

Sustainability performance evaluation of tropical fruit supply chain in Indonesia using the best-worst method

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Abstract: Studies on the sustainability assessment of supply chain performance in tropical fruit still have limitations, whereas similar studies are more widespread in the manufacturing sector. This study aims to assess the sustainability performance of the tropical fruit supply chain in Indonesia. Performance evaluations were conducted for three producer organisations of tropical fruit with members ranging from 70 to 200 people in Banyuwangi Regency, the largest production centre in Indonesia. This study proposes a new approach, the best-worst method (BWM), to prioritise supply chain performance criteria derived from the SCOR (Supply Chain Operations Reference) model based on assessments by experts managing producer organisations. In the SCOR model, environmental and social criteria are added, resulting in seven criteria for evaluating supply chain performance, which include reliability, responsiveness, agility, cost, asset management, GreenSCOR, and social. Thus, the integration of BWM and SCOR can ensure higher consistency and reliability than traditional methods for assessing sustainable supply chain performance. The results revealed that reliability is the most important criterion for supply chain performance, which shows how important the maintenance of product quality is. In contrast, agility received the lowest score, indicating that there is a need to improve performance with respect to responding to high demand, managing safety stocks, and overtime in the shipping process. Moreover, this study gives a glimpse into the importance of evaluating sustainability performance for the tropical fruit sector, having perishable characteristics and great contributions to rural development. Hence, this study provides a solid practical guide for decision-makers in assessing the sustainable supply chain of tropical fruits in Indonesia.

Keywords: best-worst method; performance evaluation; supply chain; sustainability; tropical fruit

In recent years, the global supply chain has faced increasingly frequent disruptions caused by natural disasters, geopolitical conflicts, and pandemics, which can lead to difficulties, such as food shortages (Bakhshi Sasi et al. 2024; Ching-Pong Poo et al. 2024). To effectively address supply chain challenges, a robust supply chain performance evaluation framework is crucial

to improve operational efficiency, thereby minimising losses and ensuring product quality that meets consumer demand (Alimo 2021; Ayyildiz and Taskin Gumus 2021; Yang and Guo 2021).

The agri-fresh supply chain, particularly concerning tropical fruits is crucial for the stability of the rural economy, offering livelihoods to a substantial segment

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of the population through its perishable commodities and dynamic, high-value agricultural markets with considerable export potential. This vital sector suffers from inefficiencies, substantial post-harvest losses, and quality assurance challenges, which considerably diminish its potential impact. Indonesia yearly forfeits around 30% of its agricultural production due to insufficient supply chain management methods (Alimo 2021). Resolving this ongoing dilemma necessitates a novel, contextually tailored strategy for assessing and enhancing supply chain performance through producer organisations (POs).

Theoretical frameworks such as the SCOR (Supply Chain Operations Reference) model and best-worst method (BWM) provide highly effective solutions. The SCOR model systematically evaluates supply chain processes to identify inefficiencies within the organisation and improve its operational processes significantly for a comprehensive performance boost by empowering decision makers with decisive performance improvements (Kusrini et al. 2019a; Ruamsuke and Ongkunaruk 2021; Sutoni et al. 2021). Another component in the decision process under consideration is BWM, which is a constantly used unique tool that ranks performance criteria for effective decision making in complex supply chain environments (Oubrahim et al. 2022).

Previous studies have used the SCOR and BWM approaches to assess the sustainability of supply chain performance. Although these methods have been implemented in the manufacturing industry, the challenges faced by the agri-fresh sector remain underexplored. For instance, Jain et al. (2022) applied the integration of these two methods to assess the performance of the waste electrical and electronic equipment (e-waste) supply chain. Its application in agricultural supply chains, particularly among producer organisations in Indonesia, remains limited and requires further attention. The integration of SCOR and BWM methodologies can provide a comprehensive understanding of the tropical fruit supply chain, identifying constraints for improvement. This study aims to: (i) identify and validate sustainability performance attributes relevant to the tropical fruit supply chain in Indonesia using the SCOR framework, (ii) determine the relative importance of these attributes through the BWM, (iii) provide practical recommendations for improving supply chain sustainability in tropical fruit systems.

