characteristics of the business

Source: Authors' elaboration based on Akman and Baynal (2014).

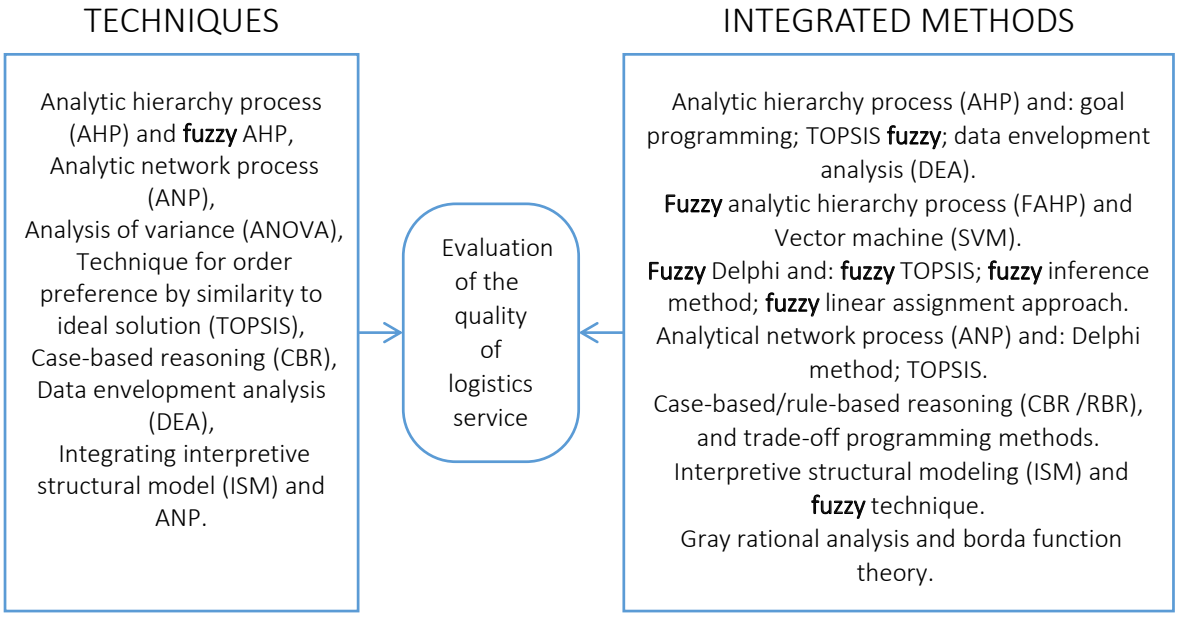

Figure 1. Techniques and methods of assessing the logistics service quality

processes of providing logistics services by various logistics operators limits the possibility of accumulating statistical material.

Linguistic estimates based on trapezoidal numbers for the values of the linguistic variable within the given method will avoid problems associated with a low level of certainty when assessing the quality of logistics service. Furthermore, this helps combine qualitative and quantitative assessments in one model and carry out evaluations in linguistic terms (high/average/low, attractive financial conditions/good/average/unattractive, and others), making the evaluation more understandable and flexible.

Scientists use a significant number of criteria for evaluating the quality of logistics services in their research (Table 1).

Table 1. Criteria for evaluating the logistics service quality

№	Criteria	Sources
1	Prices of basic services/costs.	Alkhatib et al. (2015); Filina-Dawidowicz and Gajewska (2018); Özbek and Eren (2013); Akman and Baynal (2014); Bajec and Tuljak-Suban (2017); Kucukaltan et al. (2016); Chaohe and Lijie (2010); Özispa et al. (2020); Seo et al. (2018)
2	Information technology (IT) capability, computerization, information support, communications.	Alkhatib et al. (2015); Falovych (2018); Bajec and Tuljak-Suban (2017); Arabelen and Kaya (2021); Özispa et al. (2020); Seo et al. (2018)
3	Optimization of current assets (inventory level) and their disposal, minimization of operational costs for cargo processing depending on the scale of the client's business, increasing the efficiency of the use of transport, warehouse, IT, the presence of special restrictions and priorities, quality of fixed assets/assets specificity, optimization capability/continuous improvement/the ability to meet or exceed promises/development potential.	Bajec and Tuljak-Suban (2017); Hryhorak (2017); Kucukaltan et al. (2016); Özispa et al. (2020); Seo et al. (2018)
4	Accurate delivery time/reliability on time, delivery timeliness of deliveries delivery.	Bajec and Tuljak-Suban (2017); Alkhatib et al. (2015); Kisperska-Moroń and Krzyżaniak (2009); Özbek and Eren (2013); Akman and Baynal (2014); Kucukaltan et al. (2016); Özispa et al. (2020); Seo et al. (2018)
5	Faultlessness of deliveries.	Kisperska-Moroń and Krzyżaniak (2009); Alkhatib et al. (2015); Hryhorak (2017)
6	Completeness of deliveries, accurate quantity, and quality of goods.	Bajec and Tuljak-Suban (2017); Stock et al. (1998); Alkhatib et al. (2015); Falovych (2018)
7	Frequency of deliveries, frequency of cargo delivery, order processing/order fulfillment/order cycle time/number of orders.	Stock et al. (1998); Alkhatib et al. (2015); Falovych (2018); Özispa et al. (2020)
8	Flexibility of deliveries, flexibility in operations and delivery of service, deep assortment, a wide range of assortment.	Bajec and Tuljak-Suban (2017); Zimon (2015); Alkhatib et al. (2015); Stock et al. (1998); Filina-Dawidowicz and Gajewska (2018); Özbek and Eren (2013); Falovych (2018); Hryhorak (2017); Seo et al. (2018)
9	Staff quality/education, managerial skills, empathy (caring, individualized attention the firm provides its customers), understanding of customer demands.	Bajec and Tuljak-Suban (2017); Franceschini and Rafele (2000); Kucukaltan et al. (2016); Chaohe and Lijie (2010); Özispa et al. (2020); Seo et al. (2018)
10	Firm reputation, degree of reputation, and position in industry/brand building/degree of image contribute/ethical image.	Bajec and Tuljak-Suban (2017); Özbek and Eren (2013); Akman and Baynal (2014); Kucukaltan et al. (2016); Chaohe and Lijie (2010); Arabelen and Kaya (2021); Seo et al. (2018)
11	Firm background experience/company age/ experience specific to industry/market knowledge.	Filina-Dawidowicz and Gajewska (2018); Özbek and Eren (2013); Akman and Baynal (2014); Özispa et al. (2020); Seo et al. (2018)
12	Availability of services, level of customer service, service quality.	Frąś (2014); Alkhatib et al. (2015); Seo et al. (2018)
13	Knowledge sharing, information exchangeability/information sharing/ship management knowhow database.	Seo et al. (2018); Akman and Baynal (2014)
14	Customer satisfaction/continuous improvement in customer satisfaction.	Bajec and Tuljak-Suban (2017); Kucukaltan et al. (2016); Limbourga et al. (2016); Kilibarda and Andrejic (2012)
15	Strategic partnership/risk sharing/ability to understand contractor needs.	Bajec and Tuljak-Suban (2017); Franceschini and Rafele (2000); Arabelen and Kaya (2021)
16	Transport services, frequency of transport accidents, transport time.	Bajec and Tuljak-Suban (2017); Chaohe and Lijie (2010); Arabelen and Kaya (2021)
17	Financial stability.	Bajec and Tuljak-Suban (2017); Kucukaltan et al. (2016)
18	Breadth of services/range of services, value-added service.	Bajec and Tuljak-Suban (2017); Seo et al. (2018)
19	Distribution services, product availability.	Filina-Dawidowicz and Gajewska (2018); Akman and Baynal (2014)

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Table 1 (cont.). Criteria for evaluating the logistics service quality

№	Criteria	Sources
20	Reliability of deliveries, safety and security in delivery.	Alkhatib et al. (2015); Akman and Baynal (2014); Falovych (2018); Arabelen and Kaya (2021); Özispa et al. (2020)
21	Flexibility in billing and payment/terms of payment.	Kucukaltan et al. (2016)
22	Innovativeness, innovation capability, innovation solutions.	Alkhatib et al. (2015); Arabelen and Kaya (2021)
23	Time of order implementation, order cycle time, delivery circumstance, and degree of the transit time of goods.	Falovich (2018); Hryhorak (2017); Kucukaltan et al. (2016); Chaohe and Lijie (2010); Özispa et al. (2020)
24	Variable prices/extra costs.	Bajec and Tuljak-Suban (2017); Özispa et al. (2020)
25	Quality certification/ISO standards/effective legislation.	Bajec and Tuljak-Suban (2017); Seo et al. (2018)

According to Hwang and Shen (2015), criteria were grouped according to the following aspects: Performance (D_1), Service (D_2), Cost (D_3), Quality assurance (D_4), IT (D_5), and Intangible (D_6).

Alkhatib et al. (2015) offered the following structuring of criteria for evaluating and selecting a logistics provider:

- Excellent performance records (operational, financial, and non-financial metrics);
- Distinguished logistics resources and capabilities;
- A wide range of value-added logistics services.

