Evaluating supply chain sustainability and agility using fuzzy logic approach: a case in Indonesian agroindustry

Sawarni Hasibuan[1*], *Ika Yunita*[2], *Iskandar* Zulkarnaen[3]

[1]Industrial Engineering Department, Universitas Mercu Buana, South Meruya, Indonesia.
[2]Industrial Engineering Master Alumni, Universitas Mercu Buana, South Meruya, Indonesia.
[3]Industrial Engineering Program, Universitas Bhayangkara Jakarta Raya, Bekasi, Indonesia

Abstract. Agility and sustainability are critical, complementary concepts that enable businesses to navigate increasing uncertainties and complexities, as highlighted by the COVID-19 pandemic. In agroindustry, business processes face significant challenges in adapting to such unpredictable conditions, requiring robust strategies to enhance agility and sustainability. This study adopts a fuzzy logic approach to address ambiguities and uncertainties inherent in traditional performance assessments. A sustainability-agility evaluation framework was developed for the chicken meat industry, calculating FSCSAI values of 0.58, 0.72, and 0.86, which classify the industry as "very sustainable and agile (VSA)" based on Euclidean distance calculations. Additionally, challenges such as "using agile enabling technology" and "market response and sense" were identified, and actionable recommendations were proposed. This study makes two significant contributions: (1) demonstrating the applicability of the fuzzy logic method for assessing sustainability-agility in agroindustry and (2) providing insights for companies and policymakers to address critical challenges and implement targeted improvements. Despite its contributions, the study acknowledges limitations related to the reliance on decision-maker perceptions and emphasizes the importance of expert involvement. The findings offer a systematic framework for evaluating sustainability-agility indices, with practical applications for the chicken meat sector and beyond.

1. Introduction

Covid-19 has greatly affected all fields, including health, social and economic. The COVID-19 pandemic has raised several challenges to the sustainability of the poultry industry, including disruptions in the supply chain, oversupply, animal welfare, and human welfare [1], [2]. Long before COVID-19, the company faced tough business competition due to the entry of many competitors in the global market. However, with Covid-19, the business situation has become more uncertain. For businesses to survive in situations of uncertainty,

* Corresponding author: sawarni02@mercubuana.ac.id

agility is needed [3], [4]. Agility is a key performance measure of corporate practice that needs to be carefully measured to determine a significant improvement in an organization's competitive ability [5]. In a competitive environment characterized by high turbulence and harsh shocks, such as the current state of the COVID-19 environment, strategic agility can offer a viable way to adapt and respond to opportunities through the existing situation by looking at changes in consumer sentiment due to COVID-19 [3].

In the supply chain concept, these changes and challenges force supply chains to adopt new strategies to improve their ability to respond quickly and cost-effectively to unexpected changes in the market [6]. For an organization to be competitive and viable, it must be able to integrate agile and sustainable systems [5]. Sustainability is the company's responsibility to create, protect, and grow long-term environmental, social, and economic value for all stakeholders involved in bringing products or services to consumers. Strategic agility describes how an organization's senior management can demonstrate the capacity to adapt, be flexible, and creative. To forecast unexpected shocks inside and outside the business environment in which it operates and respond to them proactively, quickly, and effectively to transform these threats into opportunities [7]. By combining strategic agility with sustainability, organizations will be able to meet customer needs by appropriately using resources. To formulate a new strategy is necessary to assess the current supply chain sustainability and agility index as a consideration in making policies or strategies. This study proposes an assessment of the supply chain sustainability-agility index using the fuzzy concept.

The concept of agility in sustainability can increase flexibility and responsiveness to change, enable learning and provide benefits by providing sustainable results for the company [8]. There is a shift from functional to cross-functional within agile, from efficiency to effectiveness and flexibility, and from static to responsive with a primary customer orientation [9]. Agility has four characteristics: create a future, anticipate opportunity, adapt quickly, and always learn [10]. It means that agility has the same goal as sustainability in creating a company/organization to be sustainable.

The fuzzy concept is used in this study because the traditional assessment of sustainability and agility performance still contains ambiguity and uncertainty factors. Using the fuzzy concept, the assessor can use linguistic terms to assess indicators in natural language expressions, and each linguistic term can be associated with a membership function [10]. In the fuzzy approach, the ranking performance and importance weights of the agility and sustainability variables assessed by experts are expressed in linguistic terms. Then the appropriate fuzzy numbers are used to present linguistic values, and simple fuzzy arithmetic operations that will be used to synthesize these fuzzy numbers are fuzzy-supply chain-sustainability-agility-index (FSCSAI). The resulting FSCSAI will provide an overview of the organization's overall performance.

