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Article

Decision-making model: Determination of logistics service providers selection criteria

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Abstract: Outsourcing logistics operations is a common trend as businesses prioritize core activities. Establishing a sustainable partnership between businesses and logistics service providers requires a systematic approach. This study is needed to develop a more effective and adaptive framework for logistics service provider selection by integrating diverse criteria and decision-making methodologies, ultimately enhancing the precision and sustainability of procurement processes. This study advocate for leveraging industry-based knowledge in procurement, emphasizing the need to define decision-making elements. The research analyzes nearly 300 logistics procurement projects, using a neural network-based methodology to propose a model that aids businesses in identifying optimal criteria for evaluating logistics service providers based on extensive industry knowledge. The goal of this study is to develop and test a practical model that would support businesses in choosing most suitable criteria for selection of logistics service providers based on cumulative market patterns. The results of this study are as follows. It introduces novel elements by gathering and systematizing unique market data using developed data processing methodology. It innovatively classifies decision-making elements, allocating them into distinct groups for use as features in a neural network. The study further contributes by developing and training a predictive model based on a prepared dataset, addressing pre-defined goals, expectations related to green logistics, and specific requirements in the tendering process for selecting logistics service providers. Study is concluded by summarizing suggestions for future research in area of adopting neural networks for selection of logistics service providers.

Keywords: decision-making; logistics providers; neural networks; model

1. Introduction

In contemporary business dynamics, enterprises are engaged in competition not solely based on their products but, in certain instances, predominantly on the efficacy of their supply chains. Consequently, an intricately formulated supply chain management strategy has the potential to constitute a substantial proportion of the value that businesses deliver to their end customers. Presently, the prevalent trend involves outsourcing logistics operations to external entities, as businesses increasingly recognize the efficiency gained by focusing on and allocating internal resources to core activities, whether in production, sales and marketing, or value creation. Acknowledging this paradigm shift, the imperative for an effective collaboration and partnership strategy has become pivotal for numerous businesses and their third-party logistics service providers.

Building a sustainable partnership between businesses and logistics service providers is a complex process and requires systematic approach. According to practical background, a following hypothesis is proposed: using industry-based

accumulated knowledge might be supportive for companies who regularly perform procurement or tendering of logistics services. One of the crucial steps in procurement process is definition of decision-making elements, such as goals of the procurement project, requirement, criteria for selection, and others. While goals and requirements must be defined according to company's strategy, vision and needs, a set of criteria for selection of logistics service providers is something that could be inherited from practical know-how of other businesses and integrated into individual procurement process. Therefore, there was a massive analysis conducted of nearly 300 logistics procurement projects with the purpose to accumulate business knowledge and, by applying methodology based on neural networks, suggest a model that could support businesses in definition of most suitable criteria for evaluation of logistics service providers based on massive industry know-how.

The goal of this study is to develop and test a practical model that would support businesses in choosing most suitable criteria for selection of logistics service providers based on cumulative market patterns. The object of this research is decision-making process for logistics service provider selection, while the subject of the research is definition of criteria for logistics service providers selection. With the purpose to reach the goal, there are following objectives defined:

- To conduct literature review with the focus on aspects related to procurement of logistics services and cooperation and synergies with logistics service provider.
- To collect, process and classify data from logistics procurement projects for training the model.
- To develop and train neural network model for prediction of logistics service provider evaluation criteria.
- To conduct practical application of the model based on specific business case.

There are following elements of novelty found this this research:

- Unique market data gathering and systematization. The research pioneers in the collection and organization of market data, employing a novel methodology developed within the scope of this study. This methodology involves the systematic aggregation, categorization, and analysis of diverse market data pertinent to logistics service providers.
- Elaboration of decision-making elements classification. One of the key contributions of this research lies in the elaboration of a comprehensive classification framework for decision-making elements relevant to the selection of logistics service providers. This framework categorizes decision-making elements into distinct groups, based on their significance and relevance to the selection process.
- Feature engineering for neural network development. Building upon the classified decision-making elements, the research employs sophisticated feature engineering techniques to extract meaningful features for the development of a neural network model. These features serve as inputs to the model, enabling it to effectively predict selection criteria and outcomes.
- Model development and training for prediction. Leveraging the meticulously prepared dataset, the research undertakes the development and training of a predictive model. This model is specifically designed to forecast selection criteria aligned with predefined goals associated with the logistics service provider

selection process. Additionally, it incorporates considerations regarding green logistics practices and fulfills requirements pertinent to the tendering process.

- Integration of green logistics expectations. A noteworthy aspect of the research involves the integration of green logistics expectations into the selection criteria for logistics service providers. By incorporating environmental sustainability metrics and criteria into the model, the research contributes to the promotion and adoption of eco-friendly practices within the logistics industry.

There are following limitations considered in this research:

- Limited scope of data sources. The study relies heavily on data gathered from logistics procurement projects, which might not capture the full spectrum of criteria and considerations that businesses employ in selecting logistics service providers.
- Assumption of homogeneity in industry knowledge. While the study emphasizes the accumulation of industry-based knowledge, it might overlook the diversity of business contexts and strategies across different industries. The model's effectiveness could be hindered by the variability in requirements and expectations among businesses in distinct sectors.
- Neural network model complexity and interpretability. Although neural network models offer advanced predictive capabilities, their complexity might pose challenges in terms of interpretability and transparency. Businesses may struggle to understand the underlying mechanisms driving the selection criteria recommended by the model, which could affect their trust and acceptance of the model's outputs.
- Data quality and preprocessing challenges. The quality and consistency of data collected from logistics procurement projects could be variable, leading to challenges in preprocessing and cleaning the dataset for model training. Inaccuracies or inconsistencies in the data could introduce biases and errors into the model, potentially undermining its reliability and robustness.

As a result of this research, it is proposed that developed model provides contribution to sharing market knowledge of sustainable decision-making among companies and different industries. This paper is organized as follows. Initially literature review is conducted with the focus on aspects related to selection and evaluation of logistics service providers, and cooperation and synergies with logistics service provider. Afterwards, data collection methodology for model training is described, followed by analysis of processed tender data. Afterwards, preparation of the dataset is described, and description of the model is provided. Eventually, practical application of the model is done, concluded with discussions and recommendations.

2. Literature review

In scope of this study, a literature review has been conducted with the focus on three aspects related to procurement of logistics services: selection and evaluation of logistics service providers, multiple-criteria decision-making methods, and cooperation and synergies with logistics service provider.