Thus, the review and generalization of literary sources showed that the list and grouping of logistics service quality criteria needs clarification. It can be significantly supplemented, but the use of too many indicators to evaluate the logistics service is not economically justified, because it requires high labor costs for collecting, processing information, and conducting calculations. Furthermore, the structuring of the criteria needs to be refined following the current conditions of global logistics chains. This actualizes the problem of clarifying the criteria and their structuring: finding synthetic criteria that embody the multifaceted characteristics of the processes of providing logistics services; updating the structuring of criteria under the current conditions of customization of logistics services.

Among the methods of evaluating the quality of logistics service, fuzzy sets methods have indisputable advantages compared to deterministic and probabilistic methods. This is caused by the possibility of covering quantitative and qualitative parameters of logistics services under conditions of uncertainty. Therefore, the study aims to develop a model for assessing the quality of logistics service based on a specified list of criteria, their grouping, and the application of the mathematical apparatus of the fuzzy sets theory.

2. RESULTS

The task of assessing the quality of logistics service is formulated as follows: let there be a certain number of specialized logistics service companies operating on the market – logistics operators/providers (levels 3PL - 5PL) – whose quality of logistics service is given by a vector, in a certain way formalized data on the presence (absence) of one or another service and its parameters. Then, as a result of the assessment of the quality of logistics service provided by logistics providers, a decision is made regarding their classification as offering a high, medium, or low level of logistics service.

When solving the task of evaluating the logistics service quality, quality is understood as an integral indicator that characterizes customer satisfaction and is based on four key elements:

- customer satisfaction, which takes into account the overall impression of cooperation with the provider of logistics services;
- service quality, which takes into account both the complexity and availability of logistics services;
- reliability and flexibility of the service;
- relations between the logistics provider and service consumers.

Based on the generalization of the above approaches of criteria structuring and selection aimed at the formation of an integral indicator for the evaluation of the logistics service quality, their grouping was carried out according to the following aspects.

Company reputation is to some extent a consequence, not a cause, of the quality of the logistics service. Thus, it can be considered as a certain indicator that characterizes the intangible quality parameters (criteria No. 9, 10, 11, 14, 15, and 25 in Table 1) and quantitative parameters, such as financial stability (criterion No. 17). In addition, company reputation is affected by a synthetic indicator of the satisfaction level of customers and partners, which depends on price factors (criteria No. 1 and 24), factors related to the optimization of operational activities (criteria No. 3, 22), as well as factors of communication with customers (criterion No. 2).

Product availability/quality is an important aspect related to the complexity of the services provided, the quality of the products supplied, taking into account the availability of services and products, and the possibility of their replacement or delayed delivery in case of absence. This aspect embodies both quantitative and qualitative parameters (criteria No. 6, 12, 18, and 19).

Reliability/flexibility is the main aspect that takes into account the logistics service quality, which is subject to the strictest requirements from the point of view of timeliness, comprehensiveness of delivery, and flexibility, and which embodies, first of all, the quantitative parameters (criteria No. 4, 5, 7, 8, 20, and 21).

Consumer service reflects precisely the interaction of the logistics company with the client, to the extent that this interaction satisfies the consumer regarding information support, feedback, transparency of information, financial benefits, and a comprehensive list of services offered. This aspect considers both qualitative and quantitative parameters (criteria No. 1, 2, 9, 12, 13, 16, 18, and 23).

Under the specified aspects of logistics service quality assessment, a generalization, addition, and grouping of logistics service quality criteria and indicators were carried out. As a result, it made

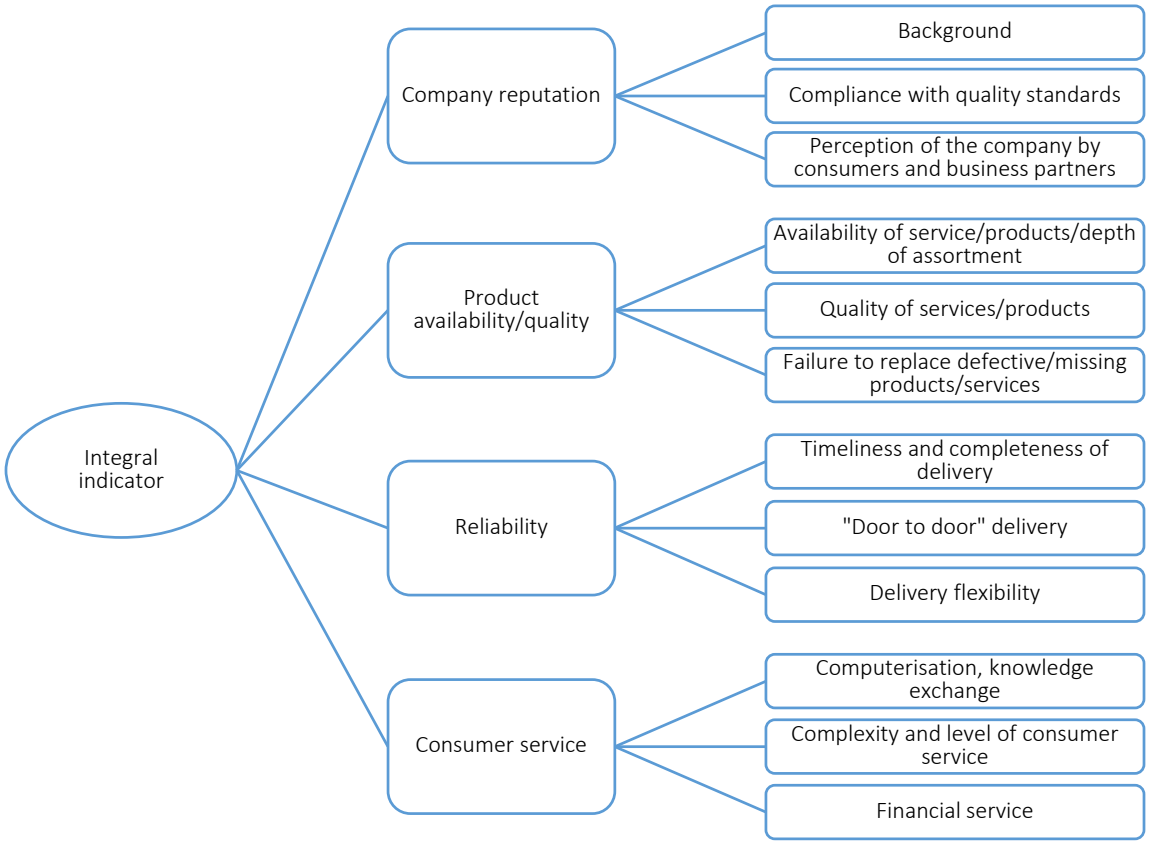

Figure 2. Model for evaluating the logistics service quality of logistics operators/providers

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Table 2. Component assessments of the logistics service quality

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of linguistic variable				Interval
A	Company reputation	A_3	Excellent	0.600	0.735	0.853	1	From 0.618 to 1
		A_2	Good	0.375	0.499	0.558	0.618	From 0.382 to 0.618
		A_1	Poor	0	0.118	0.236	0.382	From 0 to 0.382
B	Product availability/ quality	B_3	High	0.600	0.735	0.853	1	From 0.618 to 1
		B_2	Satisfactory	0.375	0.499	0.558	0.618	From 0.382 to 0.618
		B_1	Unsatisfactory	0	0.118	0.236	0.382	From 0 to 0.382
C	Reliability	C_3	High	0.600	0.735	0.853	1	From 0.618 to 1
		C_2	Medium	0.375	0.499	0.558	0.618	From 0.382 to 0.618
		C_1	Low	0	0.118	0.236	0.382	From 0 to 0.382
D	Customer service	D_3	High	0.600	0.735	0.853	1	From 0.618 to 1
		D_2	Medium	0.375	0.499	0.558	0.618	From 0.382 to 0.618
		D_1	Low	0	0.118	0.236	0.382	From 0 to 0.382

it possible to build an assessment model in which the integral indicator (S) is a three-level convolution. Partial indicators (a11, a12, ..., d33 in Tables A1A4) are combined into generalizing criteria (A, B, C, D), which, in turn, form the resulting indicator. Based on partial indicators and generalizing criteria, a linguistic assessment is issued to determine the integral indicator of the logistics service quality.

The model for assessing the logistics service quality of logistics operators/providers based on the defined criteria and indicators for the next use of the fuzzy set method is presented in Figure 2.

Three levels of parameters are included in the model: 12 input parameters, 4 intermediate parameters, and one output parameter. Each parameter is defined as a set of linguistic terms with a linear (trapezoidal) membership function. Intermediate parameters with their linguistic evaluation, trapezoidal numbers for the values of the linguistic variable, and the interval are given in Table 2.