Several previous studies in assessing using fuzzy numbers include [11]–[13], research related to fuzzy index agility, among others [14]–[16], whereas [17]–[19] was doing research on the fuzzy index sustainability. Until now, there has been no research that integrates the assessment of the fuzzy sustainability index with agility. And this is a novelty in this article.

2. Method

This research was conducted in a case study of the integrated chicken meat industry because the chicken meat industry is one of the important sectors in the Indonesian economy and the main producer of animal protein sources that are in great demand. In addition, there is not much literature that assesses agility for the agroindustry sector. Generally, the assessment is carried out only to assess the sustainability index. The following are the steps in assessing the agility and sustainability index using a fuzzy logic approach:

2.1 Selecting criteria for assessment

The dimensions used for agility assessment use the supply chain agility concept [20], and the assessment of sustainability dimensions is taken from FAO [21]. And a total of 24 indicators for each dimension were taken from the literature study, as shown in Table 1.

2.2Determination linguistic scale for assessment

After identifying the dimensions and indicators, the agility and sustainability rating scale is limited by using fuzzy logic through linguistic and translation assessments [15], as shown in Table 2.

2.3 Determination of FSCSAI

The FSCSAI represents the sustainability and agility index of the poultry supply chain as a whole. FSCSAI is determined by two levels of calculation using the fuzzy logic method. Before calculating the FSCSAI, determine the sustainability agility performance rating for each dimension, where each dimension has several indicators. If *Rij* and *Wij* each representing a rank (*R)* and weight (*W)* at *i* dimension (*i= 1, 2, …, n)* and *j* indicator (*j= 1, 2, …, m)*. Then, the performance rating of each dimension can be calculated by the equation (1).

$$Rating\ for\ SA_i = \sum_{j=1}^{m} \left(R_{ij} x W_{ij}\right) / \sum_{j=1}^{m} W_{ij} \tag{1}$$

Because, *Ri* and *Wi*, each represents the performance rating and weights on each dimension; FSCSAI as a whole can be calculated by the equation (2):

$$FSCSAI = \sum_{I=1}^{n} \left(R_i x W_i\right) / \sum_{i=1}^{n} W_i \tag{2}$$

2.4 Matching the FSCSAI with linguistic terms to identify supply chain agility sustainability level

After knowing the value of FSCSAI, the level of supply chain agility sustainability (L) can be determined by comparing FCSAI with the appropriate linguistic terms in L using Euclidean distance. The linguistic variable for L is Extremely Sustainable and Agile [ESA (0.70, 0.85, 1.00)], Very Sustainable and Agile [VSA (0.55, 0.70, 0.85)], Sustainable and Agile [SA (0.35, 0.5, 0.65)], Fairly Sustainable and Agile [FSA (0.15, 0.30, 0.45)], Slowly Sustainable and Agile [SSA (0.00, 0.15, 0.30)]. Euclidean distance (D) between FSCAI and FSCAL can be calculated by the equation (3).

$$D(FSCSAI, L) = \left\{ \sum_{x \in p} \left[f_{FSCSAI}(x) - f_{FSCSAI}(x) \right]^2 \right\}^{\frac{1}{2}} \tag{3}$$

Table 1 Indicators for evaluating agility and sustainability

Dimension (SA)	i	Indicators	j
Process integration	1	Supply chain operations flexibility [5], [15], [20], [22], [23]	1
		Production capacity flexibility [5], [15], [20], [22]–[24]	2
		Product development flexibility [15], [20], [24], [25]	3
		Integrated processes [22], [26]	4
Information integration	2	Information flow within the supply chain [5], [15], [23], [25], [27]	1
		Use of agile-enabling technologies [5], [20], [22], [24]–[27]	2
Collaborative relationship	3	Management competence [15], [22], [27]	1
		Competence of employees [22], [27]	2
		Just-in-time variable [22]	3
Customer sensitivity	4	Market response and senses [5], [15], [23], [25]	1
		Customer satisfaction [15], [22], [23], [25]	2
Economic resilience	5	Cost [5], [26], [28], [29]	1
		Quality [5], [21], [28]–[30]	2
Environmental integrity	6	Emissions [21], [26], [28], [30], [31]	1
		Water [5], [21], [28], [30], [31]	2
		Air [5], [21], [28], [30], [31]	3
		Energy [5], [21], [26], [28]	4
		Waste [21], [28], [31]	5
		Renewable resources [24]–[26]	6
Social well-being	7	Animal welfare [21]	3
		Employee [21], [31]	4
		Safety and health [5], [21], [28], [30], [31]	5
Good governance	8	Management commitment [29], [32]	1
		Corporate ethics [21]	2