2.1. Selection and evaluation of logistics service providers

In the initial stages, it is proposed to review different viewpoints on decision-making process from various authors. Decision-making unfolds through distinct phases, encompassing problem identification, preference formation, alternative evaluation, and the selection of optimal choices. According to Tzeng and Huang (2011), when scrutinizing situations governed by a single criterion, decision-making is notably straightforward, as the optimal alternative is easily discernible. However, complications arise in scenarios involving multiple criteria, wherein weighted factors, preference dependencies, and conflicts among criteria necessitate more sophisticated approaches.

The typical decision-making process is often delineated as follows: actions are taken to address a specific problem. Sammut-Bonnici (2015) points out a flaw in this method, as there may be distinct actions and observable outcomes, but their interconnection is not always clear. Strategic choices, at times, introduce an entirely new set of issues. To approach decision-making scientifically, it is imperative to distinguish between facts and values. As per Pomerol and Adam (2004), values represent the decision maker's goals and true desires, while facts are verifiable or falsifiable information. Therefore, the assessment of a choice is only meaningful when the decision maker's intentions are understood. Consequently, evaluating decision quality requires an understanding of the decision-maker's utility and the probabilities associated with potential outcomes. According to Political Science (2020), decision-making involves formulating comprehensive organizational management policies, spanning administrative and business processes. Kanal (2020) suggests classifications such as programmed and non-programmed decisions, organizational and personal decisions, generic and unique decisions, routine and strategic decisions, and policy and operating decisions. Alternatively, Sammut-Bonnici (2015) presents five distinct and sometimes mutually exclusive perspectives on decision-making: decision-making as a plan, ploy, pattern, position, and perspective.

2.2. Critical view of applied multiple-criteria decision-making methods

Examining the aforementioned perspectives and classifications reveals that the selection of a logistics service provider incorporates multiple characteristics drawn from various viewpoints.

The selection and evaluation of logistics service providers stand out as a widely discussed subject within the realm of 3PL activities. The prominence of this theme is attributed to its close association with the overarching decision-making challenge and the diverse methodologies employed in this field of study. Subsequent insights drawn from scientific literature are shared and deliberated upon. The concepts presented by Wang et al. (2015) receive substantial support, emphasizing that the selection of a 3PL transcends routine market screening and mere comparison of commercial proposals. Echoing this sentiment, Perçin and Min (2013) assert that engaging a 3PL service provider is a multifaceted process due to the prevalent trend of long-term contractual cooperation in the market and the distinct nature of transportation and logistics services. Bansal et al. (2014) posit that partnering with a suitable 3PL enhances a company's adaptability to market changes. A pivotal aspect of the 3PL selection

process, as identified by numerous authors, is the establishment of selection criteria. Jharkharia and Shankar (2007) categorize these criteria into determinants, dimensions, and enablers, while Hwang and Chang (2015) propose six groups: service, performance, cost, quality, assurance, IT, and intangible criteria. Zhang et al. (2012) delineate five major categories: operational capabilities, financial performance, improvement and compatibility, client relationships, and enterprise culture. Additionally, Rattanawiboonsom (2014) suggests three groups: contextual, uncertainty, and implementation. While consensus exists on the significant role of selection criteria in the decision-making process, it is imperative to recognize that these criteria represent only a subset of the elements involved, as elaborated further in this study.

A prevalent misconception, both in scientific literature and industry practices, is the singular focus on defining optimal criteria. This narrow approach overlooks crucial elements in the decision-making process, such as the overarching goals and business needs. Furthermore, the methods employed in decision-making must align with the specific needs of individual companies. Contemporary studies predominantly concentrate on the selection process itself, incorporating the adaptation of optimal methodologies and the creation of diverse hybrid approaches. However, the meaningfulness of the process and the actual needs of companies, as well as the incorporation of external factors into the decision-making process, warrant equal consideration. The prevailing emphasis on the selection process may obscure the true economic needs of decision-makers engaging logistics service providers, owing to insufficient input data and information. Therefore, the accuracy and reliability of data play a pivotal role in the decision-making process, underscoring the importance of meticulously collecting and adapting input data for the execution of decision-making models.

Based on the empirical literature review, the most frequently utilized methods for multiple-criteria decision-making in the selection of logistics service providers are Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP), which exhibit close interconnections. The primary merits associated with these methodologies include their ease of application, intuitive nature, and the ability to conduct cost and benefit analyses based on the outcomes derived from AHP and ANP (Saaty and Vargas, 2006; Saaty, 2010). However, a key limitation of these methods lies in their detachment from the external environment, preventing decision-makers from directly integrating historical data and experiential insights regarding collaboration with specific logistics service providers (Cooper, 2012). The Best-Worst Method (BWM) emerges as a relatively novel and user-friendly decision-making approach designed to prioritize selection criteria. While it could complement the decision-making process, its functionality remains constrained, necessitating integration with other methods (Rezaei, 2015; Rezaei, 2016). Similar to AHP, ANP, and BWM, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) also faces limitations in terms of incorporating experiential knowledge related to specific logistics service providers. Nonetheless, TOPSIS adopts a distinct approach by generating an ideal positive solution to problem-solving, representing an optimal set of characteristics for logistics service providers. This attribute proves valuable and can be integrated into hybrid decision-making models to facilitate result

prioritization, comparing the characteristics of each logistics service provider against the most desirable set (Roszkowska, 2011). On the other hand, Data Envelopment Analysis (DEA) demonstrates utility in benchmarking. However, it is acknowledged that this method is seldom employed in isolation due to its inability to furnish a definitive answer regarding the most suitable logistics service provider, a critical concern within the business environment. Consequently, the benchmarking functionality inherent in DEA ought to be integrated into hybrid models to aid in evaluating the relevance of individual logistics service providers for the company (Ramanathan, 2003; Zhu, 2014).

