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An Integrated Decision Support System (DSS) for Sustainable Supplier Selection, Evaluation, and Benchmarking Using a FIS Approach

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Abstract

Applications of sustainable supplier selection criteria in supply chain management (SCM) remain underdeveloped compared to other evaluation methods. This study focuses on three main dimensions of sustainable supplier performance: economic, environmental, and social criteria. The research aims to identify significant criteria within each dimension that are crucial for sustainable supplier selection process. These criteria will be utilized to develop a decision support system (DSS) that integrates a fuzzy inference system. The proposed model offers a holistic approach to supplier evaluation by considering economic performance, environmental impact and social responsibility. By incorporating these dimensions, the model ensures that the selection process aligns with broader corporate and environmental goals. The approach enables companies to make informed and sustainable decisions, ultimately contributing to a more resilient and responsible SCM. Furthermore, the fuzzy inference system effectively handles the inherent uncertainty and vagueness in supplier performance data. To enhance the robustness and reliability of the decision-making process, the proposed model can be integrated with multi-objective linear programming models, making it a valuable tool for supply chain managers. The findings of this work revealed that the economic criteria of supplier selection focus on quality, flexibility, cost, lead time, relationships, and technical capability. The environmental criteria include resource consumption, eco-design, recycling, emissions, and sustainability practices. The social criteria emphasize stakeholder involvement, staff training, safety, rights, and accident prevention in supplier selection. In summary, this comprehensive framework evaluates and benchmarks supplier sustainable performance, supporting more resilient and sustainable SCM.

Keywords
Sustainability, supplier selection criteria, performance evaluation, decision support system, supply chain management.

1. Introduction
Sustainable supplier selection is a critical factor in the success of any organization. This process is a strategic decision that has a long-term impact on the sustainability and overall performance of the supply chain, influencing the organization's success (Gimenez & Tachizawa 2012). At present, ranking suppliers and evaluating their performance using traditional techniques (such as direct audits or site visits) are insufficient to cope with the ever-rising consumer demands (Hasan et al. 2020). The existing research on the integration of benchmarking in supplier selection and performance evaluation remains limited. Additionally, the increasing pressure from consumers and stakeholders emphasizes the critical importance of ensuring the sustainability of supply chain performance through effective supplier selection (Zhu et al. 2022). Sustainability is becoming a necessity in supplier selection due to its profound impact on long-term business success, regulatory compliance, and corporate social responsibility.

Recently, many initiatives have been launched in the Gulf Cooperation Council (GCC) area to advocate sustainability either directly or indirectly. UAE launched its own "Vision 2030" (Saradara et al. 2023) which emphasizes sustainability, economic diversification, and the development of a knowledge-based economy. To achieve those objectives, the traditional approach for industries in the UAE regarding procurement and supplier selection must change to cope with the increasing demand for sustainability and efficiency. The supplier selection process is sub-optimal in the industrial landscape in the region, as there are multiple barriers, such as balancing sustainability with economic competitiveness, complexity in managing multi-tiered supply chains, and the lack of data transparency (Runtuk et al. 2024).

The supplier selection process encompasses several tasks (Weele 2010). It begins with identifying the needs and requirements. After formulating the selection criteria, a company calls for tenders ensuring that suppliers adhere to these criteria. The next step involves reviewing the information submitted by suppliers. This is an iterative procedure that will be repeated until a final decision is made. The final step is evaluating the supplier's performance, which marks the end of the supplier selection process and provides feedback regarding the selected supplier. The aforementioned process is essential for greening supply chains (Rao 2002). According to (Chen et al. 2020), selecting sustainable suppliers fosters a smart supply chain enhancing the sustainability of the entire network.

Moreover, (Shaw et al. 2012), proposed a Fuzzy AHP and Fuzzy MOLP model to select suppliers who can reduce the carbon emission in the supply chain. However, the available literature relies on hypothesized models rather real case studies as it is explained in section 2. The three key concepts of supplier management, supplier selection, supplier performance evaluation, and the integration of both, have been extensively researched and studied. However, coupling the three concepts in one Decision Support System (DSS) and using it as a benchmarking tool for sustainable supplier management was not given enough devotion.

A vast spectrum of research has been conducted on supplier selection methods. The majority of this research has adopted the integrated multiple-criteria decision analysis (MCDM) methods on supplier evaluation, such as Fuzzy-AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Gnanasekaran et al. 2010); FAHP and TOPSIS for green supplier selection strategies (Muralidhar et al. 2012); and Evaluating agile supplier selection criteria and ranking of suppliers (Y. Beikkhakhian et al. 2015). Additionally, data mining techniques have been used for supplier selection and evaluation (Liou et al. 2021), with recent research incorporating machine learning into the evaluation process (Ma & Li 2024).

Traditional supplier selection methods have a lot of disablers that need to be overcome, as they lack multi-criteria analysis, are unable to handle uncertainty, are subjective in the decision-making process, are unable to handle data adequately, they fail to address sustainability, and they over-rely on historical data. Therefore, the need to develop a systematic and sustainable evaluation system to efficiently classify suppliers and benchmark their performance for continuous improvement is essential. Therefore, the objective of this research is to propose a hybrid DSS, that integrates fuzzy inference systems (FIS). The model is expected to be a generic DSS model that can be adopted in any industry regardless of the nature of the business (service or manufacturing).

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The following sections in this paper will be dedicated towards the literature review of sustainability and supplier selection methods, the methodology used in this research and the results of the research.