Table 2 Fuzzy number for approximating linguistic variable

Performance Rating (R)		Importance Weight (W)	
Linguistic variable	**Fuzzy Number**	**Linguistic variable**	**Fuzzy Number**
Worst (W)	(0.00, 0.05, 0.15)	Very Low (VL)	(0.00, 0.05, 0.15)
Very Poor (VP)	(0.10, 0.20, 0.30)	Low (L)	(0.10, 0.20, 0.30)
Poor (P)	(0.20, 0.35, 0.50)	Fairly Low (FL)	(0.20, 0.35, 0.50)
Fair (F)	(0.30, 0.50, 0.70)	Average (M)	(0.30, 0.50, 0.70)
Good (G)	(0.50, 0.65, 0.80)	Fairly High (FH)	(0.50, 0.65, 0.80)
Very Good (VG)	(0.70, 0.80, 0.90)	High (H)	(0.70, 0.80, 0.90)
Excellent (E)	(0.85, 0.95, 1.00)	Very High (VH)	(0.85, 0.95, 1.00)

2.5 Identification the weak factors using the fuzzy performance importance index (FPII)

After assessing the level of supply chain sustainability-agility, the weakness indicators should be identified using FPII [33]. FPII represents effects that will contribute to the level of sustainability and agility. The lower variable of FPII, then, the lower the degree of contribution of that variable. FPII can be calculated by the equation (4).

$$FPII_{ij} = W_{ij}^{'} \; x \; R_{ij} \qquad (4)$$

Where $W'_{ij} = [(1, 1, 1) - W_{ij}]$. Wij is a fuzzy number for the weights on the indicator ij.

All FPII must be ranked because fuzzy numbers do not always produce a fully ordered set like real numbers [17]. So, the ranking of fuzzy numbers is based on the centroid method for the membership function (u, m, l), as given in equation (5). Where u, m and l are the lower, middle and upper numbers of the triangular fuzzy number, respectively.

$$Ranking\ score = (u + 4m + l)/6 \quad (5)$$

3. Result and Discussion

Research on measuring the supply chain sustainability-agility index has been carried out at the chicken meat company in Central Java, Indonesia. This chicken meat company has an integrated business model ranging from feed, and livestock, to chicken slaughterhouses.

3.1 The performance ratings and importance weights of poultry supply chain sustainability agility indicators

Based on the company's condition, the experts evaluate the comprehensive performance rating and the importance of the indicators (*Rij* and *Wij*) and the dimensional weights (*Wi*) using linguistic variables. The results are shown in Table 3.

Table 3 Supply chain sustainability and agility ratings and weight

Dimension	Indicators	*Wi*	*Wij*	*Rij*
Process integration (SA_1)	Supply chain operations flexibility (SA_{11})	H	H	G
	Production capacity flexibility (SA_{12})		H	G
	Product development flexibility (SA_{13})		FH	F
	Integrated processes (SA_{14})		H	VG
Information integration (SA_2)	Information flow within the supply chain (SA_{21})	FH	FH	G
	Use of agile-enabling technologies (SA_{22})		H	F
Collaborative relationship (SA_3)	Management competence (SA_{31})	FH	FH	G
	Competence of employees (SA_{32})		FH	VG
	Just-in-time variable (SA_{33})		H	G
Customer sensitivity (SA_4)	Market response and senses (SA_{41})	H	H	F
	Customer satisfaction (SA_{42})		H	VG
Economic resilience (SA_5)	Cost (SA_{51})	H	H	VG
	Quality (SA_{52})		H	VG
Environmental integrity (SA_6)	Emissions (SA_{61})	H	H	VG
	Water (SA_{62})		H	VG
	Air (SA_{63})		FH	VG
	Energy (SA_{64})		FH	VG
	Waste (SA_{65})		H	VG
	Renewable resources (SA_{66})		H	VG
Social well-being (SA_7)	Animal welfare (SA_{71})	FH	H	VG
	Employee (SA_{72})		FH	VG
	Safety and health (SA_{73})		H	VG
Good governance (SA_8)	Management commitment (SA_{81})	FH	H	G
	Corporate ethics (SA_{82})		FH	VG

3.2 Approximation of the linguistic terms by fuzzy number

Based on Table II, the results of the evaluation of the linguistic variables from the experts were converted into fuzzy numbers. These fuzzy numbers are shown in Table 4.