This study uses seven criteria to measure the sustainability performance of supply chains, consisting of reliability, responsiveness, agility, cost, asset management,

GreenSCOR, and social considerations. It is essential to measure the sustainability performance of tropical fruits supply chain in Indonesia at the producer organisation level to improve supply chain process such as optimising operations, efficiency, and driving organisational success in a complex supply chain management environment.

This study contributes to the literature on agricultural fresh food supply chains by integrating the SCOR model and BWM to systematically evaluate supply chain performance. While many studies have assessed agricultural supply chains, few have focused on tropical fruit supply chains in developing countries, particularly in the context of Indonesia, using a performance-based sustainability framework. Moreover, there is limited research that operationalises sustainability through specific and measurable performance attributes. By addressing this gap, this study not only enriches the theoretical discussion on sustainable supply chain management but also offers actionable evaluation tools for practitioners and policymakers. These findings are expected to support data-driven decision-making processes aimed at improving supply chain effectiveness and farmers' livelihoods.

MATERIAL AND METHODS

This study was carried out in Banyuwangi Regency, East Java, Indonesia. It focuses on a region renowned for its tropical fruit production which possesses significant potential for the modern retail market and export (high-value market) through a collective marketing framework. This study intentionally designated Banyuwangi Regency as a focal point for tropical fruit production. It is characterised by elevated levels of collective action activities predominantly facilitated by POs. In 2023, East Java Province was Indonesia's predominant tropical fruit production region with the highest production located in Banyuwangi Regency.

In this study, three experts were selected to provide judgements in the BWM analysis. All three experts are heads of producer organisations, designated as PO1, PO2, and PO3, with each having a membership ranging from 70 to 200 people. The experts have been actively involved in managing agri-fresh food supply chains, particularly tropical fruit commodities, in Indonesia. Each expert has between 15 and 20 years of experience in coordinating production, handling post-harvest processes, and distributing agricultural products through both traditional and modern market channels. Their roles include managing logistics,

negotiating with buyers, and implementing sustainable farming practices within their communities. The members of the producer organisations consist of farmers and distributors. This study interviewed the three experts from three areas, including Purwoharjo District, Pesanggaran District, and Sempu District, Banyuwangi Regency during July and August 2024 to collect data. The research location map is presented in Figure 1.

In this study, the three selected experts are the heads of farmer groups from the three main tropical fruit production areas in the research region. They have extensive experience in supply chain management, collective decision-making, and direct involvement in organising production, distribution, and marketing activities. This selection is not intended to achieve statistical generalisation but rather to obtain analytical insight based on a collective understanding that represents the main actors in the context of agricultural-based communities. According to Rezaei (2015) the validity of BWM lies in the consistency and relevance of expert input rather than the number of participants, especially in specialised domains. This approach has been followed by several peer-reviewed studies where small but credible expert panels have been employed in BWM, such as in supply chain sustainability studies

(Gupta and Barua 2017), third-party logistics assessments (Pamucar et al. 2019), and in port governance strategy (Munim et al. 2020). Such studies endorse that credible results could be drawn from a small number of expert respondents who are highly knowledgeable about the issue at hand, especially where the research problem is structurally well specified and their knowledge is considerably practical.

This study uses the integration of SCOR and BWM models to evaluate the performance of the tropical fruit supply chain in Indonesia. Supply chain performance evaluation in producer organisations often incorporates subjective variables, such as product quality and response to customer request. By integrating the perspective of producer organisations as supply chain actors, BWM allows for a more accurate estimation of criteria weights. BWM is also user-friendly in that input data is limited. By making use of the performance indicators derived from the experiences of producer organisations, BWM provides a more enhanced SCOR model with expert evaluations. This results in a clear and specific sustainability performance assessment for the tropical fruit supply chain.

Supply Chain Operation Reference (SCOR) model. The SCOR model serves as a powerful means for assessing and enhancing supply chain performance.