2. Literature Review

The available literature still has limitations that need to be addressed. Both Fuzzy AHP and TOPSIS have shortcomings in achieving effective sustainable supplier selection, as each method has its own constraints. For instance, TOPSIS assumes linearity in the relationships between criteria and performance, which is often unrealistic in sustainability measurements, in addition to its inability to handle ambiguity in decision criteria. On the other hand, Fuzzy AHP is unable to handle complex interdependencies on its own, thus, when coupling it with MOLP the interdependencies could be better managed allowing for a more flexible, nonlinear representation of relationships among criteria using fuzzy logic (Laith et al. 2023).

FIS is a framework that utilizes fuzzy logic to map inputs to outputs using human-like reasoning processes, that can be used in complex systems where data may be ambiguous, which allows for a better decision-making process under unclear or uncertain circumstances. (Gu et al. 2023). FIS can be useful in multiple areas of the supply chain, such as in the supplier selection process, inventory management, demand forecasting and transportation and logistics (Carrera & Mayorga 2008). AHP is a decision-making framework that is commonly used in multi-criteria decision-making (MCDM) to solve complex problems by structuring them into a hierarchy of goals, criteria, sub-criteria, and alternatives, this framework combines both, qualitative and quantitative approaches, resulting in an effective tool for decision-making (Saaty 2008).

Integrating AHP with sustainability metrics is a robust approach for decision-making in projects that are focused on sustainability, as it allows organizations to evaluate all alternatives by balancing the three main dimensions of sustainability: economic, environmental, and social (Kumar & Jain 2018). Researchers such as (Dweiri et al. 2019), studied the integration of the knowledge-based systems (KBS) into the supplier evaluation processes, which enhances decision-making by analyzing complex criteria, that leads to a more informed and effective supplier selection experience. One limitation is that there is no DSS that integrates supplier selection, supplier performance evaluation, and supplier performance benchmarking concepts in one model. Moreover, there is no generic DSS that can be employed by all organizations regardless of their business nature. Finally, there is no benchmarking tool for the supplier's performance against optimum performance.

Moreover, organizations face many challenges when trying to integrate sustainable practices into supplier selection and performance evaluation, such as; Lack of standardized criteria, which dismantles the sustainable procurement, as different organizations prioritize a variety of sustainability dimensions which causes the supplier evaluation process to be more complex (Touboulic & Walker 2020). The complexity of global supply chains, as a result to the limited visibility and differences in regional regulations, organizations fail to accurately assess the sustainable suppliers' criteria (Ghadge et al. 2020). Lack of supplier engagement, as any suppliers lack the motivation or the ability to include sustainable practices within their business unless provided with clear incentives or requested to do so by their customers (Li & Wu 2021).

Limited internal capabilities, organizations might lack the required expertise and capabilities to effectively implement and monitor sustainability across their supply chains, due to the above-mentioned reasons (Dubey et al. 2020). In conclusion, the development of a generic model holds significant importance across various industries. Its inclusive nature allows manufacturing companies to optimize the decision-making process by balancing conflicting criteria such as minimizing the costs while maximizing environmental sustainability. This model aids in selecting suppliers who offer the best balance between cost-efficiency and sustainability. Additionally, energy and renewable resources companies can leverage the proposed model to identify suppliers that minimize the procurement costs, maximize the components' quality, and comply with the environmental regulations.

3. Methodology

As seen from the literature reviewed, there is a gap in this area fill, the objective of this research is to identify and validate a set of key performance indicators for sustainable supplier selection based on expert consensus, then develop an integrated DSS based on FIS and benchmark the supplier's performance concerning other suppliers. The hybrid approach of combining FIS-AHP, knowledge-based systems leverage the strengths of each methodology while mitigating each of their individual limitations, resulting in a robust framework that can be used in complex decision-making in sustainable supplier selection.

The methodology used for developing and implementing the Integrated Decision Support System (DSS) for sustainable supplier selection, evaluation, and benchmarking can be broken down into three main phases: Development, Implementation and Benchmarking, *Figure 1*.

3.1 DSS Development Phase

The development phase encompasses multiple stages within; the identification, verification, and approval of criteria, in addition to the development of the DSS itself using Fuzzy Inference Systems (FIS) and the Analytic Hierarchy Process (AHP). The data collection process to build the model was performed based on phases.

First, the general criteria were identified after extensive literature research on all relevant criteria, then a binary survey was sent to experts to verify which of the criteria are significant enough to be considered when building the model, the expert would mark the criterion as significant or not based on their own judgement. Then the relevant criteria were identified if they showed at least 70% agreement rate from the responses. Once the finalized list of significant criteria was available, two more surveys were then sent to a smaller sample of experts, as it requires deep focus on the matter. The first survey is a pairwise comparison survey that will provide the weight given for each criterion, and the second survey will be to collect and build the fuzzy rules that will be incorporated into the model, as exposed in *Figure 1*.

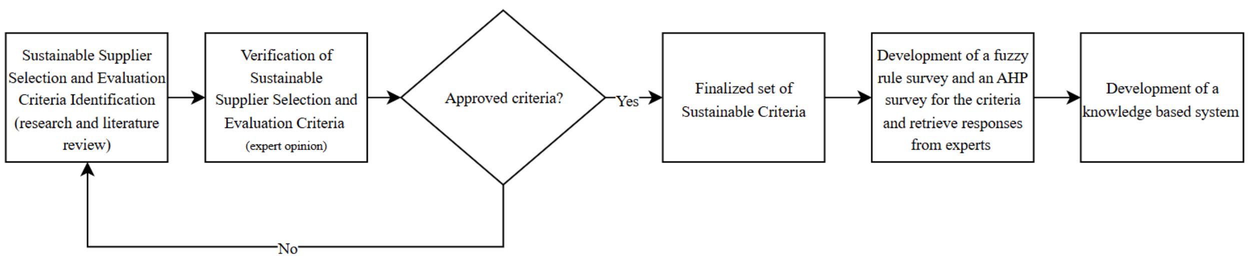

Figure 1. DSS development phase steps

After collecting all needed information, critical criteria, AHP weight for each criterion and the fuzzy rules to be embedded in the model, building the knowledge base system (KBS) was the next step. The software MATLAB was used to build the KBS using the information gathered, yielding in a supplier performance evaluation system.