3.3 Aggregate fuzzy ratings with fuzzy weights to obtain an FSCSAI

Before calculating the FSCSAI, calculations were made for each dimension's sustainability and agility performance ratings. The performance rating of each dimension can be calculated by equation (1). For example, the result of calculating the performance rating for the dimension 'Process integration (SA1)' using equation (1) is (0.52, 0.66, 0.80). Similarly, to obtain performance ratings for other dimensions of the poultry industry supply chain sustainability-agility (Table 5). After getting the performance ratings from dimensions. The FSCSAI is calculated by equation (2), with the results of the FSCSAI being (0.58, 0.72, 0.86).

Table 4 Linguistic variables approximated by fuzzy number

Dimension	Indicators	*Wi*	*Wij*	*Rij*
SA_1	SA_{11}	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)	(0.50, 0.65, 0.80)
	SA_{12}		(0.70, 0.80, 0.90)	(0.50, 0.65, 0.80)
	SA_{13}		(0.50, 0.65, 0.80)	(0.30, 0.50, 0.70)
	SA_{14}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
SA_2	SA_{21}	(0.50, 0.65, 0.80)	(0.50, 0.65, 0.80)	(0.50, 0.65, 0.80)
	SA_{22}		(0.70, 0.80, 0.90)	(0.30, 0.50, 0.70)
SA_3	SA_{31}	(0.50, 0.65, 0.80)	(0.50, 0.65, 0.80)	(0.50, 0.65, 0.80)
	SA_{32}		(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)
	SA_{33}		(0.70, 0.80, 0.90)	(0.50, 0.65, 0.80)
SA_4	SA_{41}	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)	(0.30, 0.50, 0.70)
	SA_{42}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
SA_5	SA_{51}	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
	SA_{52}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
SA_6	SA_{61}	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
	SA_{62}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
	SA_{63}		(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)
	SA_{64}		(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)
	SA_{65}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
	SA_{66}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
SA_7	SA_{71}	(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
	SA_{72}		(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)
	SA_{73}		(0.70, 0.80, 0.90)	(0.70, 0.80, 0.90)
SA_8	SA_{81}	(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)	(0.50, 0.65, 0.80)
	SA_{82}		(0.50, 0.65, 0.80)	(0.70, 0.80, 0.90)

Table 5 Linguistic variables by fuzzy number

Dimension	***Rij***
SA_1	(0.50, 0.65, 0.80)
SA_2	(0.50, 0.65, 0.80)
SA_3	(0.50, 0.65, 0.80)
SA_4	(0.30, 0.50, 0.70)
SA_5	(0.70, 0.80, 0.90)
SA_6	(0.70, 0.80, 0.90)
SA_7	(0.70, 0.80, 0.90)
SA_8	(0.50, 0.65, 0.80)

The obtained FSCSAI is tested for consistency by first changing the fuzzy scale into a single value by defuzzification of each performance rating and weight. Defuzzification is a process of converting the fuzzy output to a single/crisp feasible output. In this study, the crisp value used the centroid method approach. The result of the FSCSAI calculation using the crisp approach is 0.71. These results indicate that the results of fuzzy and crisp approaches are consistent.

3.4 Matching the FSCSAI with an appropriate level

Euclidean distance (D) from FSCSAI to each member in the set L is calculated using equation (3). The value of D(FSCAI, L) is shown in Table 6. It can be seen from Table 6, that the FSCSAI for the company's supply chain in the case study was identified as "Very Sustainable and Agile (VSA)" with a value of D(FSCSAI, L)=0.04. The position of the linguistic FSCSAI and the membership function corresponding to L is shown in Fig 1.