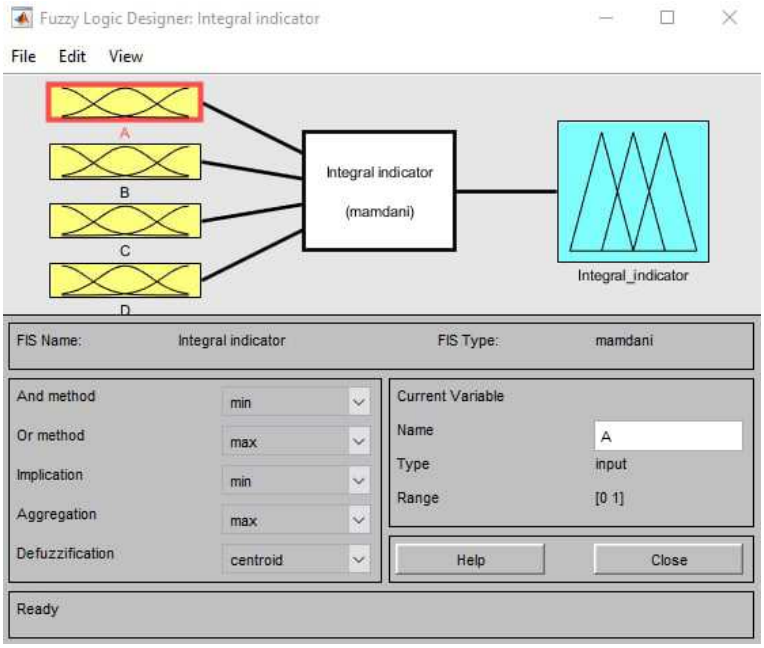
Intervals for changing parameters are components of logistics service quality assessment. They include company reputation, product availability/quality, reliability, and customer service and are built based on the "golden ratio" or Fibonacci numbers as the basis of harmonic division.

The initial parameter of the developed model is an integral indicator of the quality of logistics service (S); the terms and value intervals of this indicator are given in Table 3. The value intervals of the integral indicator are established based on the three gradations of the Harrington scale, which correspond to the linguistic categories: low, satisfactory (average), and high (good). In this case, the areas corresponding to the low, satisfactory, and high levels correspond to the intervals (0.00 0.37), (0.37 0.69) and (0.69 1.00), respectively (Samokhvalov & Burba, 2018).

According to the schematic representation of the logistic service quality assessment model (Figure 1), each intermediate parameter is formed as a result of the input parameters of the model – partial indicators. The structure of each intermediate indicator and the intervals of change of the partial input indicators, determined as a result of the study of the practice of logistics activity (in nat-

Table 3. General evaluation of the logistics service quality for the developed model

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of linguistic variable				Interval
S	Quality of logistics service	S_1	Low	0	0.13	0.25	0.37	From 0 to 0.37
		S_2	Medium (Satisfactory)	0.35	0.46	0.57	0.69	From 0.37 to 0.69
		S_3	High	0.67	0.78	0.89	1.00	From 0.69 to 1.00



Note: The model uses the Matlab software environment.

Figure 3. Intermediate parameters (A, B, C, D) and the integral output indicator of the logistics service quality

ural indicators), the survey of logistics specialists (in points), statistical data (in percentages) are given in Appendix A, Tables A1-4.

Therefore, the intervals for changing the background indicator are determined based on monitoring logistics providers' operation terms in years: work on the logistics services market for up to 3 years, from 3 to 10 years, and more than 10 years. The intervals for changing the flexibility of the delivery indicator are determined according to the number of parameters that the logistics company agrees to adapt to the client's requirements.

The intervals for changing the conformance to generally accepted quality standards indicator (availability of documents) are determined by the expert method in points according to the presence of the necessary documents confirming the quality standards (certificates, etc.). Similarly, intervals for indicators are separated into points: quality of services/products (level of compliance with ISO standards and/or other standards); reliability of replacement of low-quality/missing products/services (degree of replacement of low-quality/missing products/services); timeliness and completeness of delivery (frequency of cases of delayed deliveries or their incomplete fulfillment); door-to-door delivery (the degree of proximity of the delivery point to the customer); and financial service (level of discounts and payment deferral terms).

The indicator perception of the firm by consumers and business partners is evaluated according to statistical data in the percentage of surveyed consumers/partners who positively assessed the experience of cooperation with the firm. Respectively, the intervals are separated according to the following logic. A questionable perception of the firm corresponds to a situation when less than 75% of respondents positively evaluated the experience of working with the company; good perception – 75-90%; and excellent perception – 90-100%. In a similar way, percentage intervals are distinguished for the indicators: availability of service/products/depth of assortment (percentage of available services/goods), computerization, exchange of knowledge (percentage of orders delivered without additional communication with the client); and complexity and level of consumer service (what percentage is the number of logistics company's services from the number of potentially possible services).

To obtain intermediate parameters – components of the integral indicator of the quality of logistics

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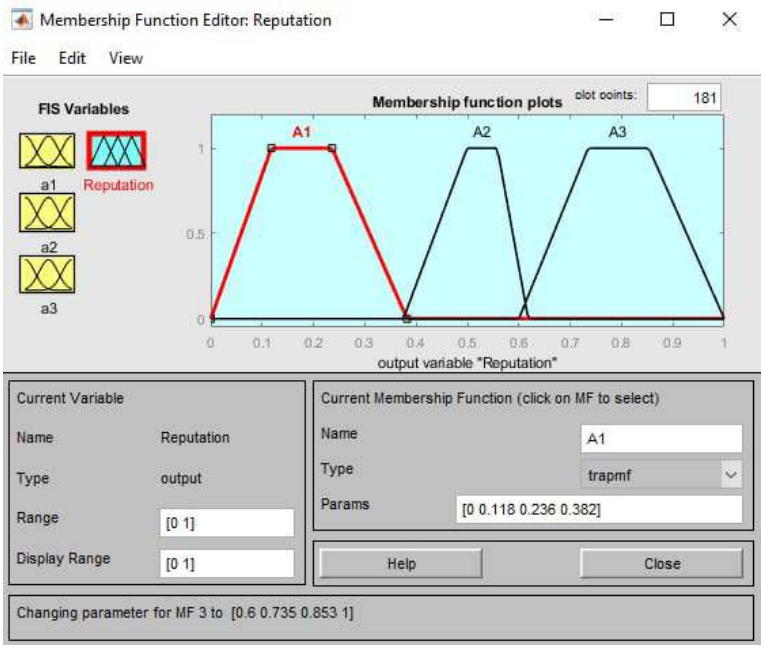


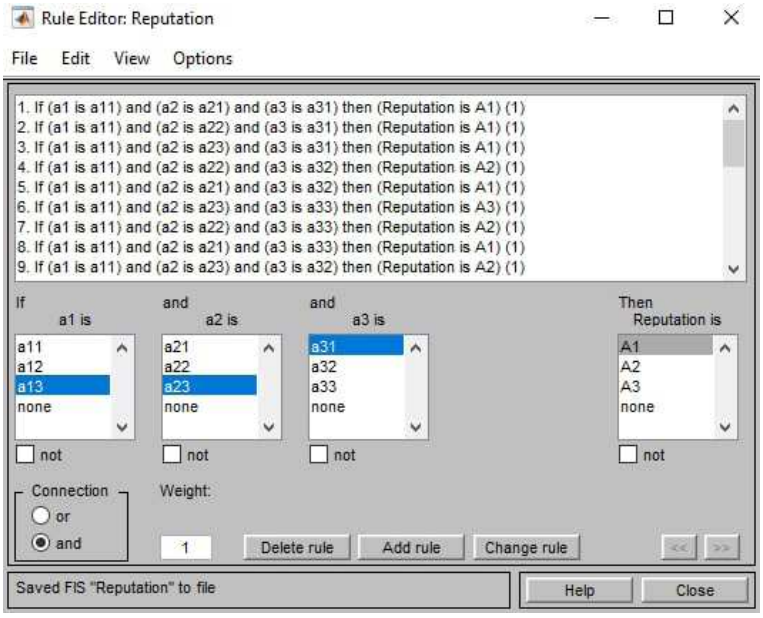
Note: The model uses the Matlab software environment.

Figure 4. Obtaining the intermediate parameter company reputation (A1) in the form of the membership function editor

service and the direct integral indicator – the model uses rules formed with specialists' involvement in the logistics field (Tables A4-9, Appendix A).

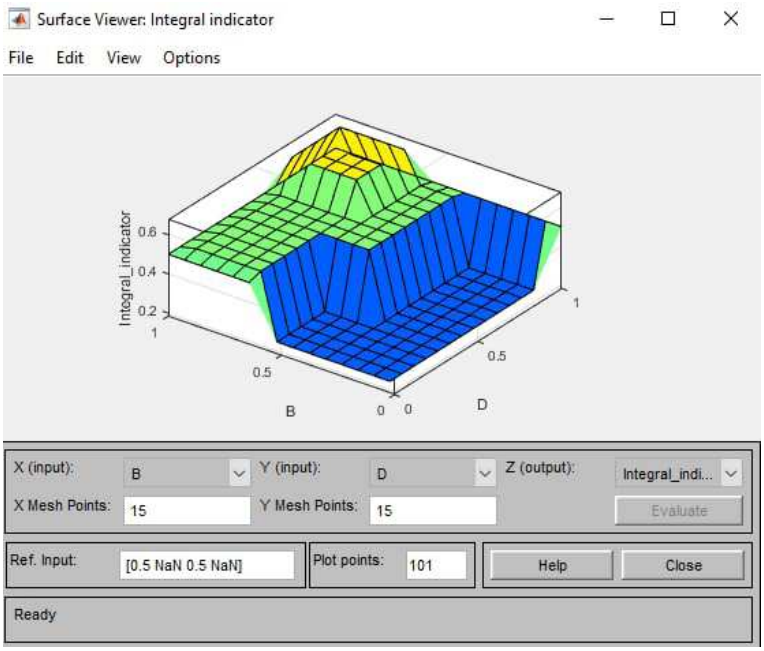
The model was built using the theory of fuzzy sets using the special Fuzzy Logic Toolbox module of the Matlab software. The structure of the integrated indicator of the quality of logistics service is presented in a triangular form in Figure 3.