3.2 DSS Implementation Phase

The DSS Implementation Phase can be best described by putting the developed (DSS) into practice. It can be achieved by collecting actual data from a company, applying the DSS for the supplier selection and performance evaluation processes, and ensuring that the system is functioning well for that company. The objective of this phase is to validate the theoretical framework and architecture developed in the previous phase and ensure their effective application in a practical setting. This could be achieved by integrating the model with the organization’s internal enterprise systems such as ERP. These systems can handle data entry, optimize the decisions and provide all the alternatives for the decision-makers.

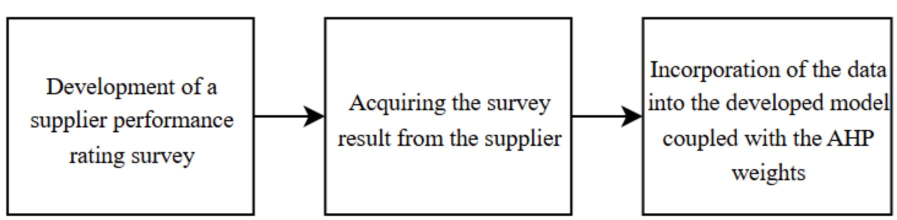

Figure 2. DSS implementation phase steps

The final phase is crucial for comparing supplier performance against optimal standards to identify potential areas for improvement. The benchmarking phase will involve the development of a Multi-Objective Linear Programming (MOLP) model that incorporates established benchmarks and compares the supplier's performance against these standards. These benchmarks would be mainly related to Environmental, social, and governance (ESG) rules and regulations, which include but are not limited to ISO certifications regarding environmental, social and governance standards. The implementation of this phase is planned for future work.

4. Results

4.1 Sustainable Supplier Selection and Evaluation Criteria Identification

After reviewing multiple papers on sustainable supplier selection criteria, it became evident that there is a consensus around the three main categories: economic, environmental and social criteria. Zimmer et al. (2016) reviewed the literature concerning the sustainable supplier selection, considering 143 sources before establishing that there are three main dimensions. The respective criteria for the three dimensions that fall under their umbrellas are as follows:

- Economic criteria: with Quality, flexibility, price, lead time, relationship, and technical capability as the main criteria that belong to the economic dimension.
- Environmental criteria: under it fall; resource consumption, eco-design, recycling, wastewater, energy consumption, re-use, air emissions, environmental code of conduct as main criteria.
- Social criteria: the final dimension represents the Involvement of stakeholders, staff training, social code of conduct, the rights of stakeholders, safety practices, annual number of accidents.

In real-life applications, each company uses a different set of criteria when choosing a supplier. Therefore, it is essential to establish a generic and inclusive set of criteria. After compiling all potential criteria for the model, a survey was distributed to industry experts to validate these criteria.

4.1.1 Verification of Sustainable Supplier Selection and Evaluation Criteria

After the initial stage of identifying the criteria, expert opinions were needed to verify which of the criteria were relevant and significant for use in the model. A survey was developed and published, consisting of 4 main sections, starting with demographics of the experts, followed by a section for each of the three dimensions. 40 expert opinions, who are involved in such matters, were recorded. The experts' filled positions related to supply chain, varied from supply chain directors in multinational companies that advocate sustainability to consultants that focus on sustainability.

4.1.2 Criteria Selection

The survey identified 70 criteria for supplier selection, of which 16 were chosen to be represented in the model based on the percentage of agreeability which represents the level of consensus among survey participants regarding the relevance of each criterion presented in the survey. This approach ensures that the model focuses on the most relevant factors by filtering out the less critical criteria, to create a more streamlined and accurate model. Moreover, it confirms that the criteria used in the model have a high level of experts' consensus, thereby enhancing the credibility of the model's outcomes.

Scholars, such as (Sandford & Hsu 2007), consider a 70-80% agreement response significant, as it serves as the benchmark for consensus when using the Delphi technique. More recent studies, such as the systematic review conducted by (Diamond et al. 2014), confirm this threshold. Their analysis of 100 Delphi studies identified that the definition of consensus was based on percent agreement, with 75% being the median threshold. By selecting the criteria that meet the 70-80% threshold, the model includes factors that most experts agree are relevant. This high level of agreement makes the data robust, reflecting a strong and representative consensus. Consequently, the model is based on credible inputs, enhancing the quality and reliability due to the expert-backed validity of the criteria.

From the 23 environmental criteria identified, 3 criteria exceeded the 70% agreement threshold suggested by (Sandford & Hsu 2007). Similarly, 3 out of the 21 social criteria, and 19 out of 26 economic criteria surpassed 70%. Given the substantial difference between the number of selected criteria between economic, environmental, and social dimensions, and to prevent the model from being focused on the economic dimension, the agreement threshold for the economic dimension was set at the higher end of the acceptable range at 80%. This adjustment resulted in ten sub-criteria for the economic criteria instead of 26, while the environmental and social dimensions were set at the lower end of the range at 70%, each totaling three sub-criteria. Table 1 provides the finalized criteria based on expert opinions. While the threshold for including economic criteria was raised to 80% (compared to 70% for environmental and social dimensions) to prevent overrepresentation of economic factors, it is possible that this adjustment could create a selection bias. Specifically, underrepresentation of environmental and social criteria may not only reflect expert disagreement in criteria but could also indicate lower familiarity with these dimensions among some of the respondents, especially those from cost-driven industries.