Table 6 The Euclidean distance from FSCAI to each member in set L

	D				
	ESA	***VSA***	***SA***	***FSA***	***SSA***
FSCSAI	0.23	0.04	0.38	0.73	0.99

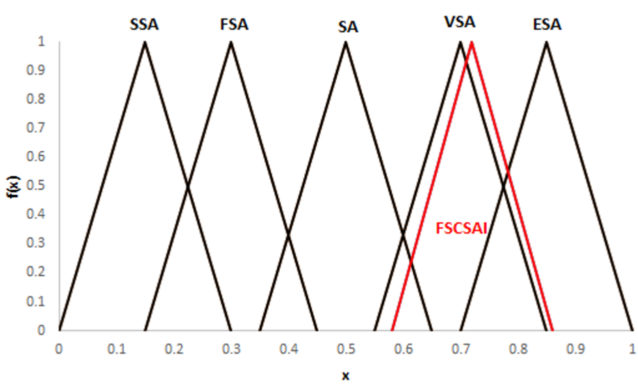

Fig. 1. Linguistic levels to match FSCSAI

3.5 Identification and analysis of the principles challenges

By adjusting the linguistic variables by looking at the minimum D, the level of sustainability and agility in this case study company was identified as 'very sustainable and agile'. Next is to identify the challenges in supply chain sustainability agility. Using equation (4), the FPII of each variable can be calculated. In equation (5), the FPII is ranked using a value of 0.20 as the lower threshold to determine the critical challenges that need to be improved. Tthere are 2 indicators that pose challenges in supply chain sustainability-agility in the poultry industry: ' use agile enabling technology' and 'market response and sense.'

The COVID-19 pandemic has made the use of agile technology important, starting from managing and processing resources to becoming products to the delivery process [34]. The use of agile technology can answer the issue of worker vulnerability during the COVID-19 pandemic to the safety and health of workers [2]. The use of agile technology in companies can assist decision-makers regarding the value proposition and help companies strengthen bonds with customers and adopt more effective policies and practices [35]. Even companies that use technology can better survive during the Covid-19 pandemic than companies that don't use technology [36].

Based on the literature review results [36], there was a change in consumer behavior due to the COVID-19 pandemic in the case of the tourism, retail, and education sectors. Measurement of supply chain agility at dairy production companies in Saudi Arabia suggests that customer and market indicators are important indicators that are the focus of management during the COVID-19 pandemic and cost and process indicators [15]. The existence of social distancing and work-from-home policies provides new market opportunities as long as the industry is observant in seeing opportunities by having customer sensitivity to create innovations. New market opportunities can appear suddenly, and businesses must respond immediately to support a circular economy [37]. Customer sensitivity is included in the strategy of marketing agility to show the potential of the existing market to support a developing economy and a more sustainable business [38].

After identifying the challenging variables, several suitable strategies have been proposed, including:

1. The location of distribution channels is as close as possible to consumers, where the company can place frozen carcass stalls in traditional markets.
2. Change in sales and payment systems from face-to-face to online.
3. Design a technology information system along the supply chain.
4. Increase the use of technology in the production process.

4. Conclusions

Using a fuzzy logic approach to analyze the chicken meat industry, the results indicate that the industry is categorized as very sustainable and agile. However, challenges persist, especially in the adoption of agile enabling technologies and enhancing market responsiveness. Tackling these issues is essential for sustaining and advancing both sustainability and agility in agro-industry operations.

The study emphasizes the effectiveness of fuzzy logic in overcoming the ambiguities inherent in performance evaluations, proposing a new framework to assess sustainability-agility indices. The findings offer valuable guidance for businesses and policymakers, providing insight into existing gaps and suggesting strategies to improve the integration of sustainability and agility. Despite its contributions, the study recognizes limitations, particularly the dependence on decision-makers' perceptions when defining fuzzy logic membership functions. To enhance the reliability and applicability of these evaluations, strategic decision-makers must collaborate with experts, ensuring a comprehensive assessment that considers economic, social, resource, and environmental factors.

This research provides a structured approach to evaluating sustainability-agility performance, with practical implications for the chicken meat industry and the broader agro-industry sector. It serves as a foundational resource for future research and decision-making, supporting the development of resilient and adaptable strategies in an increasingly unpredictable business landscape.