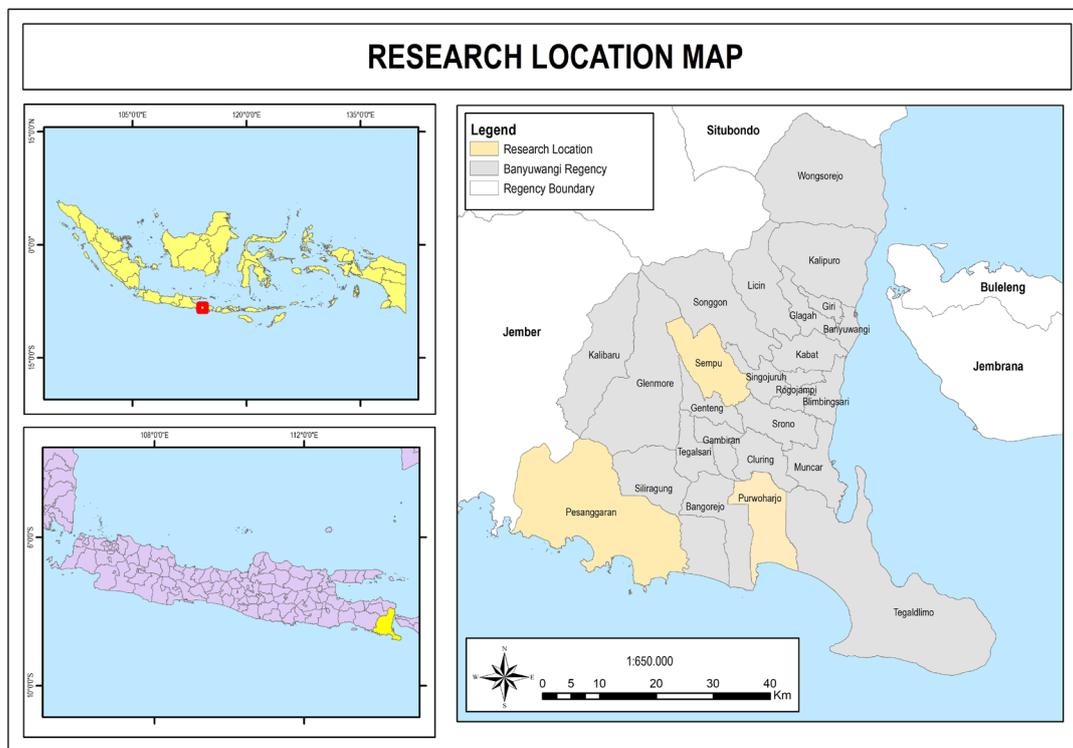


Figure 1. Research location map of sustainability performance evaluation of supply chain

Source: Data processed by authors in ArcGIS

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It sets up an integrated base for evaluating and managing supply chain processes by locating operational strengths and weaknesses (Putri et al. 2019; Prasetyaningsih et al. 2020). The study reveals that the SCOR model can assist producer organisations of Indonesia's tropical fruit supply chain in identifying performance measures on product quality and consumer satisfaction. In contrast, organisations may combine these performance indicators to evaluate their performance to that of market standards and competitors, including in the agri-fresh section where freshness and quality are prime (Kusrini et al. 2019b, c). The SCOR framework helps producer organisations come out practically and easily out of the very complex problems attached to handling, storing, and transportation of products through supply chain because of the perishable nature of products (Ruamsuke and Ongkunaruk 2021).

As a result of the flexibility provided by the SCOR model, an advanced technique such as BWM can be relied upon to evaluate and prioritise metrics from producer organisation's practitioners with respect to sustainability performance of their tropical fruit supply chain. Organisations can rely on BWM to identify where the different SCOR metrics arise in level of importance, so as to eventually tailor the entire review process to be focused and effective (Jain et al. 2022). Table 1 illustrates the SCOR matrix for evaluating sustainability performance of supply chain in producer organisations.

Best-worst method (BWM). Supply chain management employs BWM to assess and prioritise criteria based on best and worst choices. It is also effective in evaluating and ranking performance metrics for the SCOR model and in identifying critical supply chain performance indicators by enabling decision-makers to articulate their preferences. Prior research indicates that BWM can proficiently rank performance indicators inside manufacturing systems, particularly in the setting of supply chains (Khan et al. 2022; Bagherian et al. 2024).