Table 1. Final Sub-Criteria according to experts' opinions

Dimension	Main category	Criteria	Discerption
Economic	EC1: Cost related criteria	EC 1.1 Product overall price	Cost of the product offered by the supplier including shipping and additional costs
	EC2: Quality of products related criteria	EC 2.1 Technical capability	Supplier's expertise in producing high product standards and maintaining them
		EC 2.2 Reputation	Supplier's standing in the market
	EC3: Repair services related criteria	EC 3.1 Reliability and responsiveness to claims and complaints	Consistency and promptness in providing assistance and resolving issues & the number of successfully addressed issues/defects
	EC4: Production facilities related criteria	EC 4.1 Equipment and supply availability	Access to necessary machines/ equipment/ tools now and in the future & Ability to meet demand now and in the future
	EC5: Service performance related criteria	EC 5.1 Delivery schedule & reliability	Delivery times across the year & the dependability of delivery service being on time
		EC 5.2 Transportation quality	Condition of products during and after the transport service
		EC 5.3 Supplier Reputation and history	Supplier's delivery market image & track record of past performance with said company and other companies
		EC5.4 Professionalism	Conduct and competence of the supplier
		EC 5.5 Average lead time	Time taken from order to delivery
Environmental	EN 1: Green image related criteria	EN 1.1 Market reputation	Overall market perception in terms of being eco-friendly
	EN 2: Pollution reduction related criteria	EN 2.1 Use of harmful materials	Employment of toxic substances
	EN 3: Green competencies related criteria	EN 3.1 Use of environmental-friendly materials	Utilization of eco-friendly materials
Social	S 1: Employment practices related criteria	S 1.1 Child labour	Illegal employment of children
		S 1.2 Disclosure of information	Transparency in sharing information with the public
		S 1.3 Adherence to law and regulations	Compliance with legal standards

4.2 Decision Support System Development

After identifying all the relevant criteria, two key steps were completed before building the model, which were building the AHP and the FIS rules. These steps were carried out through two separate surveys directed towards industry experts. Given the complexity of these surveys and the need for focused expert insights, the number of respondents was lower than in the initial survey.

Five experts were asked to complete both surveys, following the recommendation of (Skulmoski et al. 2007)), who suggested that between 5-7 expert opinions are sufficient when the focus is on deep expertise. It is important to note that the research approach employed in this study was inspired by the work of (Dweiri and Kablan 2006), who demonstrated the application of this methodology.

4.2.1 The AHP model

AHP was employed to determine the weights of the sustainable criteria determined in the first survey, which are essential for effective sustainable supplier selection. The AHP survey was sent to the experts to compare and rate each criterion with the other within each dimension. A scale from 1 to 9 on both ends (where 9 is extremely important and 1 is equally important) was used. After gathering the expert responses, the weight for each criterion was calculated as shown in Table 2.

Table 2. The AHP weights

Sub Criteria	Weight	Criteria	Weight	Dimension	Weight
Product overall price	0.333	Cost	0.541	Economic dimension	0.742
Technical capability	0.028	Quality of products	0.08		
Reputation	0.047				
Reliability and responsiveness to claims and complaints	0.074	Repair services	0.146		
Equipment and supply availability	0.052	Production facilities	0.085		
Delivery schedule & reliability	0.131	Service performance	0.148		
Transportation quality	0.047				
Supplier Reputation and history	0.079				
Professionalism	0.04				
Average lead time	0.17				
Market reputation	0.651	Green image related criteria	0.651	Environmental dimension	0.096
Use of harmful materials	0.203	Pollution reduction related criteria	0.203		
Use of environmental-friendly materials	0.146	Green competencies related criteria	0.146		
Child labour	0.17	Employment practices	1	Social dimension	0.162
Disclosure of information	0.429				
Adherence to law and regulations	0.401				

4.2.2 The FIS Model

In this phase, a third survey was distributed to the same experts with the objective of deriving the fuzzy rules for the MATLAB model to be used. These fuzzy rules will be used in a later stage to create the fuzzy decision-making system (FDMS), which enables it to handle the inherent uncertainty and subjectivity associated with sustainable supplier selection criteria. The aim of the survey was the formulation of the "if-then" rules, which define how different combinations of criterion ratings influence the overall supplier performance, which supports a flexible and adaptive decision support system.

After consolidating the answers from the AHP survey, which provided the AHP weights, and calculating the AHP weight for each sub-criterion, criterion and dimension, along with the fuzzy rules survey which provided the "if then' rules, a MATLAB model was created using the fuzzy logic designer module. The models created were Mamdani-type 1 models. Using the fuzzy model, the number of inputs is the number of sub criteria, criteria or dimensions and their wights, and the number of outputs, are the level above the used inputs.

4.3 Implementation

After calculating the AHP weights and finalizing the seven models needed; dimensional, economic criteria, environmental criteria, social criteria, economic sub-criteria, environmental sub-criteria and social sub-criteria, the model was ready the implementation. This involved piloting it within a company to assess its performance. A survey was sent to a supplier in the UAE which aimed to inquire how they would rate their own operations as a percentage point in terms of each sub-criterion.

Once the values were received, each MATLAB model was executed using the rule inference system function, incorporating the supplier's values along with the AHP weights calculated from the survey. The sub-criteria values provided by the supplier were used as inputs for the criteria models, which were then utilized in the dimensional model. The results from the aforementioned steps are presented in Figure 3, 4, 5, 6, 7, 8 and 9. Based on the results shown in the figures, the supplier evaluated in this model achieved an overall performance of 50.7% according to the criteria established earlier.