After entering the input parameters (Tables A1-4) and the rule base (Tables A5-8), intermediate parameters of the fuzzy model (A – Company reputation, B – Product availability/quality, C –



Note: The model uses the Matlab software environment.

Figure 5. Fragment of the rule base for obtaining the intermediate parameter company reputation

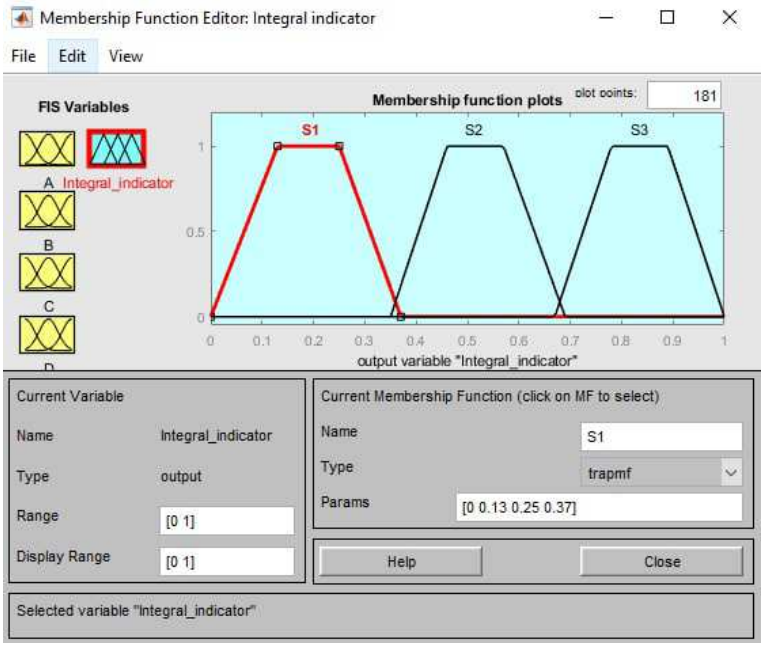


Note: The model uses the Matlab software environment.

Figure 6. Assessment model of the logistic service quality

Reliability, and D – Consumer service) were obtained. An example of obtaining the intermediate parameter of company reputation (A) in the form of an editor of membership functions and a fragment of the rule base, implemented in Matlab software, is shown in Figures 4-5.

Figure 6 presents one of the 6 possible graphical interpretations (depending on the combination of intermediate parameters A, B, C, D) of the conducted modeling of logistics service quality assessment in the Matlab software environment.



Note: The model uses the Matlab software environment.

Figure 7. Integral indicator of the logistics service quality (S) in the form of membership functions of the fuzzy output system

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The integrated indicator of assessment of the logistics service quality (S), in the form of the implementation of the membership function editor of the fuzzy output of the simulation results, implemented in the Matlab software, is presented in Figure 7. Moreover, the base of rules for obtaining the specified integrated indicator is given in Table A9, Appendix A.

The proposed model was developed using expert methods. Therefore, its use implies constant refinement due to changes in cause-and-effect relationships and the structure of indicators due to the need to consider both the external and internal environment of the operation of logistics companies. The model needs to be adapted to the operating conditions of logistics service providers. As a result, the intervals of input parameters may undergo significant adjustments depending on the conditions prevailing at a certain time on the world market of logistics services.

Data from three typical representatives of large international logistics companies operating in Ukraine and employing 250 or more people were used to test the model (Clutch, 2022). These companies are: UNI-LAMAN GROUP – Ukrainian logistics company; Asstra-Associated Traffic AG – International Logistics and Supply Chain Company; UTEC Logistics – Logistics and Supply Chain Company; Stoles Logistics – Ukrainian logistics company; DSV Logistics – Global Transport Logistics Company; LAM Global Transport Solutions – Ukraine Logistics and Supply Chain Company; KM Group of Companies.

The evaluation of the quality of logistics service of the companies selected for analysis (Company No. 1, Company No. 2, Company No. 3) was carried out using the developed model. The results obtained for Company No. 1 are shown in Figure 8, according to Companies No. 2 and No. 3 are shown in Figures A1-2, Appendix A. These figures show the defuzzification of intermediate modules to the final level of the developed fuzzy model – an integral indicator of logistics service quality.

Generalizing results of using the developed model to assess the logistics service quality of three companies are shown in Table 4.

Based on the obtained results, it is possible to draw a conclusion about the quality of the logistics service of the companies (according to their linguistic assessment). Thus, for Company No. 1 – the quality of logistics service is high; for Company No. 2 – the quality of logistics service is medium or satisfactory; and for Company No. 3 – the quality of logistics service is medium or satisfactory.

Based on the developed model, an integral indicator of the logistics service quality and a corresponding linguistic assessment of logistics companies operating in the market of logistics services of Ukraine and typical representatives of this sector of the economy were obtained. It was established that two companies among the three provide logistics service, the quality of which is medium or satisfactory. Thus, the integral indicators of Companies No. 2 and 3 are equal to 0.5,

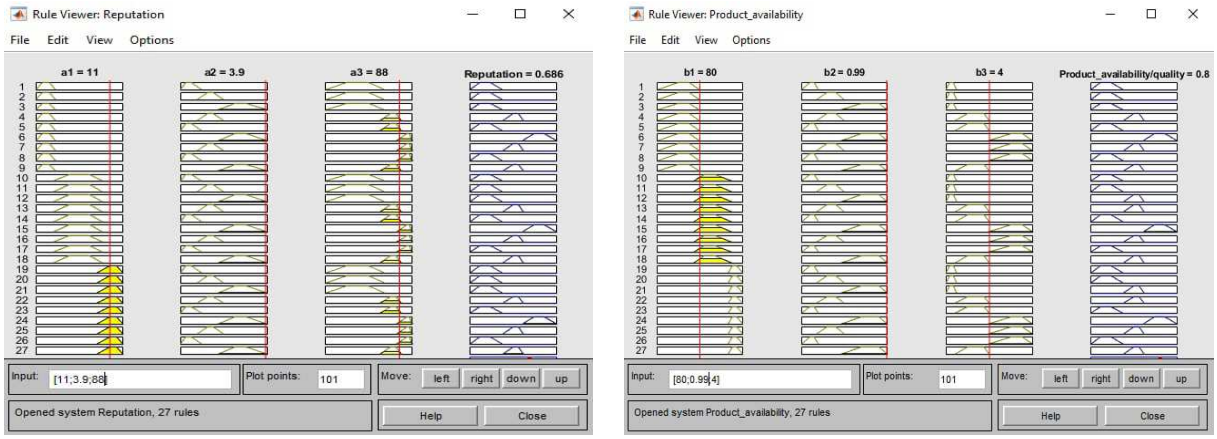

Figure 8. Implemented data defuzzification to the final level of the developed fuzzy model – an integral indicator of the quality of logistics service for Company No. 1