2.3. Collaboration and synergies with logistics service providers

Collaboration and synergies with logistics service providers are intricately linked to the selection and evaluation topic. However, this engagement extends beyond the initial selection phase to encompass a broader scope of studies, including post-selection cooperation. Notably, a noteworthy study in this field is attributed to Andersson and Norrman (2002), who delved into the procurement of logistics services. Additionally, investigations by Knemeyer et al. (2003) and Wilding and Juriado (2004) focused on logistics outsourcing processes from the customer's perspective. In practice, diverse approaches exist for fostering cooperation with 3PL. The primary concepts of cooperation with 3PL service providers can be elucidated through two dimensions: vertical and horizontal. This conceptualization, as well defined by Pomponi et al. (2013) and Albers et al. (2014), denotes vertical cooperation as involving subcontracting or subordinating, often occurring between 3PL service providers and 2PL carriers. On the other hand, horizontal cooperation involves mutual interests and synergies, encompassing resource and benefit sharing, frequently observed between two or more 3PL service providers and sometimes between the customer and 3PL. The insights of Keers and Van Fenema (2015) play a crucial role, addressing the challenge of finding a compromise between the interests of 3PL and those of the customers. Brekalo and Albers (2016) identify three distinguishing factors between vertical and horizontal concepts: motivation, the nature of the relationship, and interdependence. It is essential to underscore that the primary goal for companies engaging in cooperation with 3PL should extend beyond receiving transportation and storage services and making payments. The overarching objective should also include building synergies leading to the improvement of financial outcomes for both the customer and the logistics service provider. In the current economic landscape, characterized by post-pandemic conditions and associated processes, the decision to change a 3PL provider becomes both risky and challenging. Any such decision must be obligatorily accompanied by an evaluation of the associated costs. The significance of switching costs is emphasized by Barker et al. (2021), who argue that a highly integrated 3PL into the customer's supply chain stands to benefit from increased customer loyalty and higher margins.

2.4. Contemporary studies

There are several contemporary studies that are remarkable in this area. Bonab et al. (2023) presented an integrative methodology employing MCDM methodologies

within a spherical fuzzy framework aimed at addressing the selection of sustainable and resilient IoT suppliers. It underscores the significance of incorporating sustainability and resilience considerations into supplier selection processes, utilizing methodologies such as the BWM for criteria prioritization and SFS-multi-normalization multi-distance assessment for assessing suppliers. Moosavi et al. (2023) employs a versatile fuzzy robust optimization methodology in conjunction with meta-heuristic techniques to construct a closed-loop supply chain framework, and evaluates objectives aimed at cost minimization, workforce optimization, and demand regulation. The findings indicate that uncertainties amplify transportation and operational expenditures, while endorsing it as a proficient algorithm for addressing substantial numerical complexities.

In concluding literature analysis, it is pertinent to note that contemporary studies in this domain tend to be more theoretical than practical. There is a pressing need for studies aimed at developing cooperation models, including mathematical and economic models, between customers and logistics service providers. Such models would demonstrate the tangible economic and financial benefits that companies and logistics service providers could achieve through the establishment of efficient cooperation. It is worth mentioning that above listed methodologies themselves rely and are dependent on choice of selection criteria, and therefore there is a need for the model that could accumulate market knowledge and support traditional decision-making methodology.

3. Data collection methodology for model training

The data used for training the model was collected from road freight service tender documents issued by various companies (primarily manufacturing) in Europe between 2019 and 2023 and obtained in cooperation with leading European 3PL service provider. There were in total 294 tender projects (considered to be samples in dataset) studied launched by 184 different companies. The following documents were investigated: general framework agreements, service level agreements, standard operating procedures, and environmental policies. While analyzing above mentioned documents, particular statements were extracted that describe following elements: the goal of a tender, 3PL selection criteria, requirements towards 3PL providers, and expectations concerning green logistics.

Within the framework of this investigation, the delineated methodology for data acquisition is as follows. **Figure 1** delineates a comprehensive procedure for the analysis of procurement documentation. The data collection process comprises four principal stages, as illustrated in the figure: the selection of companies and projects for data gathering, the retrieval of procurement project documentation from the identified companies, the formulation of search queries, components, and the analysis of procurement project documentation, and the search for the answers to defined inquiries within the documentation, culminating in information processing.

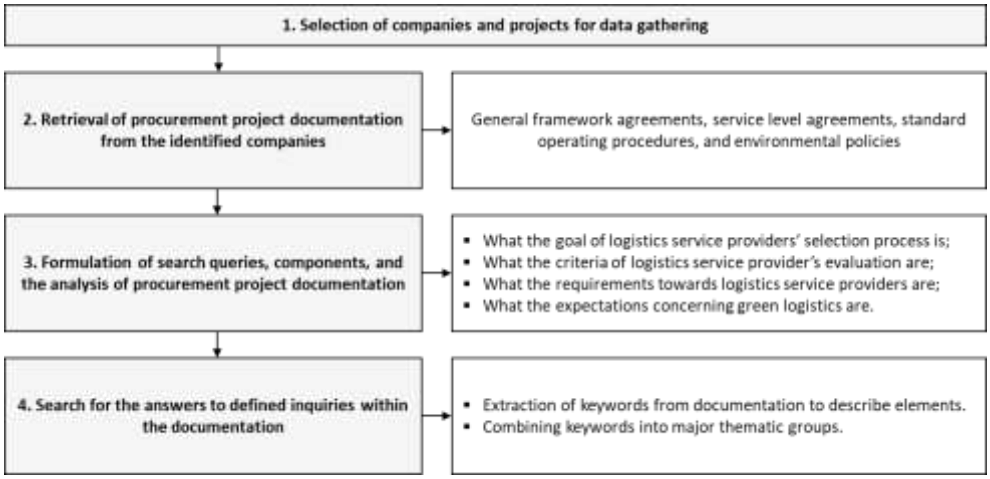

Figure 1. Procedure for the analysis of procurement documentation.

According to above mentioned, in stage one there was a need to ensure the acquisition of representative and precise data for the decision-making model, it is crucial to compile a list of companies that accurately reflect the behavioral patterns within specific industries. It is evident that decision-making elements can vary across different industries. The chosen companies for data collection encompass a diverse range of industries, primarily focusing on the manufacturing sector. Notably, the results of this analysis, within the proposed decision-making model, will be universally applicable without the need for segregation by industry. This universal application is facilitated by the inherent nature of the proposed model, which establishes linkages between various elements of the decision-making process.

In stage two the procurement project documentation has been gathered from selected companies, encompassing a thorough examination of documents from 294 procurement projects. The documentation scrutinized includes four main categories: general framework agreements, service level agreements, standard operating procedures, and environmental policies. The decision to explore such a comprehensive range of documentation serves a specific purpose. It is essential to note that the content of the documentation set provided by individual companies in the procurement process often varies, and it may not comprehensively include all types of documents. To ensure the extraction of the most useful data possible, the decision was made to investigate these four specific document types. It is important to highlight that there is no default standard for how an individual company chooses to elucidate elements of the decision-making process. Moreover, the way a company presents this information may differ from the approach taken in this research. For example, based on the chosen definition and the presentation style adopted by a company, it is inferred that a specific statement may qualify as a requirement for a logistics service provider, even if the company does not explicitly state it as such.