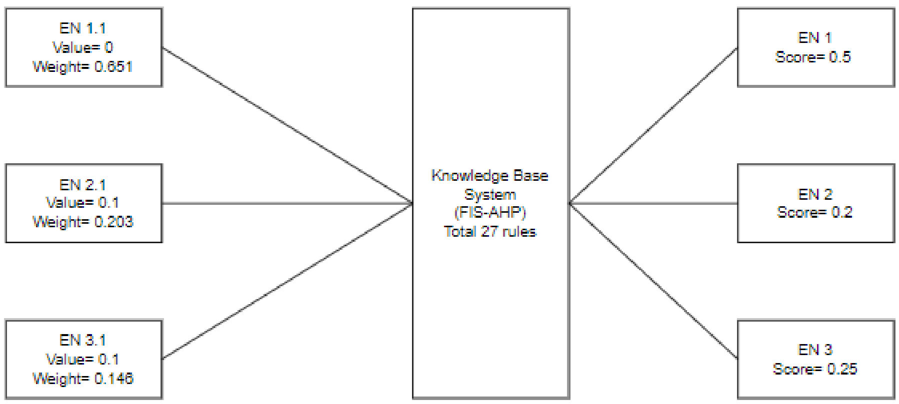

Figure 3. Environmental sub-criteria rules output

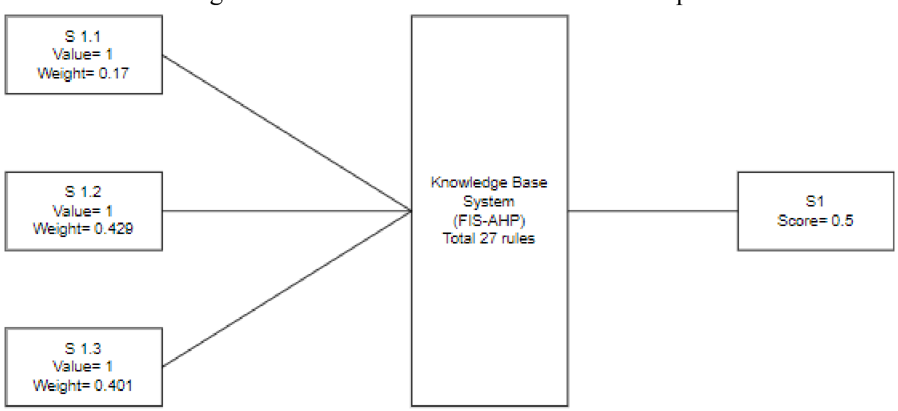

Figure 4. Social sub-criteria rules output

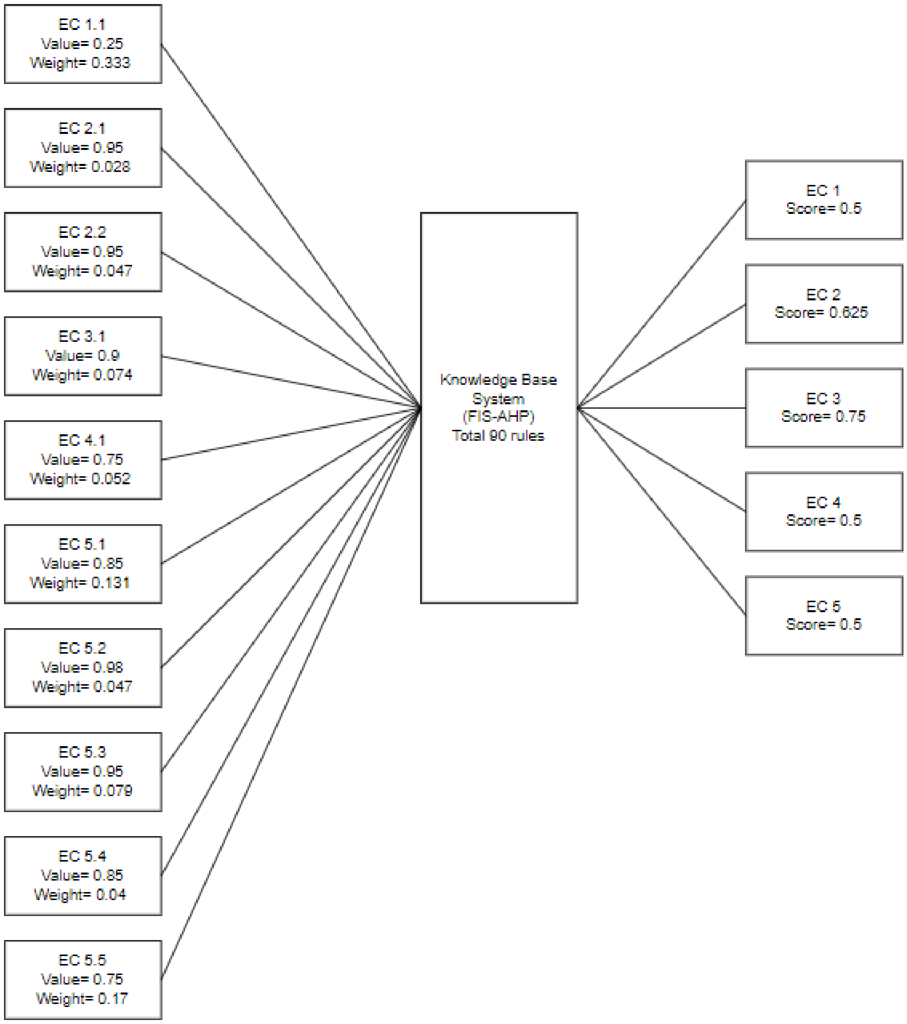

Figure 5. Economic sub-criteria rules output

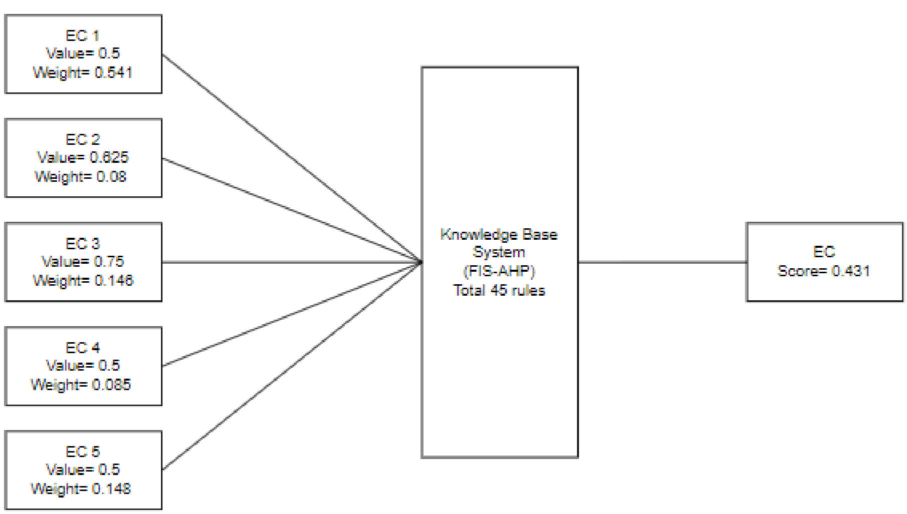

Figure 6. Economic criteria rules output

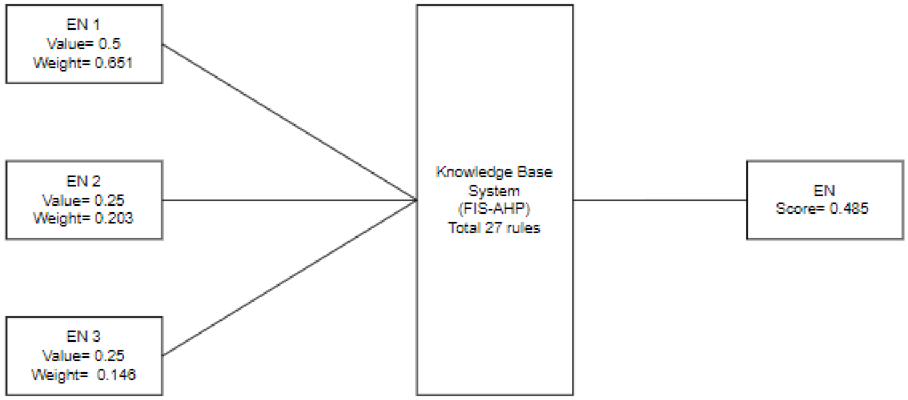

Figure 7. Environmental criteria rules output

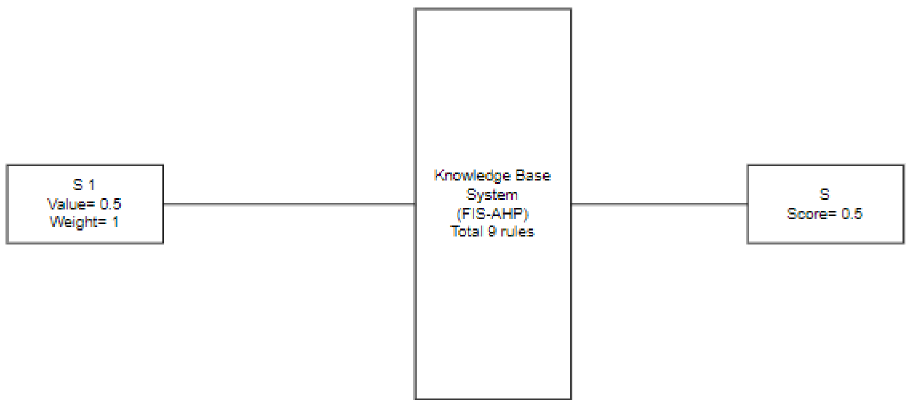

Figure 8. Social criteria rules output

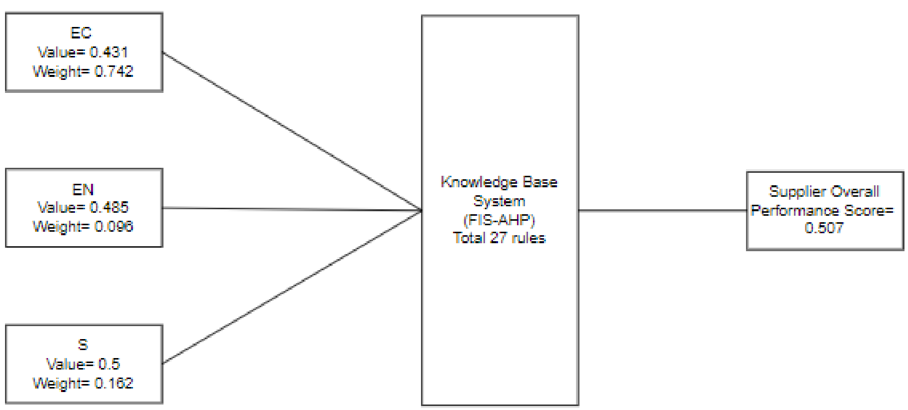

Figure 9. Dimensions rules output

The final step to complement the work done so far involves creating a benchmarking tool that leverages the knowledge base system and the data gathered from the case supplier. This tool would suggest improvements to their operations to enhance overall performance. This can be accomplished by building a multi-objective linear programming optimization model and solve it. An optimization software, such as CPLEX *OPL,* can be used to embed the critical criteria and their weights alongside the supplier's data, to identify necessary changes for improved performance. As this requires further research and analysis, it is planned for future work based on this paper.