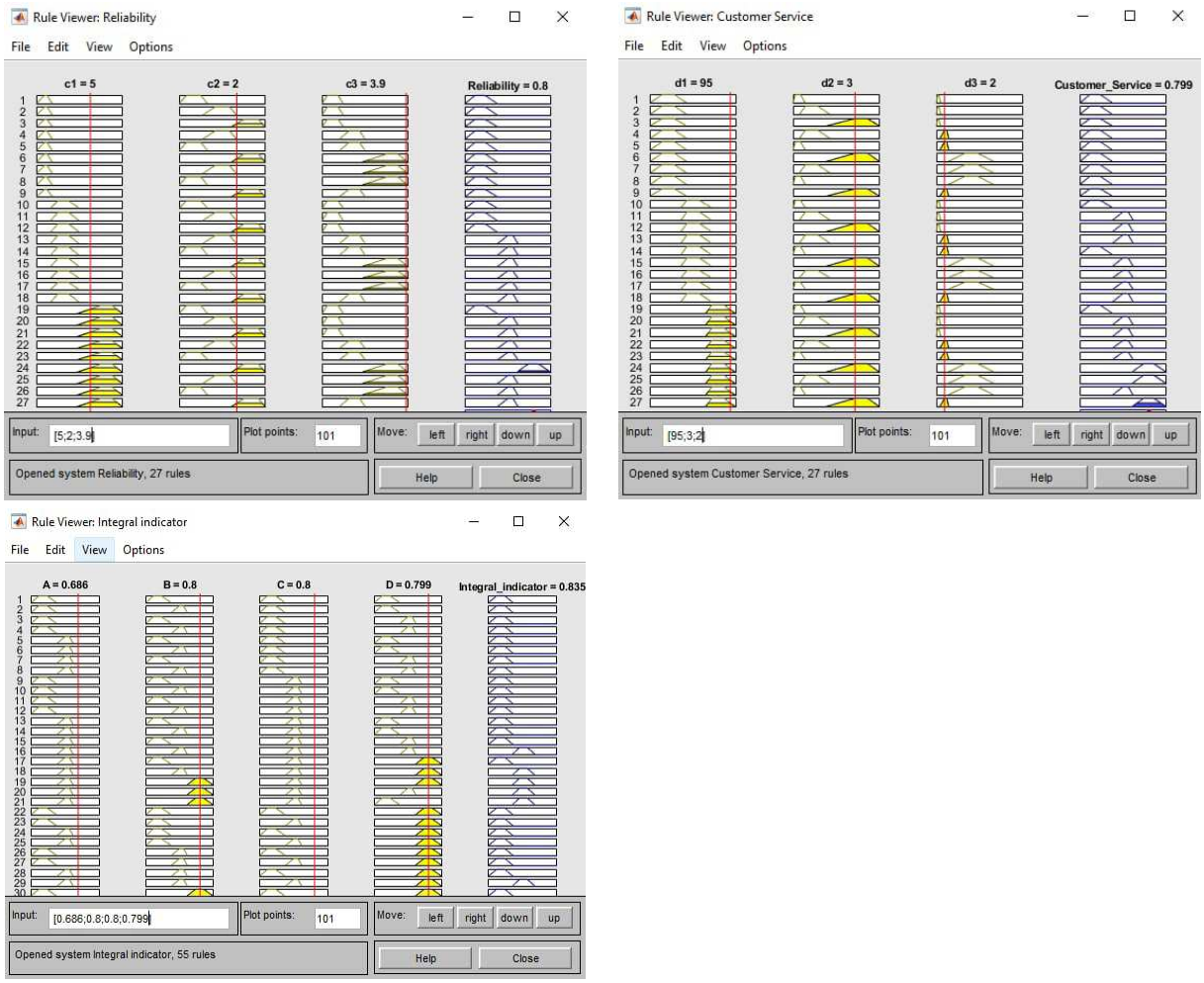

Figure 8 (cont). Implemented data defuzzification to the final level of the developed fuzzy model – an integral indicator of the quality of logistics service for Company No. 1

Table 4. Generalized input, intermediate parameters, and evaluation results of the integral indicator of the logistics service quality

Evaluation of the logistics service quality		Logistics Company		
		Company 1	Company 2	Company 3
Reputation (A)	Background (a_1)	11	10	12
	Compliance with generally accepted quality standards (availability of documents) (a_2)	3.9	3.9	3.9
	Perception of the company by consumers and business partners (a_3)	88	32	79.2
	Reputation (A)	0.686	0.191	0.498
Product availability (B)	Availability of service/products/depth of assortment (b_1)	80	60	99
	Quality of services/products (b_2)	0.99	0.99	0.99
	Non-failure to replace defective/missing products/services (b_3)	4	2	4
	Product availability (B)	0.8	0.5	0.8
Reliability (C)	Timeliness and completeness of delivery (c_1)	5	4	7.9
	Door-to-door delivery (c_2)	2	2.9	2.9
	Delivery flexibility(c_3)	3.9	2	3.9
	Reliability (C)	0.8	0.8	0.8
Customer Service (D)	Computerization, exchange of knowledge (d_1)	95	35	99
	Complexity and level of consumer service (d_2)	3	2	3.9
	Financial service (d_3)	2	3	2
	Customer Service (D)	0.799	0.191	0.5
Integral indicator of evaluation of the logistics service quality (S)		0.835	0.5	0.5

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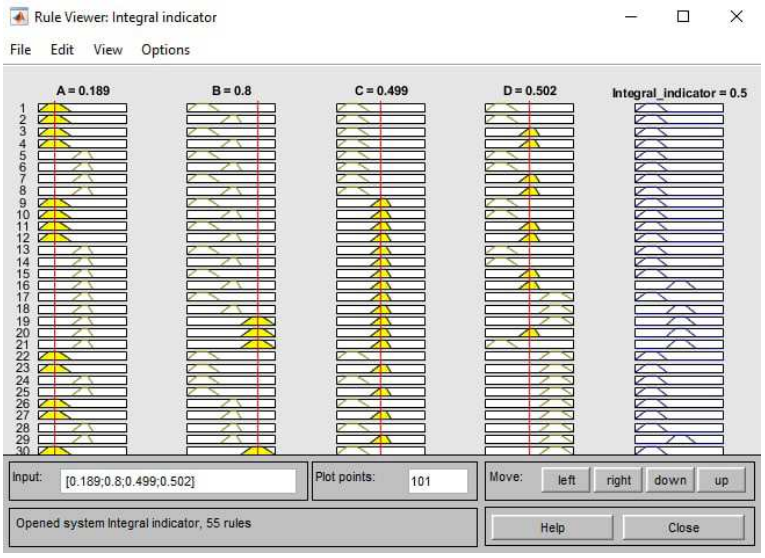

Figure 9. Defuzzification of the average values of intermediate modules to the final level of the developed fuzzy model

Table 5. Average integral indicator of the logistics service quality

Indicator assessment	Evaluation of the logistics service quality				
	Reputation (*A*)	Product availability (*B*)	Reliability (*C*)	Customer Service (*D*)	Integral indicator of evaluation of the logistics service quality (*S*)
Value	0.189	0.8	0.499	0.502	0.5
Linguistic assessment	Poor	High	Medium	Medium	Medium (satisfactory)

which corresponds to the linguistic assessment "medium quality of logistics service." One of the listed companies, Company No. 1, has an integral index of 0.835, which corresponds to the linguistic assessment "high quality of logistics service."

The average indicator of the logistics service quality is 0.5, which corresponds to the linguistic assessment "medium quality of logistics service."

Figure 9 shows the defuzzification of the average values of the intermediate parameters to the final level of the developed model.

The structure of the average indicator is presented in Table 5.

The obtained structure of the average integral indicator of the quality of logistics service reflects the different average levels of its components: from the linguistic rating "poor" to the linguistic rating "high," which indicates the different state of the main characteristics of logistics services. In addition, it allows one to obtain information about the search for reserves to improve the logistics service quality.

3. DISCUSSION

The results of the conducted modeling confirm the trend Arabelen and Kaya (2021) revealed regarding the change of priorities in evaluating LSQ. If earlier more attention was paid to the physical attributes of logistics operations (timeliness, availability, reliability, informativeness, etc.), now the focus has shifted to customer perception quality of logistics service, personal service/contact, and empathy. It is the customer's perception of the quality of logistics service that becomes a decisive factor in the competitive struggle in the logistics services market and a bottleneck in the process of increasing LSQ.

Thus, in the developed model, the proposed groups of logistics service quality criteria related to the physical attributes of logistics operations received a lin-

guistic assessment of high and medium. At the same time, the aspect that takes into account the perception of LSQ by customers received a linguistic evaluation of poor, namely:

- a high rating of component B of the average integral indicator of the LSQ assessment (product availability/quality) (see Table 5) indicates the complexity, high availability, and quality of logistics services/products, the possibility of their delayed provision/delivery. A high rating of this indicator shows a high level and quality of logistics services provided by logistics companies;

- component C – reliability/flexibility – is rated as medium, which means the feasibility of increasing the logistics service reliability due to the increase of such input parameters: timeliness and flexibility of delivery, completeness of delivery, possibilities of door-to-door cargo delivery;

- component D – consumer service – received a good rating, which suggests the feasibility of its improvement due to raising the level of computerization, consumer and financial service, improving staff qualifications;

- component A – company reputation – received a rating of poor, which requires appropriate management measures. Thus, concerning company reputation, managers need to pay attention to the perception of a company by consumers and business partners. This is influenced, first of all, by the positive or negative experience of receiving logistics services from customers or cooperation with business partners. Moreover, it is worth considering the factor of empathy (concern, individual approach to interaction), price range, availability of price preferences, discounts, financial stability of the company, systematic implementation of relevant marketing activities, and branding. The other input parameters (background and compliance with generally accepted quality standards) reflect the current state and are less elastic with respect to management efforts.

At the same time, logistics providers, focusing on the perception of LSQ by customers, should remember the nature of causal relationships. Thus, it is the physical attributes of the quality of logistics services that affect customer satisfaction and loyalty (Kilibarda & Andrejic, 2012). In this aspect, the study agrees with Jamkhaneh et al. (2022) that the internal relations of logistics service quality criteria should be taken into account since there may be certain cause-and-effect relationships between the criteria, which may affect the modeling results. On the other hand, the proposed method of evaluating LSQ is based on a holistic approach (Arabelen & Kaya, 2021) to evaluate logistics service quality. It assumes the inclusion in the evaluation process of both tangible (physical) and intangible characteristics (empathy, loyalty on the part of clients).

The revealed reserves of improving the quality of logistics service through the improvement of the reputation indicate the need to intensify marketing efforts and ensure a high level of physical attributes of logistics services. In turn, this will contribute to the establishment of long-term partnership ties between logistics providers and clients, based on trust and devotion. Thus, further research may be concerned with examining the impact of customer satisfaction with logistics services on the quality of the logistics provider's relationship with its customers. In this context, the findings of Ali et al. (2022) are interesting, as they revealed the positive impact of customer satisfaction on the quality of relationships and mutual interaction based on trust, dependence, and loyalty.

Regarding the problems and prospects for further research, the obtained model for assessing logistics service quality has certain limitations. This applies to the sample that was chosen for modeling. Namely, only three typical representatives from a large number of logistics providers that serve Ukrainian businesses in the market of international cargo transportation were sampled.

Additionally, the expediency of specifying the set of input parameters of information and financial flows depends on changes in the internal and external logistics environment of companies, especially in aspects of requirements of customs legislation, the implementation of innovative cargo processing technologies, and customs clearance of cargo. In the context of the introduction of innovative technologies, it will be promising to study the impact of Industry 4.0 on the quality of logistics services.