In stage three, with the purpose to address uncertainties and ambiguities inherent in these documents, four essential questions have been devised to guide the analysis and facilitate the extraction of pertinent information: what the goal of logistics service providers' selection process is; what the criteria of logistics service provider's evaluation are; what the requirements towards logistics service providers are; what the expectations concerning green logistics are. Aligned with these questions, four distinct

elements (goals, criteria, requirements, and green logistics) have been delineated. The focus is on uncovering these elements within the procurement documentation to enhance clarity and understanding.

Eventually, in stage four the analysis initiates with a comprehensive review of procurement project documentation. This review aims to identify key definitions, sentences, or paragraphs that potentially hold answers to the previously established four questions. Recognizing that a single paragraph may address multiple questions, it is crucial not to segregate this information in the initial stages of analysis. The outcome of this step involves generating an extensive list comprising unique entries: company and corresponding statements. Stage four is then subdivided into two distinct sub-steps: extraction of keywords from documentation to describe defined elements and combining keywords into major thematic groups. These sub-steps serve to refine the extracted information, allowing for a more structured and coherent understanding of the procurement project documentation.

4. Analysis of processed tender data

The analyzed dataset encompasses ten distinct groups of criteria, each assigned a specific share of importance, and the frequency with which they are mentioned across a set of documents. The criteria and their corresponding shares are shown in **Figure 2** as follows: price factor (16%), reputation and profile (16%), service quality (14%), legal compliance (12%), capacity (11%), flexibility (9%), personnel and communication (7%), geographical coverage (6%), certification (5%), and eco-friendliness (4%).

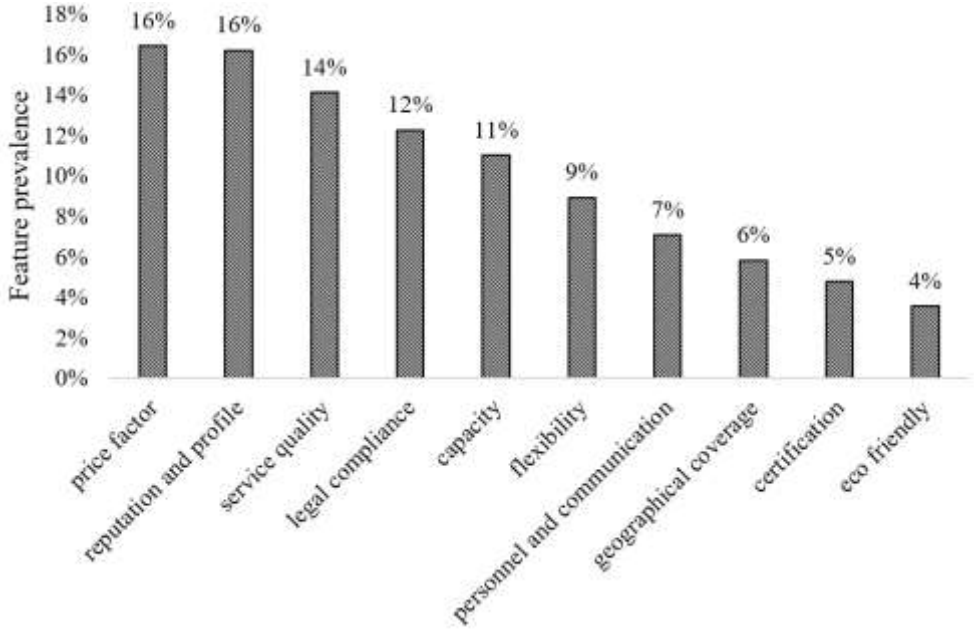

Figure 2. Groups of criteria.

The predominant criterion in this evaluation is the "price factor," constituting 16% of the overall decision-making process. This criterion has been cited 79 times across the documents, underscoring its pivotal role in the selection of logistics service providers. Parallel to the price factor, "reputation and profile" also command a 16%

share, with 78 mentions. The close alignment of these two criteria in terms of both share and quantity reflects the intricate balance between economic considerations and the perceived standing of service providers within the industry.

Following closely behind, "service quality" claims a 14% share, with 68 mentions, emphasizing the significance of the actual performance and reliability of logistics services in the decision-making matrix. "Legal compliance" and "capacity" are subsequent considerations, with 12% and 11% shares, respectively. These criteria, highlighted in 59 and 53 mentions, underscore the importance of adherence to legal standards and the ability to meet varying capacity demands as critical elements in the selection process.

Further down the hierarchy of prevalence, the criteria of "flexibility," "personnel and communication," and "geographical coverage" contribute 9%, 7%, and 6%, respectively. These factors, denoted by 43, 34, and 28 mentions, illuminate the nuanced facets of operational adaptability, effective communication channels, and extensive geographical reach as influential factors shaping decision-making.

In the latter tier of criteria, "certification" and "eco-friendliness" carry 5% and 4% shares, corresponding to 23 and 17 mentions. These considerations reflect a growing trend in the logistics industry, where adherence to industry-specific certifications and environmentally conscious practices are gaining recognition as integral components of a logistics service provider's overall appeal.

In the examination of the goals associated with the logistics service provider selection process, an in-depth analysis has been undertaken to delineate the relative significance of various objectives within the decision-making framework. The dataset encompasses eight distinct goals, each assigned a specific share of importance and quantified by the frequency of their mention across a set of documents. The goals and their corresponding shares are shown in **Figure 3** as follows: cost reduction (30%), supplier portfolio optimization (24%), service quality improvement (15%), long-term cooperation development (9%), implementation of innovations (6%), increase of capacity (6%), implementation of digitalization (5%), and involvement of new suppliers (4%).