In practice, the BWM frameworks involve an approach procedure where experts first focus criteria related to the performance of supply chains. Next, the experts determine the best and worst criteria to create a benchmark. This relieves the burden on decision-makers from a huge amount of pairwise comparisons, which is a classic problem in most traditional Multi-Criteria Decision Making (MCDM) methods such as Analytic Hierarchy Process (AHP). Hence, it is because of that the efficacy of BWM in dealing with complicated decision-making scenarios that makes it especially suited for evaluating sustainability performance of supply chains (Öz 2022).

The integration between BWM and the SCOR model brings more understanding of the whole supply chain dynamics. BWM is also flexible enough to accommodate a wide variety of decision-making situations, especially in terms of group decision making, which further proves it useful for evaluating supply chains (Haseli et al. 2021; Gao et al. 2024). It uses BWM as criteria such as cost, quality, and delivery performance to assess suppliers for organisations (Govindan et al. 2023; Hailiang et al. 2023). It has additionally used BWM for risk assessment within supply chains and has solved many problems supply chain managers face (Ali et al. 2024; Masudin et al. 2024; Paillin et al. 2024). This study used the BWM Linear Solver, as Rezaei (2016) outlined, which comprises four primary stages.

i) Determine a set of sustainability performance criteria of supply chain. In this phase, the manager or head of the producer organisation as decision-maker outlines n criteria, which are presented with c_1, c_2, \dots, c_n .

ii) Determine the best and the worst supply chain performance indicators based on the opinion of the decision-maker.

iii) Conduct a comparative analysis by evaluating each alternative supply chain performance criterion against both the optimal and least effective criteria using a 1-to-9 scale. In comparisons with the optimal criteria, a score of 1 denotes equal relevance, whereas a score of 9 indicates a significantly superior performance of the optimal criteria relative to the alternative. The results are expressed as a preference $A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$ with a_{Bj} indicating the relative preference of the optimal criterion compared to the alternative performance index j . In comparisons involving the least effective criteria, a score of 1 indicates equal relevance, while a score of 9 denotes that the alternative criterion is completely superior to the least effective criterion. The outcomes are represented in the vector $A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T$, where a_{jW} denotes the preference of performance criterion j relative to the least significant criterion. These vectors offer a systematic evaluation of the alignment between alternative criteria and both optimal and least effective benchmarks.

iv) Determine the importance weight of each of the supply chain performance criteria which presented as $w^*_1, w^*_2, \dots, w^*_n$. The objective is to ascertain the appropriate weights of the supply chain criterion to maximise the absolute differences such as

$$\left| \frac{w_B}{w_j} - a_{Bj} \right| \quad \text{and} \quad \left| \frac{w_j}{w_w} - a_{jw} \right| \quad \text{for all } j \text{ is minimised,}$$

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Table 1. SCOR matrix for evaluating sustainable supply chain performance in producer

No	Performance criteria	Performance measures	Descriptions
1.	Reliability	accuracy of demand	rating (1–10)
		price from farmers	USD/kg
		selling price from PO	USD/kg
		price information	knowledge about price information
		the period of time for shipment	time in a week
		shipment amount	tonne
		quantity and capability of transportation infrastructure	tonne
		punctuality in shipment	% punctuality in shipment
2.	Responsiveness	product quality	% best quality
		frequency of shipment to high value market	time in a week
		duration of shipment from PO to high value market	day
		demand shipment	rating (1–10)
3.	Agility	fulfilment of extreme demands	number of alternative suppliers
		safety stock	tonne
		overtime in shipment processing	day
4.	Cost	retribution fees for shipping	USD
		shipping costs	USD
		return fee on shipping activity	USD
		labour wages & management in sorting and packaging	USD
5.	Asset management	payment contract system	the existence of a contract system
		payment period	day
		pay-off period	month
6.	GreenSCOR	organic certificate	the number of areas that have achieved organic certification
		green process	number of environmentally friendly process
		strategic planning for ecological management	number of planning for the ecological management
		product innovation/diversification	number of diversification products to reduce waste due to its perishable nature
7.	Social	job opportunity	number of employees in supply chain
		potential for professional advancement	number of job advancements /developments
		community relations	total reports in press
		health and safety	frequency rates of injury during activity in supply chain

PO – producer organisation; SCOR – Supply Chain Operations Reference

Sources: APICS (2015, 2017); Marimin et al. (2020); Jain et al. (2022)

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which corresponds to the following min-max model for supply chain performance:

$$\begin{aligned} \min \max_j &= \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_W} - a_{jW} \right| \right\} \\ \text{subject to} & \quad \sum_j w_j = 1 \\ & \quad w_j \geq 0 \quad \forall j \end{aligned} \tag{1}$$

This mathematical programming model describes the scenario.