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CONCLUSION

The purpose of this study was to develop a model for assessing the quality of logistics services based on the proposed list of criteria and their grouping. The generalization of theoretical sources regarding methodological tools and the most used in the analysis of LSQ criteria, the application of the mathematical apparatus of the theory of fuzzy sets made it possible to obtain a model that includes 12 criteria combined into four groups: company reputation, product availability/quality, reliability/flexibility, and customer service.

The value of the integral indicator of the logistics service quality, obtained from the conducted modeling, testified to the low level of evaluations of the criteria that form the company reputation group. This confirms the current trend of shifting attention from the physical attributes of logistics operations to customer satisfaction, empathy, personal perception of the quality of the service received, and trust. It also indicates the existing reserves for improving the quality of logistics services through the development of appropriate management mechanisms.

For logistics companies, this model can be used for logistics service management, retrospective analysis of its quality, vague forecasting of this indicator, and establishment of its own competitive status. In addition, this model will allow logistics companies to systematically approach the problem of improving the logistics service quality and consider all aspects of this process. Finally, it helps combine the available data, characterized by uncertainty regarding their structure, time interval, lack of formalization, and clearly defined international terminology.

For consumers, the developed model can be used to rate logistics companies, choose the best carrier, and conclude long-term contracts for obtaining logistics services with providers who deserve the utmost trust. This is especially topical in the increased risks of international transportation caused by Russia's military aggression against Ukraine.

The advantage of the developed model is that the number of input parameters is optimized to cover all critical components of logistics service quality assessment. At the same time, this model does not overload the assessment process by collecting a large amount of hard-to-reach information without accumulated statistical material. Information about the model's input parameters can be obtained from available sources, such as sites of logistics companies and customer and employee reviews about employers, companies, and employees.

AUTHOR CONTRIBUTIONS

Conceptualization: Tetiana Kolodizieva, Kateryna Melnykova.
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Formal analysis: Elina Zhelezniakova, Viktoriia Pysmak.
Funding acquisition: Oleh Kolodiziev, Elina Zhelezniakova.
Investigation: Tetiana Kolodizieva, Viktoriia Pysmak.
Methodology: Elina Zhelezniakova, Tetiana Kolodizieva.
Project administration: Oleh Kolodiziev, Viktoriia Pysmak.
Resources: Oleh Kolodiziev, Kateryna Melnykova.
Sofware: Elina Zhelezniakova, Kateryna Melnykova.
Supervision: Oleh Kolodiziev, Tetiana Kolodizieva.
Validation: Kateryna Melnykova, Viktoriia Pysmak.
Visualization: Tetiana Kolodizieva, Elina Zhelezniakova.
Writing – original draf: Viktoriia Pysmak, Kateryna Melnykova.
Writing – review & editing: Oleh Kolodiziev, Viktoriia Pysmak.

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APPENDIX A

Table A1. Indicators for evaluating company reputation (*A*)

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of a linguistic variable				Interval
a_1	Background	a_{11}	Little work experience	0	1	2	3	Work in the logistics services market for up to 3 years
		a_{12}	Medium work experience	2.5	5	8	10	Work in the market of logistics services from 3 to 10 years
		a_{13}	Extensive work experience	9	11	12	13	Work in the market of logistics services for more than 10 years
a_2	Compliance with generally accepted quality standards (availability of documents)	a_{21}	There is no match	0	0.25	0.5	1	There are no documents (1 point)
		a_{22}	Partial	0.75	1.25	1.5	2	Documents are partially available (2 points)
		a_{23}	Full	1.7	2.5	3	4	Documents are available (4 points)
a_3	Perception of the company by consumers and business partners	a_{31}	Questionable	20	40	60	75	Less than 75% of surveyed consumers/partners positively evaluated the experience of cooperation with the company
		a_{32}	Good	70	80	85	90	75-90% of surveyed consumers/ partners positively evaluated the experience of cooperation with the company
		a_{33}	Excellent	85	95	97	100	90-100% of surveyed consumers/ partners positively evaluated the experience of cooperation with the company

Table A2. Service/product availability/quality assessment indicators (B)

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of a linguistic variable				Interval
b1	Availability of service/ products/depth of assortment	b11	Unsatisfactory accessibility	60	70	75	80	Delivery covers up to 80% of available services/goods
		b12	Satisfactory accessibility	77	82	87	95	Delivery covers 80%-95% of available services/goods
		b13	Excellent accessibility	93	95	97	100	Delivery covers 95%-100% of available services/goods
b2	Quality of services/ products	b21	Low	0	0.1	0.15	0.2	Most services/goods do not meet ISO and/or other standards (0.2 points)
		b22	Medium	0.17	0.3	0.4	0.5	Services/products, in some cases, do not meet ISO and/or other standards (0.5 points)
		b23	High	0.45	0.7	0.9	1	Services/products fully comply with ISO and other standards (1 point)
b3	Failure free to replace defective/ missing products/ services	b31	Unsatisfactory	0	0.35	0.7	1	Lack of replacement of low-quality (0 points)/missing (1 point) products/services
		b32	Satisfactory	0.8	2	3.5	4	Partial replacement of low-quality items (2 points)/missing (4 points) products/services
		b33	Excellent	3.8	6	7	8	Replacement of all low-quality (6 points)/absent (8 points) (products/ services)

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Table A3. Indicators of reliability/flexibility (C)

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of a linguistic variable				Interval
c_1	Timeliness and completeness of delivery	c_{11}	Significant violation of terms/ completeness of delivery	0	0.25	0.75	1.5	Deliveries are systematically delayed and incomplete (0 points); deliveries are systematically delayed but are carried out in full (1 point); deliveries are not delayed but are often incomplete (1.5 points)
		c_{12}	Partial violation of terms and/or completeness of delivery	1	2	3	4	Individual cases of delay (2 points) of deliveries or incomplete execution (4 points)
		c_{13}	Timely, complete delivery	3.7	6	7	8	All deliveries are made on time and complete (8 points)
c_2	Door-to-door delivery	c_{21}	No offer	0	0.25	0.75	1	Delivery to the nearest railway (1 point)
		c_{22}	Partial offer	0.8	1.25	1.75	2	Delivery to the nearest railway station/port (2 points)
		c_{23}	Availability of an offer	1.8	2.25	2.75	3	Door-to-door delivery (3 points)
c_3	Delivery flexibility	c_{31}	Low flexibility/ frequency	0	0.25	0.75	1	Lack of readiness to adapt according to the needs of the customer up to 1 parameter deliveries (up to 1 parameter)
		c_{32}	Medium flexibility/ frequency	1	1.25	1.5	2	Willingness to adapt according to the needs of the customer up to 2 delivery parameters
		c_{33}	High flexibility/ frequency	1.8	3	3.5	4	Willingness to adapt the time, volume, assortment, delivery size, etc. to the customer's needs (4-3 delivery parameters)

Table A4. Indicators for evaluating the level of consumer services (D)

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of a linguistic variable				Interval
d_1	Computerization, exchange of knowledge	d_{11}	Unsatisfactory exchange of information regarding delivery through computerization	30	40	50	60	Less than 60% of orders delivered without additional communication with a client
		d_{12}	Partial exchange of information regarding delivery through computerization	55	60	70	80	60-80% of orders delivered without additional communication with a client
		d_{13}	Satisfactory exchange of information regarding delivery through computerization	75	80	90	99	80-99% there were orders delivered without additional communication with a client
		d_{14}	Complete data transparency regarding delivery, fully computerized	95	97	99	100	All orders delivered without additional communication with a client
d_2	Complexity and level of consumer service	d_{21}	Low	0.5	0.6	0.8	1	Services provided during delivery, 30-49% of potentially possible services (1 point)
		d_{22}	Medium	0.75	1	1.5	2	Services provided before or after delivery, during delivery, 50-79% of potentially possible services (2 points)
		d_{23}	High	1.8	3	3.5	4	Services provided before delivery, during delivery, after delivery, 80-100% of potentially possible services (4 points)

Table A4 (cont.). Indicators for evaluating the level of consumer services (D)

Symbol	Name	Symbol	Linguistic assessment	The trapezoidal numbers for the values of a linguistic variable				Interval
d_3	Financial service	d_{31}	Unattractive financial conditions	0	0.3	0.6	1	Discounts are not provided (0 points), are provided (1 point), prepayment
		d_{32}	Standard financial conditions	0.75	2	2.5	3	Discounts are provided, payment within 3 banking days
		d_{33}	Good financial conditions	2.7	7	10	14	A discount is provided for a large wholesale batch, payment deferral for up to 14 days
		d_{34}	Very attractive financial conditions	11	14	17	21	A discount, deferred payment is provided for a large wholesale batch (credit 21-14 days)

Table A5. Rules for forming an assessment of company reputation (A)