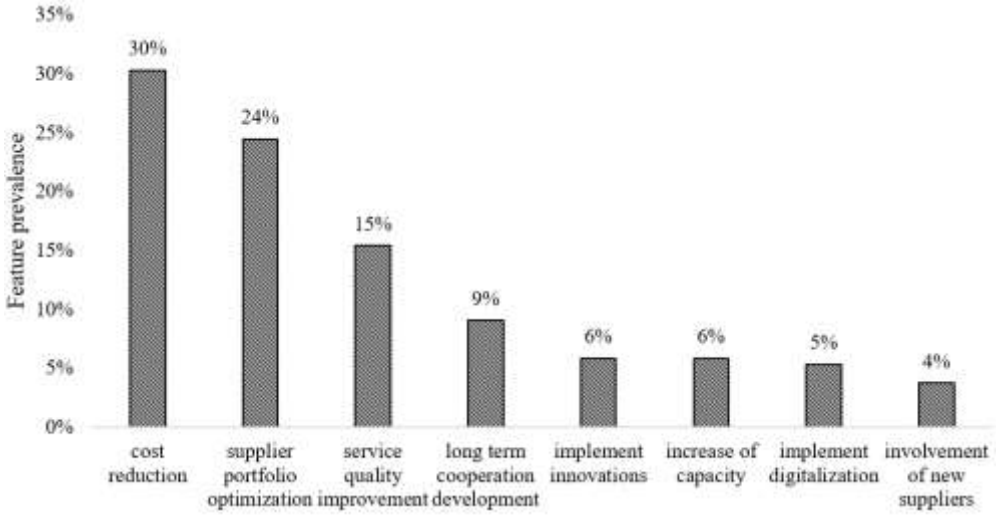

Figure 3. Groups of goals.

At the forefront of the decision-making landscape is the goal of "cost reduction," which commands a substantial 30% share. This goal, mentioned 57 times across the documents, underscores the paramount importance placed on economic considerations in the logistics service provider selection process. The emphasis on cost reduction reflects the overarching imperative for organizations to enhance efficiency and minimize operational expenditures, aligning with the contemporary drive for fiscal prudence.

Closely following is the goal of "supplier portfolio optimization," constituting a significant 24% share with 46 mentions. This goal highlights the strategic emphasis on refining and streamlining the array of suppliers engaged in the logistics network. The objective of optimizing the supplier portfolio speaks to a nuanced approach that seeks to enhance efficiency, mitigate risks, and foster a more resilient and responsive supply chain ecosystem.

"Service quality improvement" constitutes the third key goal, accounting for a 15% share with 29 mentions. This objective underscores the commitment to elevating the overall performance and reliability of logistics services, emphasizing the importance of a high-quality service offering as a cornerstone in the decision-making process.

In the subsequent tiers of importance, the goals of "long-term cooperation development," "implementation of innovations," and "increase of capacity" contribute 9%, 6%, and 6%, respectively. These objectives, quantified by 17, 11, and 11 mentions, reflect a multifaceted approach that considers not only immediate cost considerations but also the long-term strategic relationships, technological advancements, and scalability of logistics services.

Further down the hierarchy, the goals of "implementation of digitalization" and "involvement of new suppliers" carry 5% and 4% shares, corresponding to 10 and 7 mentions. These goals signal a recognition of the transformative potential of digital technologies in optimizing logistics processes and the strategic value of diversifying supplier networks.

In the examination of expectations concerning green logistics in the selection of logistics service providers, a thorough analysis has been conducted to discern the relative importance of various environmentally conscious aspects within the decision-making process. The intersection of green logistics and environmental concerns constitutes a prominent focal point within contemporary discourse surrounding supply chain management. This discussion is underscored by shifts within the energy sector and broader economic dynamics. It is widely acknowledged that green logistics necessitates examination through three distinct lenses: social, economic, and environmental imperatives. The imperative for further research in this domain is evident, given the evolving landscape of the transportation and storage industries, which is shaped not only by logistics service providers but also by the active advocacy of consumers. The findings of this study corroborate the increasing significance of green logistics within the decision-making processes of businesses, wherein many emphasize their expectations regarding environmental considerations when selecting logistics service providers. Moreover, third-party logistics service providers are compelled to embrace environmentally sustainable logistics solutions to remain competitive in today's market. Failure to do so poses a significant risk to their viability

in the face of heightened environmental consciousness among competitors.

The dataset encapsulates eight distinct green logistics expectations, each assigned a specific share of importance and quantified by the frequency of their mention across a set of documents. The expectations and their corresponding shares are shown in **Figure 4** as follows: reduce emissions and waste (22%), develop sustainability policies (18%), sustain adherence to rules and policies (16%), improve sustainability strategy (14%), align sustainability strategy with the provider (12%), introduce green equipment (9%), implement material reuse (6%), and implement reporting (3%).

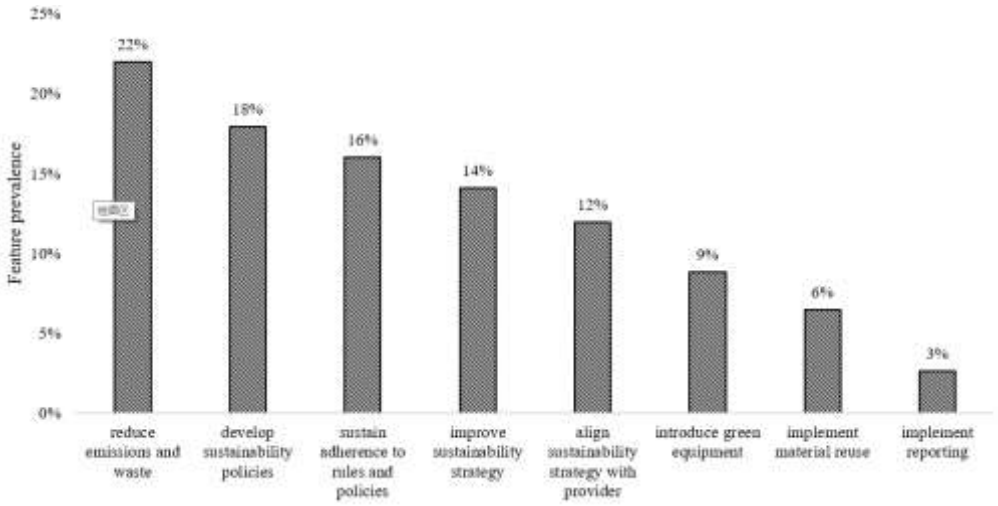

Figure 4. Groups of expectations concerning green logistics.

Foremost among these expectations is the desire to "reduce emissions and waste," commanding a substantial 22% share. This expectation, mentioned 92 times across the documents, reflects a heightened awareness and emphasis on the environmental impact of logistics operations. Customers are placing a significant premium on service providers who actively contribute to minimizing their carbon footprint and waste generation, aligning with broader societal imperatives for sustainable business practices.