Objective function: $\min \varepsilon$

Subject to:

$$\begin{aligned} \left| \frac{w_B}{w_j} - a_{Bj} \right| &\leq \varepsilon \quad \forall j \\ \left| \frac{w_j}{w_W} - a_{jW} \right| &\leq \varepsilon \quad \forall j \\ \sum_j w_j &= 1 \\ w_j &\geq 0 \quad \forall j \end{aligned} \tag{2}$$

The optimal value of ε^* is ascertained through the resolution of the aforementioned mathematical programming model. The solution of the model in Equation (2) encompasses all positive values for w_j , where $j = 1 \dots, n$, ensuring that the sum of weights equals 1 and that the deviation of all weight ratios from their respective comparisons does not exceed ε . It is important to acknowledge that when exceeding three criteria, the aforementioned approach may yield many optimal solutions (Rezaei 2016). Assume that supply chain performance with n criteria (weight variables) possesses ε . Substituting ε with ε^* in the right-hand side of the constraints of the model in Equation (2) yields the optimal solution as the outcomes of the subsequent linear system:

$$\begin{aligned} |w_B - a_{Bj}w_j| &\leq \varepsilon^* w_j \quad \forall j \\ |w_j - a_{jW}w_W| &\leq \varepsilon^* w_W \quad \forall j \\ \sum_j w_j &= 1 \\ w_j &\geq 0 \quad \forall j \end{aligned} \tag{3}$$

In the BWM approach, when several decision-makers are involved, the decision-making process employs the geometric mean of their viewpoints. The reliability

of assessments in the BWM necessitates validation. The BWM technique exhibits flawless consistency when the requirement $a_{best,j} \times a_{j,worst} = a_{best,worst}$ is fulfilled for all j . The inconsistent rate decreases when the notion of consistency is invalid. A lower consistency ratio (CR) indicates improved consistency results in the BWM method. A CR rate below 0.1, as presented in Equation (4), indicates acceptable consistency in judgments (Rezaei 2016):

$$CR = \frac{\varepsilon^*}{\text{consistency index}} \tag{4}$$

RESULTS AND DISCUSSION

A breakdown of the sustainability performance requirements for tropical fruit supply chain according to SCOR is presented in Table 1. These criteria are broken down into two levels: performance criteria and performance measures. In order to determine the significance of weighting the criterion, the BWM approach is utilised at each respective level. At each level, the BWM technique lays out the results in detail. The results from both levels can then be added together to find the performance criterion's most important weight. The BWM approach delineates the pairwise comparison of supply chain using the geometric mean of the respondents' opinions (POs).

Supply chain performance criteria weights

In the performance criteria of the tropical fruit supply chain outlined in Table 1, the majority of POs identified 'reliability' (A1) as the most favourable criterion and 'agility' (A3) as the least favourable criterion. The geometric mean of the POs' evaluations in pairwise comparisons of all qualities, in relation to the best and worst traits, is presented in Tables 2 and 3, respectively.

Table 4 displays the BWM approach's performance weights for the analysed criteria.

Supplementary Tables S1–S7 outline the specifics of the global weight assessment for each feature sustainability performance of the tropical fruit supply chain. All respondents' replies to each supply chain performance criterion are consistent, as evidenced by CR values below the associated threshold value. This study establishes the optimal weight of the criteria by executing the BWM optimisation model for each producing organisation's response. Supplementary Table S8 illustrates the appropriate weight for PO1, with the consistency ratio below the associated threshold, indicating that the ranking and comparison are consistent.

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Table 2. The outcomes of the pairwise comparison between the optimal criterion (A1) and the other criteria.