5. Conclusion

The identification of sustainable supplier selection criteria established the three foundational pillars for the research which are economic, environmental, and social dimensions. The research confirmed that there is a strong consensus among experts, regarding the significance of the dimensions selected, that is to ensure the model's relevance. The verification phase provided the validity of the identified criteria through expert consensus, ensuring both credibility and robustness of the model to be designed.

To balance the economic, environmental, and social dimensions, 16 criteria from the initial 70 were selected systematically to ensure that the DSS is streamlined and would prioritize the most critical factors while maintaining the alignment with the expert opinions. The development phase confirmed the integration of AHP and FIS as effective tools for quantifying and addressing the complexity of supplier evaluation. This phase solidified the DSS as a versatile and adaptive model capable of handling the intricacies of sustainable decision-making in diverse supply chain contexts. Furthermore, developing the AHP model provided the precise weights for each criterion that facilitated an accurate hierarchical assessment of the supplier's performance, which were utilized when building the KBS.

The FIS model was designed to address the uncertainties and subjectivities that arise in the decision-making process by using expert-defined fuzzy rules. Coupling both models resulted in creating the KBS for this study, which would be used in the future by firms to help in their decision-making process when selecting suppliers. The implementation of the model demonstrated its practicality, as it was successful in evaluating a supplier's overall performance. By integrating real-world data form the case supplier with AHP weights and fuzzy rules, the system proved its effectiveness in creating relevant insights, establishing the way for an improved decision-making process and sustainability practices.

References

Ali, M. R., Nipu, S. M. A., & Khan, S. A. "A decision support system for classifying supplier selection criteria using machine learning and random forest approach. Decision Analytics Journal, 7, 100238," 2023.

Amindoust, A., Ahmed, S., Saghafinia, A., & Bahreininejad, A. "Sustainable supplier selection: A ranking model based on fuzzy inference system. Applied soft computing, 12(6), 1668-1677," 2012.

Awasthi, A., Chauhan, S. S., & Goyal, S. K. "A fuzzy multicriteria approach for evaluating environmental performance of suppliers. International journal of production economics, 126(2), 370-378," 2010.

Azimifard, A., Moosavirad, S. H., & Ariafar, S. "Selecting sustainable supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods. Resources Policy, 57, 30-44," 2018.

Bai, C., & Sarkis, J. Determining and applying sustainable supplier key performance indicators. Supply Chain Management: An International Journal, 19(3), 275-291, 2014.

Bai, C., & Sarkis, J. Green supplier development: analytical evaluation using rough set theory. Journal of cleaner production, 18(12), 1200-1210, 2010.

Carrera, D.A., Mayorga, R.V. Supply chain management: a modular Fuzzy Inference System approach in supplier selection for new product development. J Intell Manuf 19, 1–12, 2008.

Chen, Z., Ming, X., Zhou, T., & Chang, Y. "Sustainable supplier selection for smart supply chain considering internal and external uncertainty: An integrated rough-fuzzy approach. Applied Soft Computing, 87, 106004," 2020.

Çifçi, G., & Büyüközkan, G. "A fuzzy MCDM approach to evaluate green suppliers. International Journal of Computational Intelligence Systems, 4(5), 894-909," 2011.

Diamond, I. R., Grant, R. C., Feldman, B. M., Pencharz, P. B., Ling, S. C., Moore, A. M., & Wales, P. W. Defining consensus: a systematic review recommends methodologic criteria for reporting of Delphi studies. Journal of clinical epidemiology, 67, 2014.

Dou, Y., Zhu, Q., & Sarkis, J. "Evaluating green supplier development programs with a grey-analytical network process-based methodology. European Journal of Operational Research, 233(2), 420-431," 2014.

Dubey, R., Gunasekaran, A., Childe, S. J., & Wamba, S. F. "Building Internal Capabilities for Sustainable Supply Chain Management." International Journal of Production Economics, 2020.

Dweiri, F. T., & Kablan, M. M. Using fuzzy decision making for the evaluation of the project management internal efficiency. Decision Support Systems, 42(2), 712-726, 2006.

Ghadge, A., Er Kara, M., Moradlou, H., & Goswami, M. "Sustainability in Global Supply Chains: A Systematic Review and Research Agenda." Journal of Cleaner Production, 2020.

Gimenez, C., & Tachizawa, E. M. "Extending sustainability to suppliers: a systematic literature review. Supply Chain Management: an international journal, 17(5), 531-543," 2012.

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. "Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. Journal of cleaner production, 98, 66-83," 2015.

Gu, X., Han, J., Shen, Q. et al. Autonomous learning for fuzzy systems: a review. Artif Intell Rev 56, 7549–7595, 2023.

Hailiang, Z., Khokhar, M., Islam, T., & Sharma, A. "A model for green-resilient supplier selection: fuzzy best–worst multi-criteria decision-making method and its applications. Environmental Science and Pollution Research, 30(18), 54035-54058," 2023.

Hasan, M. M. J. D. U. A. S. &. N.-E.-A. M. "Resilient supplier selection in logistics 4.0 with heterogeneous information. Expert systems with applications, 139, 112799," 2020.