Following closely is the expectation for logistics service providers to "develop sustainability policies," constituting an 18% share with 75 mentions. This expectation underscores the growing importance of explicit and comprehensive sustainability policies as a key criterion in the selection process. Customers are increasingly seeking providers who not only embrace green practices but also have formalized strategies in place to guide and govern their sustainable initiatives.

"Sustain adherence to rules and policies" constitutes the third significant expectation, accounting for a 16% share with 67 mentions. This expectation reflects a customer-driven demand for a high level of regulatory compliance and a commitment to upholding established environmental standards and policies. Customers seek assurance that logistics service providers operate ethically and responsibly within the regulatory framework governing environmental sustainability.

In the subsequent tiers of importance, the expectations to "improve sustainability strategy" and "align sustainability strategy with the provider" contribute 14% and 12%, respectively. These expectations, quantified by 59 and 50 mentions, emphasize

the strategic and collaborative aspects of sustainability, where customers value providers that continuously enhance their overall sustainability approach and align it closely with the expectations and values of their clientele.

Further down the hierarchy, the expectations of "introducing green equipment," "implementing material reuse," and "implementing reporting" carry 9%, 6%, and 3% shares, corresponding to 37, 27, and 11 mentions. These expectations highlight the desire for logistics service providers to actively invest in environmentally friendly technologies, adopt circular economy principles, and transparently communicate their sustainability performance through robust reporting mechanisms.

In the analysis of requirements towards logistics service providers within the context of the tendering process, an examination has been undertaken to ascertain the relative importance of various aspects influencing decision-making. The dataset encompasses twelve distinct groups of requirements, each assigned a specific share of importance and quantified by the frequency of their mention across a set of documents. The requirements and their corresponding shares are shown in **Figure 5** as follows: documentation handling (14%), equipment compliance (11%), legal compliance (11%), tracking and visibility (9%), personnel and communication (9%), quality compliance (8%), certification (8%), digital solutions (7%), safety and security measures (6%), operational process compliance (6%), acceptance of contract conditions (5%), reporting (5%), and capacity (3%).

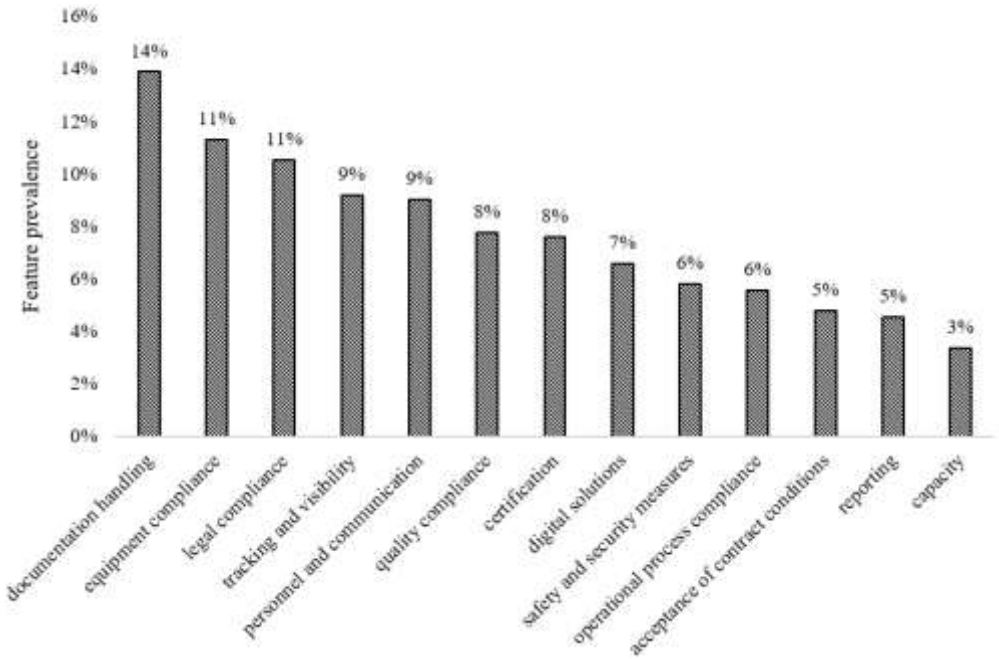

Figure 5. Groups of requirements towards logistics service providers.

At the forefront of companies' priorities is the requirement for effective "documentation handling," constituting a significant 14% share. This requirement, emphasized 177 times across the documents, underscores the critical role that streamlined and accurate documentation plays in the overall efficiency of logistics operations. Companies are keenly focused on logistics service providers that can adeptly manage the complexities of documentation within the tendering process.

Following closely are the requirements for "equipment compliance" and "legal

compliance," each contributing an 11% share with 144 and 134 mentions, respectively. These requirements reflect the emphasis on ensuring that logistics service providers adhere to both equipment specifications and legal standards. Companies seek assurance that the equipment used is in compliance with industry standards, and providers operate within the legal frameworks governing logistics operations.

"Tracking and visibility" and "personnel and communication" constitute the subsequent tier of importance, each contributing 9% to the overall requirements. With 117 and 115 mentions, respectively, these requirements underscore the importance of real-time tracking capabilities and effective communication channels in fostering transparency and collaboration within the logistics ecosystem.

In the realm of quality assurance, the requirements for "quality compliance" and "certification" contribute 8% each, with 99 and 97 mentions, respectively. These requirements highlight the significance of stringent quality standards and recognized certifications as key benchmarks for evaluating the capabilities and reliability of logistics service providers.

Further down the hierarchy, the requirements for "digital solutions," "safety and security measures," and "operational process compliance" carry 7%, 6%, and 6%, respectively. These requirements, quantified by 84, 74, and 71 mentions, emphasize the growing importance of digital technologies, safety protocols, and operational processes that align with industry best practices.

In the latter tier of requirements, "acceptance of contract conditions," "reporting," and "capacity" carry 5%, 5%, and 3%, respectively, corresponding to 61, 58, and 43 mentions. These requirements highlight the contractual and reporting aspects of logistics services, as well as the capacity considerations necessary to meet the evolving needs of the companies.

5. Preparation of the dataset and description of the model

In the dataset for training a neural network model to predict the criteria for the selection of logistics service providers, the data was organized in a tabular format where each row represents a sample or instance, and each column corresponds to a specific feature, as it is shown in **Table 1**. The features are categorized into three main groups: criteria (Crit_1 to Crit_10), goals of the tendering process (Goal_1 to Goal_8), expectations concerning green logistics (Green_1 to Green_8), and requirements towards logistics service providers (Req_1 to Req_13). The binary nature of the data indicates whether a particular condition or characteristic is present (1) or absent (0) for each sample.