Main criteria	Reliability (A1)	Responsiveness (A2)	Agility (A3)	Cost (A4)	Asset Management (A5)	GreenSCOR (A6)	Social (A7)
Reliability	1	3	7.3	3	3	3	3

SCOR – Supply Chain Operations Reference

Sources: Authors' own elaboration

Table 3. The outcomes of the pairwise comparison between additional criteria and the least favourable criterion (A3)

Main Criteria	Reliability (A1)	Responsiveness (A2)	Agility (A3)	Cost (A4)	Asset Management (A5)	GreenSCOR (A6)	Social (A7)
Agility	3	2.67	1	2.33	3	2	2

SCOR – Supply Chain Operations Reference

Sources: Authors' own elaboration

Table 4 shows that the reliability criterion has the highest normalised weight (0.485) when the BWM method is used to evaluate sustainability performance criteria in supply chain based on the SCOR model. This indicates that the reliability is the most important criteria in tropical fruit supply chain. High reliability guarantees consistent quality and delivery, which is crucial due to the perishable nature of tropical fruit. Concurrently, responsiveness ranks as the second most significant feature, assigned a weight of 0.163. This indicates the supply chain's capacity to swiftly adapt to demand and market fluctuations. In relation to tropical fruit, it is crucial to fulfil consumer expectations for fresh product. The social consideration

Table 4. Performance criterion weighting using the BWM method

Main criteria	Min w_j	Max w_j	Normalised weight $[(\max w_j + \min w_j)/2]$
Reliability	0.392	0.579	0.485
Responsiveness	0.081	0.246	0.163
Agility	0.063	0.094	0.078
Cost	0.067	0.195	0.131
Asset management	0.118	0.151	0.134
GreenSCOR	0.069	0.206	0.137
Social	0.101	0.181	0.141

BWM – best-worst method; SCOR – Supply Chain Operations Reference

Sources: Authors' own elaboration

criteria in the supply chain received a score of 0.141, ranking as the third highest criterion, signifying that producer organisations have prioritised employment opportunities, job development, social good, health, and occupational safety within the tropical fruit supply chain.

In the interim, agility exhibits the lowest performance (0.078) relative to reliability, responsiveness and social criteria. Agility is rated lower because the main focus of PO is to ensure reliability, responsiveness, and social criteria. The characteristics of tropical fruit, such as perishability, cause PO to prioritise stable and efficient operations rather than the ability to adapt or change frequently, but still pay attention to sustainability aspects, especially in social criteria and green processes. This strategic focus helps PO maintain quality and reduce risk, which are important factors for success in the tropical fruit supply chain, which is classified as an agri-fresh supply chain.

GreenSCOR achieved a score of 0.137, categorising it within the moderate range of the seven criteria, signifying that the producer organisation is emphasising environmental sustainability in its supply chain activities. Furthermore, the cost criterion possesses a moderate weight (0.131), signifying that while cost reduction is significant, it is not the foremost priority. The focus is more on ensuring quality and reliability than just cost effectiveness. Asset management carries a weight of 0.134, signifying an emphasis on the efficient use of resources, including storage and transportation. Effective asset management is crucial and it is subordinate to reliability and responsiveness in terms of significance.

The results demonstrate that reliability is the most essential sustainability performance criterion in the tropical fruit supply chain, underscoring the necessity for

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constant quality and dependable delivery. Responsiveness underscores the significance of promptly addressing demand. The diminished significance of agility, cost, and asset management, GreenSCOR and social consideration suggests that, while these elements are vital, they are subordinate to the imperative of maintaining a dependable and responsive supply chain. These findings are consistent with the characteristics of tropical fruit, where the longevity and consumer preference for freshness make reliability and prompt responsiveness crucial success factors.

Supply chain performance measures weights

The second level of the performance hierarchy, utilising the BWM approach, is the sustainability performance evaluation metric. At this stage, the BWM approach needs to establish the performance weights of the metrics associated with the main selection criteria of sustainability performance. Initially, Table 5 delineates the optimal and suboptimal measures of each feature, as determined by the respondents' (POs) understanding.

Following the use of BWM in conjunction with the SCOR model, Table 6 provides an evaluation of the most important sustainability performance characteristics that are present within tropical fruit supply chain. For each aspect, the PO has evaluated both ideal and suboptimal metrics, with a particular emphasis on areas of strength and those that could use development. This study determines the weights of characteristics and measures for this investigation by multiplying the final weight of each criterion or measure by 1 000. This research uses a scale that ranges from 0 to 1 000 points to assign points to each of the criteria. Table 6 presents the results of the evaluations given to the sustainability performance characteristics and measures.