№	Components			Combination of components (or/and)	Company reputation (A)
1	a_{11}	a_{21}	a_{31}	and	A_1
2	a_{11}	a_{22}	a_{31}	and	A_1
3	a_{11}	a_{23}	a_{31}	and	A_1
4	a_{11}	a_{22}	a_{32}	and	A_2
5	a_{11}	a_{21}	a_{32}	and	A_1
6	a_{11}	a_{23}	a_{33}	and	A_3
7	a_{11}	a_{22}	a_{33}	and	A_2
8	a_{11}	a_{21}	a_{33}	and	A_1
9	a_{11}	a_{23}	a_{32}	and	A_2
10	a_{12}	a_{21}	a_{31}	and	A_1
11	a_{12}	a_{22}	a_{31}	and	A_1
12	a_{12}	a_{23}	a_{31}	and	A_1
13	a_{12}	a_{22}	a_{32}	and	A_2
14	a_{12}	a_{21}	a_{32}	and	A_1
15	a_{12}	a_{23}	a_{33}	and	A_3
16	a_{12}	a_{22}	a_{33}	and	A_2
17	a_{12}	a_{21}	a_{33}	and	A_1
18	a_{12}	a_{23}	a_{32}	and	A_2
19	a_{13}	a_{21}	a_{31}	and	A_1
20	a_{13}	a_{22}	a_{31}	and	A_1
21	a_{13}	a_{23}	a_{31}	and	A_2
22	a_{13}	a_{22}	a_{32}	and	A_2
23	a_{13}	a_{21}	a_{32}	and	A_1
24	a_{13}	a_{23}	a_{33}	and	A_3
25	a_{13}	a_{22}	a_{33}	and	A_2
26	a_{13}	a_{21}	a_{33}	and	A_1
27	a_{13}	a_{23}	a_{32}	and	A_2

Note: $\mathbf{A}_1$ – poor; $\mathbf{A}_2$ – good; $\mathbf{A}_3$ – excellent.

Table A6. Rules for forming an assessment of product availability/quality (B)

№	Components			Combination of components (or/and)	Product availability/ quality (B)
1	b_{11}	b_{21}	b_{31}	and	B_1
2	b_{11}	b_{22}	b_{31}	and	B_1
3	b_{11}	b_{23}	b_{31}	and	B_1
4	b_{11}	b_{22}	b_{32}	and	B_2
5	b_{11}	b_{21}	b_{32}	and	B_1
6	b_{11}	b_{23}	b_{33}	and	B_3
7	b_{11}	b_{22}	b_{33}	and	B_2
8	b_{11}	b_{21}	b_{33}	and	B_1
9	b_{11}	b_{23}	b_{32}	and	B_2
10	b_{12}	b_{21}	b_{31}	and	B_1
11	b_{12}	b_{22}	b_{31}	and	B_1
12	b_{12}	b_{23}	b_{31}	and	B_2
13	b_{12}	b_{22}	b_{32}	and	B_2
14	b_{12}	b_{21}	b_{32}	and	B_1
15	b_{12}	b_{23}	b_{33}	and	B_3
16	b_{12}	b_{22}	b_{33}	and	B_2
17	b_{12}	b_{21}	b_{33}	and	B_1
18	b_{12}	b_{23}	b_{32}	and	B_2
19	b_{13}	b_{21}	b_{31}	and	B_1
20	b_{13}	b_{22}	b_{31}	and	B_1
21	b_{13}	b_{23}	b_{31}	and	B_2
22	b_{13}	b_{22}	b_{32}	and	B_2
23	b_{13}	b_{21}	b_{32}	and	B_1
24	b_{13}	b_{23}	b_{33}	and	B_3
25	b_{13}	b_{22}	b_{33}	and	B_2
26	b_{13}	b_{21}	b_{33}	and	B_1
27	b_{13}	b_{23}	b_{32}	and	B_2

Note: $\mathbf{B}_1$ – unsatisfactory; $\mathbf{B}_2$ – satisfactory; $\mathbf{B}_3$ – high.

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Table A7. Rules for forming reliability/flexibility assessment (C)

№	Components			Combination of components (or/and)	Reliability/ flexibility *(C)*
1	c_{11}	c_{21}	c_{31}	and	C_1
2	c_{11}	c_{22}	c_{31}	and	C_1
3	c_{11}	c_{23}	c_{31}	and	C_1
4	c_{11}	c_{22}	c_{32}	and	C_1
5	c_{11}	c_{21}	c_{32}	and	C_1
6	c_{11}	c_{23}	c_{33}	and	C_1
7	c_{11}	c_{22}	c_{33}	and	C_1
8	c_{11}	c_{21}	c_{33}	and	C_1
9	c_{11}	c_{23}	c_{32}	and	C_1
10	c_{12}	c_{21}	c_{31}	and	C_1
11	c_{12}	c_{22}	c_{31}	and	C_1
12	c_{12}	c_{23}	c_{31}	and	C_1
13	c_{12}	c_{22}	c_{32}	and	C_2
14	c_{12}	c_{21}	c_{32}	and	C_2
15	c_{12}	c_{23}	c_{33}	and	C_2
16	c_{12}	c_{22}	c_{33}	and	C_2
17	c_{12}	c_{21}	c_{33}	and	C_2
18	c_{12}	c_{23}	c_{32}	and	C_2
19	c_{13}	c_{21}	c_{31}	and	C_1
20	c_{13}	c_{22}	c_{31}	and	C_2
21	c_{13}	c_{23}	c_{31}	and	C_2
22	c_{13}	c_{22}	c_{32}	and	C_2
23	c_{13}	c_{21}	c_{32}	and	C_2
24	c_{13}	c_{23}	c_{33}	and	C_3
25	c_{13}	c_{22}	c_{33}	and	C_2
26	c_{13}	c_{21}	c_{33}	and	C_2
27	c_{13}	c_{23}	c_{32}	and	C_2

Note: C_1 – unsatisfactory; C_2 – satisfactory; C_3 – high.

Table A8. Rules for forming a consumer service assessment (D)

№	Components			Combination of components (or/and)	Consumer service *(D)*
1	d_{11}	d_{21}	d_{31}	and	D_1
2	d_{11}	d_{22}	d_{31}	and	D_1
3	d_{11}	d_{23}	d_{31}	and	D_1
4	d_{11}	d_{22}	d_{32}	and	D_1
5	d_{11}	d_{21}	d_{32}	and	D_1
6	d_{11}	d_{23}	d_{33}	and	D_1
7	d_{11}	d_{22}	d_{33}	and	D_1
8	d_{11}	d_{21}	d_{33}	and	D_1
9	d_{11}	d_{23}	d_{32}	and	D_1
10	d_{12}	d_{21}	d_{31}	and	D_1
11	d_{12}	d_{22}	d_{31}	and	D_2
12	d_{12}	d_{23}	d_{31}	and	D_2
13	d_{12}	d_{22}	d_{32}	and	D_2
14	d_{12}	d_{21}	d_{32}	and	D_1
15	d_{12}	d_{23}	d_{33}	and	D_2
16	d_{12}	d_{22}	d_{33}	and	D_2
17	d_{12}	d_{21}	d_{33}	and	D_2
18	d_{12}	d_{23}	d_{32}	and	D_2
19	d_{13}	d_{21}	d_{31}	and	D_1
20	d_{13}	d_{22}	d_{31}	and	D_2
21	d_{13}	d_{23}	d_{31}	and	D_2
22	d_{13}	d_{22}	d_{32}	and	D_2
23	d_{13}	d_{21}	d_{32}	and	D_2
24	d_{13}	d_{23}	d_{33}	and	D_3
25	d_{13}	d_{22}	d_{33}	and	D_3
26	d_{13}	d_{21}	d_{33}	and	D_2
27	d_{13}	d_{23}	d_{32}	and	D_3

Note: D_1 – low; D_2 – medium; D_3 – high.

Table A9. Rules for forming an assessment of the quality of logistics service of logistics operators/ providers (S)

№	Combination of components				An integral indicator of the logistics service quality
1	A_1	B_1	C_1	D_1	S_1
2	A_1	B_2	C_1	D_1	S_1
3	A_1	B_1	C_1	D_2	S_1
4	A_1	B_2	C_1	D_2	S_1
5	A_2	B_1	C_1	D_1	S_1
6	A_2	B_2	C_1	D_1	S_1
7	A_2	B_1	C_1	D_2	S_1
8	A_2	B_2	C_1	D_2	S_1
9	A_1	B_1	C_2	D_1	S_1
10	A_1	B_2	C_2	D_1	S_1
11	A_1	B_1	C_2	D_2	S_1
12	A_1	B_2	C_2	D_2	S_1
13	A_2	B_1	C_2	D_1	S_1
14	A_2	B_2	C_2	D_1	S_1
15	A_2	B_1	C_2	D_2	S_1
16	A_2	B_2	C_2	D_2	S_2
17	A_2	B_1	C_2	D_3	S_1
18	A_2	B_2	C_2	D_3	S_2
19	A_2	B_3	C_2	D_3	S_2

Table A9 (cont.). Rules for forming an assessment of the quality of logistics service of logistics operators/providers (S)