Hsu, C. C., & Sandford, B. A. "The Delphi technique: making sense of consensus. Practical assessment, research, and evaluation, 12(1)," 2007.

Jain, N., & Singh, A. R. "Sustainable supplier selection under must-be criteria through Fuzzy inference system. Journal of Cleaner Production, 248, 119275," 2020.

K. Shaw, R. Shankar, S. Yadav and L. Thakur. ""Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain," Expert Systems with Applications, vol. 39, no. 9, pp. 8182-8192," 2012.

Kannan, D., Govindan, K., & Rajendran, S. "Fuzzy axiomatic design approach based green supplier selection: a case study from Singapore. Journal of cleaner production, 96, 194-208," 2015.

Khan, Chaabane, and Dweiri. "A knowledge-based system for overall supply chain performance evaluation: a multi-criteria decision-making approach", 2019.

Kumar, S., & Jain, S. "Sustainability assessment in the automotive sector: An integrated AHP and fuzzy approach," 2018.

Laith, W., Hamood, A., & Al-Salih, R. A computational approach for fuzzy multi-criteria decision making models, 2023.

Li, Y., & Wu, X. "Engaging Suppliers in Sustainable Supply Chain Practices: Challenges and Solutions," 2021.

Liou, J. J., Chang, M. H., Lo, H. W., & Hsu, M. H. "Application of an MCDM model with data mining techniques for green supplier evaluation and selection. Applied Soft Computing, 109, 107534," 2021.

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. "An integrated framework for sustainable supplier selection and evaluation in supply chains. Journal of cleaner production, 140, 1686-1698," 2017.

Ma, Q., & Li, H. "A decision support system for supplier quality evaluation based on MCDM-aggregation and machine learning. Expert Systems with Applications, 242, 122746," 2024.

Mafakheri, F., Breton, M., & Ghoniem, A. "Supplier selection-order allocation: A two-stage multiple criteria dynamic programming approach. International Journal of Production Economics, 132(1), 52-57," 2011.

Memari, A., Dargi, A., Jokar, M. R. A., Ahmad, R., & Rahim, A. R. A. "Sustainable supplier selection: A multi-criteria intuitionistic fuzzy TOPSIS method. Journal of manufacturing systems, 50, 9-24," 2019.

P. Muralidhar, K. Ravindranath, and V. Srihari. ""Evaluation of green supply chain management strategies using fuzzy AHP and TOPSIS," IOSR Journal of Engineering, vol. 2, no. 4, pp. 824-830," 2012.

Pamucar, D., Torkayesh, A. E., & Biswas, S. "Supplier selection in healthcare supply chain management during the COVID-19 pandemic: a novel fuzzy rough decision-making approach. Annals of Operations Research, 328(1), 977-1019," 2023.

Rao, P. ""Greening the supply chain: a new initiative in South East Asia," International Journal of Operations & Production Management, vol. 22, no. 6, pp. 632-655," 2002.

Runtuk, J. K. N. P. K. &. O. S. Y. "Challenges and Solutions in Working with Green Suppliers: Perspective from a Manufacturing Industry. Sustainability, 16(20), 8744," 2024.

S. Gnanasekaran, S. Velappan, and P. Manimaran. ""An integrated model for supplier selection using fuzzy analytical hierarchy process: a steel plant case study," International Journal of Procurement Management, vol. 3, no. 3, pp. 292-315," 2010.

Saaty, T. L. Decision making with the analytic hierarchy process. International Journal of Services Sciences, 1(1), 83–98, 2008.

Saaty, T. L. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. New York: McGraw-Hill, 1980.

Saradara, S. M. K. M. M. A. R. A. &. Q. R. "On the path towards sustainable construc-tion—the case of the United Arab Emirates: a review. Sustainability, 15(19), 14652," 2023.

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Skulmoski, G. J., Hartman, F. T., & Krahn, J. "The Delphi method for graduate research. Journal of Information Technology Education: Research, 6(1), 1-21," 2007.

Thornton, L. M., Autry, C. W., Gligor, D. M., & Brik, A. B. "Does socially responsible supplier selection pay off for customer firms? A cross-cultural comparison. Journal of Supply Chain Management, 49(3), 66-89," 2013.

Touboulic, A., & Walker, H. "Overcoming the Barriers to Sustainable Procurement in Supply Chains ." Journal of Purchasing and Supply Management, 2020.

Weele, A. Van. " Purchasing and supply chain management: Analysis, strategy, planning and practice, Cengage Learning EMEA," 2010.

Y. Beikkhakhian, M. Javanmardi, M. Karbasian and B. Khayambashi,. ""The application of ISM model in evaluating agile suppliers selection criteria and ranking suppliers using fuzzy TOPSIS-AHP methods," Expert Systems with Applications, vol. 42, no. 15-16, pp.," 2015.

Zhu, Q. L. A. L. Z. Y. Y. &. M. J. "Sustainable supplier selection and evaluation for the effective supply chain management system. Systems, 10(5), 166," 2022.

Zimmer, K., Fröhling, M., & Schultmann, F. Sustainable supplier management–a review of models supporting sustainable supplier selection, monitoring and development. International journal of production research, 54(5), 1412-1442, 2016.

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Saleem Ghannam is an experienced Strategy and Management Consultant working with various governmental entities in the Middle East and Gulf Countries, he honed his experience in the region and comes from a background in Business Process Management, Digital Transformation, and Supply Chain & Logistics. Saleem holds a Master's Degree in Engineering Management from Rochester Institute of Technology in Dubai and a Bachelor's degree in Industrial Engineering from the German Jordanian University in Jordan.

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