Reference

[1] I. Yunita and S. Hasibuan, "The sustainability challenges of the poultry industry during pandemic Covid-19," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 733, no. 1, p. 012007, 2021.
[2] E. M. de Olde, "Sustainability challenges and innovations in the Dutch egg sector," *J. Clean. Prod.*, vol. 258, 2020.
[3] W. Elali, "The Importance of Strategic Agility to Business Survival During Corona Crisis and Beyond," *Int. J. Bus. Ethics Gov.*, no. 1, pp. 1–8, 2021.
[4] M. H. Alkurdi and D. Vázquez-Bustelo, "A Systematic Literature Review Protocol for the analysis of practices, measurement instruments and contextual factors inherent to Supply Chain Agility," *WPOM-Working Pap. Oper. Manag.*, vol. 13, no. 1, pp. 1–34, 2022.
[5] A. K. Singh and S. Vinodh, "Modeling and Performance Evaluation of Agility Coupled with Sustainability for Business Planning," *J. Manag. Dev.*, vol. 36, pp. 1–5, 2017.
[6] H. Carvalho, S. G. Azevedo, and V. Cruz-Machado, "Agile and resilient approaches to supply chain management: Influence on performance and competitiveness," *Logist. Res.*, vol. 4, no. 1–2, pp. 49–62, 2012.
[7] S. Denning, "What Is Strategic Agility?" [Online]. Available: https://www.forbes.com/sites/stevedenning/2018/01/28/what-is-strategic-agility/?sh=10d470a2a0b1. [Accessed: 12-Apr-2022].
[8] V. Obradovićl, M. Todorović, and S. Bushuyev, "Sustainability and Agility in Project Management: Contradictory or Complementary?," in *2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT 2018 - Proceedings*, 2018, vol. 2, pp. 160–164.
[9] D. Naslund and R. Kale, "Is agile the latest management fad? A review of success factors of agile transformations," *Int. J. Qual. Serv. Sci.*, vol. 12, no. 4, pp. 489–504, 2020.
[10] D. Ulrich and A. Yeung, "Agility: the new response to dynamic change," *Strateg. HR Rev.*, vol. 18, no. 4, pp. 161–167, 2019.
[11] W. A. Teniwut, C. L. Hasyim, and D. Arifin, "A Web-based DSS: Information System for Sustainable Fisheries Supply Chain in Coastal Communities of Small Islands Indonesia," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 11, no. 3, pp. 1186–1192, 2021.
[12] I. A. U. Alnaqash and S. J. A. Sahibb, "M.L. Estimator for Fuzzy Survival Function to the Kidney Failure Patients," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 11, no. 2, pp. 516–524, 2021.
[13] T. A. T. Mohd, M. K. Hassan, I. Aris, C. S. Azura, and B. S. K. K. Ibrahim, "Application of fuzzy logic in multi-mode driving for a battery electric vehicle energy management," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 7, no. 1, pp. 284–290, 2017.
[14] A. Al-Zabidi, A. U. Rehman, and M. Alkahtani, "An approach to assess sustainable supply chain agility for a manufacturing organization," *Sustain.*, vol. 13, no. 4, pp. 1–19, 2021.
[15] A. Ur Rehman, A. Al-Zabidi, M. AlKahtani, U. Umer, and Y. S. Usmani, "Assessment of supply chain agility to foster sustainability: Fuzzy-DSS for a saudi manufacturing organization," *Processes*, vol. 8, no. 5, pp. 1–19, 2020.