№	Combination of components				An integral indicator of the logistics service quality
20	A_2	B_3	C_2	D_2	S_2
21	A_2	B_3	C_2	D_1	S_2
22	A_1	B_1	C_1	D_3	S_1
23	A_1	B_1	C_2	D_3	S_1
24	A_2	B_1	C_1	D_3	S_1
25	A_2	B_1	C_2	D_3	S_1
26	A_1	B_2	C_1	D_3	S_1
27	A_1	B_2	C_2	D_3	S_1
28	A_2	B_2	C_1	D_3	S_1
29	A_2	B_2	C_2	D_3	S_2
30	A_1	B_3	C_1	D_3	S_1
31	A_1	B_3	C_2	D_3	S_1
32	A_2	B_3	C_1	D_3	S_1
33	A_2	B_3	C_2	D_3	S_2
34	A_1	B_3	C_1	D_3	S_1
35	A_1	B_3	C_2	D_3	S_1
36	A_2	B_3	C_1	D_3	S_1
37	A_2	B_3	C_2	D_3	S_3
38	A_3	B_1	C_3	D_1	S_1
39	A_3	B_1	C_3	D_2	S_1
40	A_3	B_1	C_3	D_3	S_1
41	A_3	B_2	C_3	D_1	S_1
42	A_3	B_2	C_3	D_2	S_2
43	A_3	B_2	C_3	D_3	S_3
44	A_3	B_3	C_3	D_1	S_1
45	A_3	B_3	C_3	D_2	S_3
46	A_3	B_3	C_3	D_3	S_3
47	A_1	B_1	C_3	D_1	S_1
48	A_1	B_1	C_3	D_2	S_1
49	A_1	B_1	C_3	D_3	S_1
50	A_2	B_2	C_3	D_1	S_1
51	A_2	B_2	C_3	D_2	S_2
52	A_2	B_2	C_3	D_3	S_3
53	A_3	B_3	C_3	D_1	S_1
54	A_3	B_3	C_1	D_2	S_1
55	A_3	B_3	C_1	D_3	S_1

Note: S_1 – low; S_2 – satisfactory; S_3 – high.

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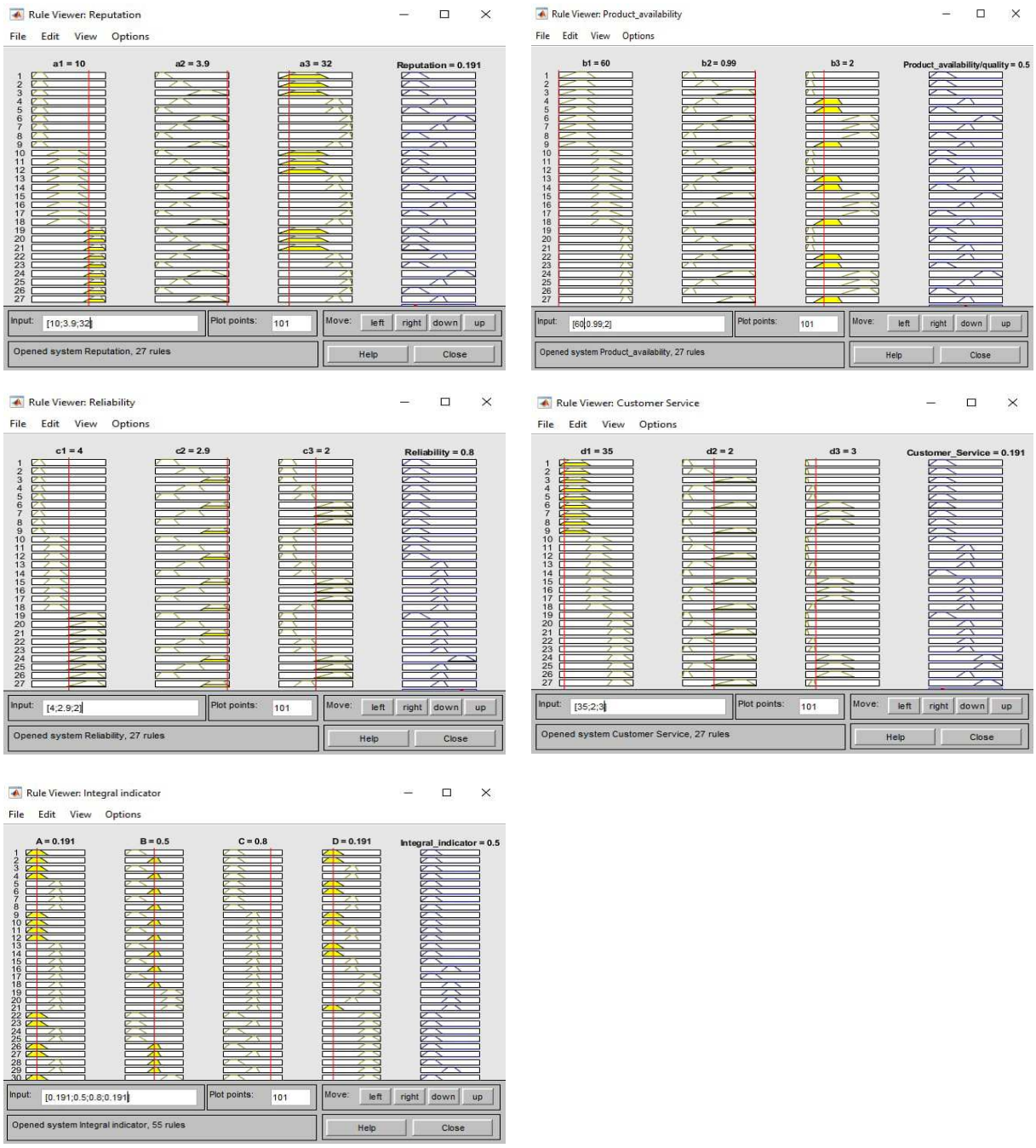

Figure A1. Realized defuzzification of data to the final level of the developed fuzzy model – an integral indicator of the quality of logistics service for Company No. 2

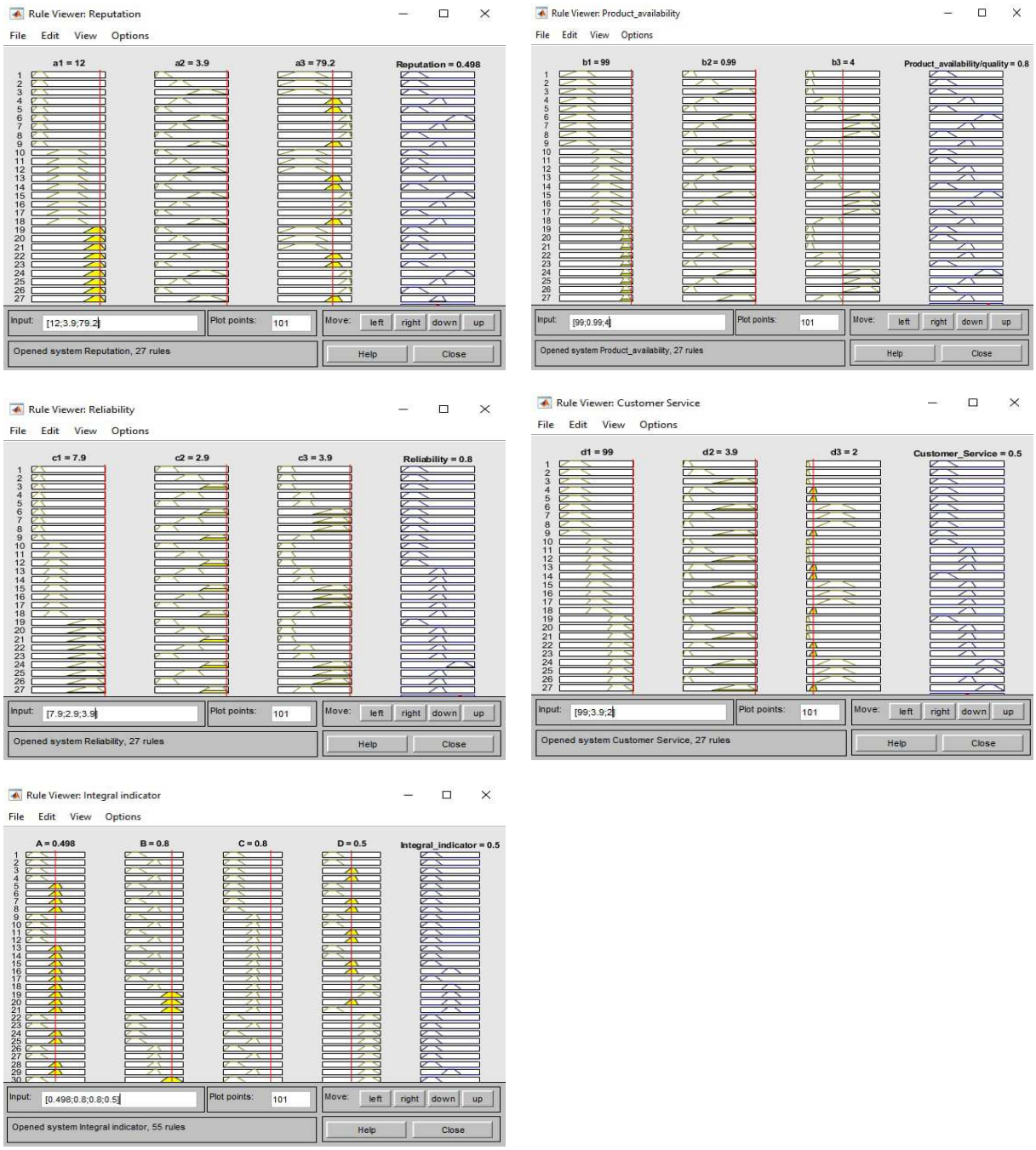

Figure A2. Realized defuzzification of data to the final level of the developed fuzzy model – an integral indicator of the quality of logistics service for Company No. 3

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