Table 1. Dataset for model training.

Samples	Crit_1	…	Crit_10	Goal_1	…	Goal_8	Green_1	…	Green_8	Req_1	…	Req_13
1	1	…	1	0	…	0	0	…	1	0	…	1
2	0	…	1	1	…	1	0	…	0	0	…	0
3	0	…	1	1	…	0	0	…	0	1	…	1
4	1	…	1	1	…	0	1	…	0	0	…	0
…	…	…	…	…	…	…	…	…	…	…	…	…
294	1	…	1	0	…	0	1	…	0	1	…	0

For the criteria columns (Crit_1 to Crit_10), the values indicate the fulfillment of specific criteria related to the selection of logistics service providers. A value of 1 suggests that the corresponding criterion is met, while 0 indicates that it is not met. Similarly, the goal columns (Goal_1 to Goal_8) represent the fulfillment of goals associated with the tendering process. The expectations concerning green logistics columns (Green_1 to Green_8) provide information on whether specific environmentally friendly practices are considered in the logistics process. Finally, the requirement columns (Req_1 to Req_13) outline various requirements towards logistics service providers.

Each row in the dataset represents a unique combination of these features for a specific sample. The dataset consists of 294 samples, with each sample having binary values for the specified criteria, goals, expectations concerning green logistics, and requirements. This structured representation of the data facilitates the training of a neural network model to learn patterns and relationships between the input features and the criteria for selecting logistics service providers. The goal is to develop a predictive model that can generalize and make accurate predictions for new instances based on the learned patterns from the training data. The algorithm of developed model is represented in **Figure 6**.

Figure 6. Algorithm of developed model.

There are several Python libraries utilized for various tasks, ranging from data manipulation to machine learning and visualization. There are following steps taken to setup the model. It begins with loading a dataset from a CSV file into a Pandas DataFrame (df_combined). Afterwards, selection of specific columns from the DataFrame as input features ‘X’ and output labels ‘y’ is done. ‘Selected_columns’ represent the features, while ‘crit_*’ columns represent the criteria to be predicted. The dataset is split into training and testing sets. 85% of the data is used for training

(X_train, y_train), and 15% is reserved for testing (X_test, y_test). A multi-layer perceptron (MLP) neural network model is created using the MLPClassifier from scikit-learn. It has one hidden layer with a number of neurons equal to the number of input features. The model is wrapped in a MultiOutputClassifier to handle multiple output targets. The training is done on the training data. The trained neural network model is saved to a file using joblib. This allows the model to be loaded later for making predictions on new data.

New data, stored in a different CSV file (df_combined_user.csv), is loaded for which predictions will be made. The feature columns are selected to match the format of the training data. The previously trained model is loaded from the saved file, and predictions (probabilities) are made on the new data (X_user). The use of predict_proba returns the probability estimates for each class, enabling a more detailed analysis.

Eventually the extraction of coefficients representing the probability of the positive class for each output feature from the predicted probabilities is done. These coefficients are then rounded and visualized using a bar chart with corresponding labels for better interpretation. The feature names are mapped to more understandable names for clarity in the plot. The resulting plot provides insights into the importance of each feature for predicting the criteria.

6. Practical application of the model

With the purpose to test developed model and compare model-obtained results with customer's pre-defined criteria, a specific case (procurement project) was considered that had been organized by a company from healthcare industry (manufacture of basic pharmaceutical products and pharmaceutical preparations) in 2023. Considered case in based on profile of multinational enterprise operating in the pharmaceutical and biotechnology sectors, which stands as one of the preeminent entities within the global pharmaceutical and biomedical landscape. Model input data was structured as shown in table below.

Data above was prepared according to original definitions discovered in company's procurement documentation. Goal associated with the logistics service provider selection process was formulated as follows: "… the objective of this RFQ is to improve the logistics performance at a competitive price", that corresponds to the defined group "cost reduction". In terms of expectations concerning green logistics in the selection of logistics service providers there were following statements found: "… the supplier shall comply with all applicable environmental laws, regulations and standards as well as implement an effective system to identify and eliminate potential hazards to the environment", which corresponds to group titled "sustain adherence to rules and policies"; and "… business partners to strive to support our climate protection goals through the products and services they deliver (e.g., by providing relevant data on climate protection)", "…we also expect our suppliers to take climate protection appropriately into account in their own operations, for example by setting climate protection goals for themselves and achieving them", which corresponds to group "improve sustainability strategy". There were also multiple requirements towards logistics service providers discovered within the context of the tendering

process: "… ensure sufficient capacities on awarded lanes" (corresponds to group titled "capacity"); "… transportation to be provided in accordance with the guidelines of Good Distribution Practice of medical products for human use" (group "certification"); "… ETA confirmation shared via online platform" (group "digital solution"); "… appropriate handling & return of customs documentation", "… related tasks such as document administration and control", "… correct logging of reason codes when applicable", "… POD and CMR administration", "… support deviation management process", "… provide correct invoices in accordance to billing guide" (group "documentation handling"); "… transportation of dedicated shipments via FTL or vans", "… transportation in line with customs requirements" (group "equipment compliance"); "… collection of orders on-time" (group "operational process compliance"); "… timely provision of milestones" (group "quality compliance"); "… provision of KPI (Key Performance Indicators) data and exception reporting" (group "reporting"); "… proactive communication with us regarding shipment status" (group "tracking and visibility").

With the purpose to compare model-predicted criteria, there was a need to discover customer's defined criteria in scope of procurement project. There were following definitions related to criteria found: "… experience of similar contracts, with references provided if requested" (corresponds to group titled "reputation and profile"); "… value for money and transparent pricing" (group "price factor"); "… experience, qualifications, and skills of staff" (group "personnel and communication"); "… overall quality of proposal" (group "legal compliance"); "… flexible and practical solution which meets the business needs" (group "flexibility"); "… acceptance of and signing of the terms and conditions" (group "certification"). As a result of simulations performed based on trained model and previously prepared input data (**Table 2**), there are following values of output coefficients obtained that are shown in **Figure 7**.