[16] C. V. Pooja and C. G. Sreenivasa, "Quantification of agility level using fuzzy logic approach: A case study in a battery manufacturing organisation," *Int. J. Serv. Oper. Manag.*, vol. 26, no. 4, pp. 428–442, 2017.
[17] H. Li, Q. Xia, L. Wang, and Y. Ma, "Sustainability assessment of urban water environment treatment public-private partnership projects using fuzzy logic," *J. Eng. Des. Technol.*, vol. 18, no. 5, pp. 1251–1267, 2020.
[18] I. Djekic, N. Smigic, R. Glavan, J. Miocinovic, and I. Tomasevic, "Transportation sustainability index in dairy industry – Fuzzy logic approach," *J. Clean. Prod.*, vol. 180, pp. 107–115, 2018.
[19] S. Hendiani and M. Bagherpour, "Developing an integrated index to assess social sustainability in construction industry using fuzzy logic," *J. Clean. Prod.*, vol. 230, pp. 647–662, 2019.
[20] M. Motadel, A. Toloie-Eshlaghy, and D. Halvachi-Zadeh, "Assessment of supply chain agility in the automotive industry of Tehran," *Eur. J. Sci. Res.*, vol. 61, no. 2, pp. 210–229, 2011.
[21] FAO, *Sustainability Assessment of Food and Agricultural System: indicators*. 2013.
[22] H. Dastyar, A. Mohammadi, and M. A. Mohamadlou, "Designing a Model for Supply Chain Agility (SCA) Indexes Using Interpretive Structural Modeling (ISM)," in *Dynamics in Logistics*, M. Freitag, H. Kotzab, and J. Pannek, Eds. Springer, Cham, 2018, pp. 58–66.
[23] R. Dubey, A. Gunasekaran, and S. J. Childe, "Big data analytics capability in supply chain agility: The moderating effect of organizational flexibility," *Manag. Decis.*, vol. 57, no. 8, pp. 2092–2112, 2019.
[24] P. Kumar, R. K. Singh, and R. Kumar, "An integrated framework of interpretive structural modeling and graph theory matrix approach to fix the agility index of an automobile manufacturing organization," *Int. J. Syst. Assur. Eng. Manag.*, vol. 8, pp. 342–352, 2017.
[25] S. Aisyah, C. Jaqin, and H. H. Purba, "Identification of Lean, Agile, Resilient, And Green (LARG) Practices on Agro Industry Indonesia," in *Proceedings of the 2019 1st International Conference on Engineering and Management in Industrial System (ICOEMIS 2019)*, 2019, vol. 171, pp. 62–69.
[26] M. Ghobakhloo, "Industry 4.0, digitization, and opportunities for sustainability," *J. Clean. Prod.*, vol. 252, pp. 1–21, 2020.
[27] M. S. Sangari, J. Razmi, and S. Zolfaghari, "Developing a practical evaluation framework for identifying critical factors to achieve supply chain agility," *Meas. J. Int. Meas. Confed.*, vol. 62, pp. 205–214, Feb. 2015.
[28] H. Allaoui, Y. Guo, and J. Sarkis, "Decision support for collaboration planning in sustainable supply chains," *J. Clean. Prod.*, vol. 229, pp. 761–774, 2019.
[29] S. K. Mangla, "Enablers to implement sustainable initiatives in agri-food supply chains," *Int. J. Prod. Econ.*, vol. 203, pp. 379–393, 2018.
[30] M. Mohanty, "Assessing sustainable supply chain enablers using total interpretive structural modeling approach and fuzzy-MICMAC analysis," *Manag. Environ. Qual. An Int. J.*, vol. 29, no. 2, pp. 216–239, 2018.
[31] Hasanuzzaman and C. Bhar, "Development of a framework for sustainable improvement in performance of coal mining operations," *Clean Technol. Environ. Policy*, vol. 21, no. 5, pp. 1091–1113, 2019.
[32] S. Luthra and S. K. Mangla, "When strategies matter: Adoption of sustainable supply chain management practices in an emerging economy's context," *Resour. Conserv. Recycl.*, vol. 138, pp. 194–206, 2018.
[33] C. T. Lin, H. Chiu, and P. Y. Chu, "Agility index in the supply chain," *Int. J. Prod. Econ.*, vol. 100, no. 2, pp. 285–299, Apr. 2006.

[34] D. S. W. Ting, L. Carin, V. Dzau, and T. Y. Wong, "Digital technology and COVID-19," *Nat. Med.*, vol. 26, no. 4, pp. 459–461, 2020.
[35] S. S. Kamble, A. Gunasekaran, H. Parekh, and S. Joshi, "Modeling the internet of things adoption barriers in food retail supply chains," *J. Retail. Consum. Serv.*, vol. 48, no. January, pp. 154–168, 2019.
[36] D. Batra, "The Impact of the COVID-19 on Organizational and Information Systems Agility," *Inf. Syst. Manag.*, vol. 37, no. 4, pp. 361–365, 2020.
[37] S. Nandi, J. Sarkis, A. A. Hervani, and M. M. Helms, "Redesigning Supply Chains using Blockchain-Enabled Circular Economy and COVID-19 Experiences," *Sustain. Prod. Consum.*, vol. 27, pp. 10–22, 2021.
[38] C. Osei and J. Amankwah-amoah, "Developing and deploying marketing agility in an emerging economy : the case of Blue Skies agility," *Int. Mark. Rev.*, vol. 36, no. 2, pp. 190–212, 2018.