It is important to note that is scope of procurement process, definition of evaluation criteria is one of key stages for businesses. Complexity of the criteria definition process is usually linked to human factor and that consistency rule can be forgotten. According to the information seen in figure above, it is suggested choosing following groups of selection criteria: compulsory recommended - price factor, reputation and profile, service quality; optionally recommended: capacity, legal compliance. By comparing obtained model-simulated results, it is possible to conclude that such groups as "price factor", "reputation and profile", and "legal compliance" where predicted by the model. However, "personnel and communication", "flexibility", and "certification" were not prioritized.

Table 2. User input data for model application.

Project	Goal_1	Green_5	Green_8	Req_4	Req_5	Req_8	Req_8	Req_10	Req_11	Req_13
2023	1	1	1	1	1	1	1	1	1	1

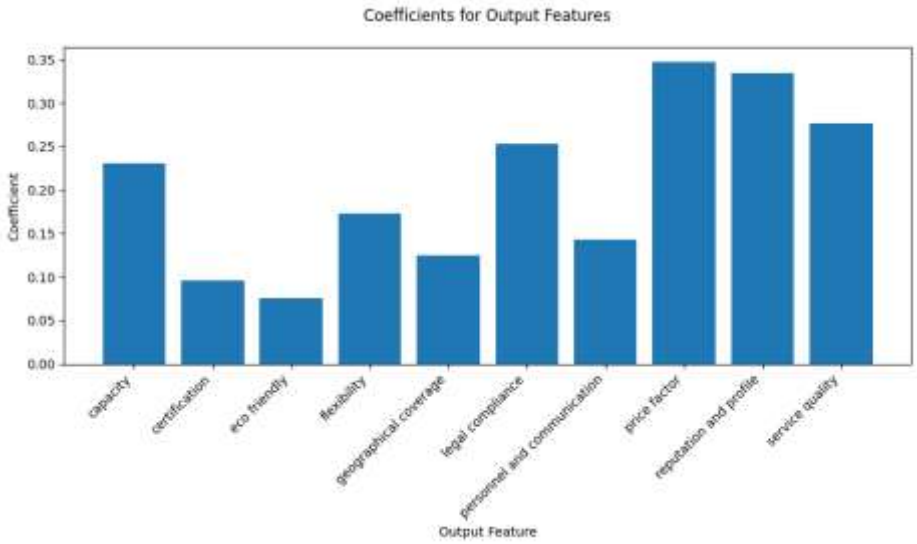

Figure 7. Results of the model application.

7. Conclusion discussions and future research directions

Application of neural networks offer a novel approach to selecting the most pertinent criteria for logistics service provider selection by leveraging their ability to capture complex patterns and relationships within the data. By harnessing the power of neural networks, researchers can dynamically adapt to evolving market conditions and incorporate diverse sources of information, leading to more robust and adaptive decision-making frameworks. Furthermore, neural networks excel in handling large volumes of heterogeneous data, enabling the integration of various factors such as cost, reliability, and geographic coverage, thus enhancing the precision and effectiveness of logistics service provider selection processes.

While methodologies such as AHP, ANP, BWM, TOPSIS, and DEA offer valuable insights into the selection of logistics service providers, each exhibits distinct strengths and limitations. The integration of multiple approaches into hybrid decision-making models appears to be a promising avenue for addressing the complexities inherent in such decisions, allowing for a more comprehensive consideration of both quantitative and qualitative factors. The methodologies are contingent upon the selection criteria chosen, emphasizing the necessity for a model capable of aggregating market insights to complement traditional decision-making methodologies.

In this research there are following contributions and most important findings provided.

- A unique market data was gathered and processed utilizing a proprietary data processing methodology developed and described in scope of the research.
- Subsequently, there is a classification of decision-making elements proposed, organizing them into specific groups that serve as features for a neural network, and provide qualitative analysis of these elements.
- Leveraging the prepared dataset, a model is formulated and trained to predict selection criteria aligned with predefined goals related to the logistics service provider selection process, as well as expectations regarding green logistics in the selection of logistics service providers and the stipulated requirements for

logistics service providers in the context of the tendering process.

- The developed model contributes significantly to disseminating knowledge on sustainable decision-making across various companies and industries. Eventually, practical application of the model is conducted based on specific business case.

Based on the results of this research, there are following conclusions made.

There are different patterns of combinations of elements (goals, requirements, green logistics aspects, criteria) observed based on individual company's data. When an individual company defines certain goal for procurement project, it is assumed that other elements (requirements, green aspects, and criteria) must be logically linked to the goal, otherwise, cause-and-effect relationship could be false that would lead to undesired results of procurement process. This fact leads to the next conclusion.

It is very important to logically determine the cause-and-effect relationship between the elements to build an effective model that support companies in decision-making process. In scope of this study, it is considered that it is in business competence to properly define goal, requirements, and green aspects, while prioritization of criteria could be delegated to developed model.

Considering wide scope of analyzed and structured data, it became possible to crystalize common patterns between behavior of companies (in terms of linking elements of decision-making and building cause-and-effect relationship) and consolidate these patterns on industry level, that eventually supported in building and training neural network model. Developed model based on neural network could be useful for businesses to adopt it to their decision-making process and models for selection of logistics service providers.

There is a crucial role of training dataset preparation that impacts accuracy of predictions and therefore overall credibility of the model. According to initial analysis of procurement projects documentation, there was a wide range of features formulated that turned out to have negative impact on accuracy of predictions. Considering quantity of samples available for the training and number of features created because of analysis and classifications, it was decided to shrink number of features into more consolidated list of goals, green aspects, requirements, and criteria. This approached heled to achieve higher accuracy of predictions and hence credibility of the model.

Additional industry data from logistics procurement projects would increase credibility of predictions of the model, therefore it is advised to continue collecting information in future, also potentially revising classification, as well as naming of the features, and integrating newly collected data into model training dataset.

Based on the discussion and conclusions provided, there are possible future studies. These future studies can contribute to advancing the understanding and application of neural networks in logistics decision-making processes and further improve the effectiveness and applicability of the developed models.

- Investigate further the integration of traditional methodologies with neural networks to create more effective hybrid decision-making models.
- Explore how neural networks can dynamically adapt to rapidly changing market conditions and incorporate real-time data for more agile decision-making in logistics service provider selection.
- Analyze the specific impact of green logistics aspects on the decision-making

process and how they can be better integrated into the selection criteria and model.

- Conduct a broader analysis across industries to identify common patterns and trends in logistics service provider selection, aiming to refine the neural network model further.

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