According to Table 6, the criterion reliability exhibits the highest score among the supply chain performance

metrics. The following ranking criteria for sustainability performance are responsiveness, social, GreenSCOR, asset management, and cost. In addition, the sustainability performance assessment showed that the agility criterion got the lowest score, which aligns with how the performance qualities in Table 4 were weighted. Table 6 shows the results of the sustainability performance evaluation of tropical fruit using the SCOR model and the BWM method. These results match the results of the BWM method evaluation of the performance criterion weight and the measurements of the best and worst performance criteria. Here is an explanation of each criterion for sustainability performance evaluation and its specific relevance to the tropical fruit supply chain in Indonesia. The inclusion of green and social criteria reflects a triple bottom line approach that aligns with the increasingly important environmental and social dimensions in evaluating supply chain sustainability.

Reliability. Reliability describes the extent to which the supply chain system can meet demand accurately, consistently, and predictably. In this study, reliability is measured through various indicators such as demand accuracy, price information, quantity and delivery accuracy, product quality, and transportation infrastructure capacity. In the context of the tropical fruit supply chain, reliability is very important because the products are perishable and have a market value that is sensitive to time and quality. A reliable supply chain can minimise product loss, enhance trade partner trust, and strengthen market competitiveness.

The foremost indicator of reliability, deemed the highest-ranked criterion, is recognised as the quality of tropical fruit. Superior product quality is crucial for establishing consumer trust and satisfaction, particularly in the agri-fresh supply chain where longevity is a significant issue. Superior product quality enhances consumer loyalty and cultivates trust and commitment

Table 5. Best and worst sustainability performance criterion measurement results

Main criteria	Worst measure	Best measure
Reliability	accuracy of demand	product quality
Responsiveness	demand shipment	duration of shipment
Agility	safety stock	overtime in shipment processing
Cost	return fee on shipping activity	labour wages & management in sorting and packaging
Asset Management	payment contract system	payment period
GreenSCOR	product innovation/diversification	green process
Social	potential for professional advancement	health and safety

SCOR – Supply Chain Operations Reference

Sources: Authors' own elaboration

Table 6. Evaluation of sustainability performance using the BWM approach

Performance criteria	Points	Measurement of performance	Points
Reliability	481	accuracy of demand	10
		price from farmers	84
		selling price from PO	84
		price information	84
		the period of time for shipment	26
		shipment amount	23
		quantity and capability of transportation infrastructure	23
		punctuality in shipment	26
		product quality	121
Responsiveness	163	frequency of shipment to high value market	60
		duration of shipment from PO to high value market	84
		demand shipment	19
Agility	78	fulfilment of extreme demands	21
		safety stock	10
		overtime in shipment processing	48
Cost	131	retribution fees for shipping	29
		shipping costs	39
		return fee on shipping activity	17
		labour wages & management in sorting and packaging	45
Asset management	134	payment contract system	18
		payment period	93
		pay-off period	24
GreenSCOR	137	organic certificate	25
		green process	51
		strategic planning for ecological management	45
		product innovation/diversification	17
Social	141	job opportunity	30
		health and safety	76
		community relations	20
		potential for professional advancement	15

BWM – best-worst method; PO – producer organisation; SCOR – Supply Chain Operations Reference
Sources: Authors' own elaboration

among supply chain stakeholders (Ramirez et al. 2021; Zhong et al. 2023). POs should prioritise continuous quality control and improvement activities to leverage this potential. Adopting robust quality management methods can enhance operational efficiency and fit more closely with customer expectations, hence increasing overall supply chain performance (Wicaksono and Illés 2022; Yadav et al. 2024).

In contrast, the lowest performance criterion is related to demand accuracy. Buyers who focus on high-value markets, especially the export sector, actually increase demand for tropical fruit when its availability in the market is reduced (off-season). Although tropical fruit can be produced year-round with the right equipment, such as additional lighting at night, on the other hand, tropical fruit cannot be kept fresh for long

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periods without special treatment such as cold storage. On the other hand, there are usually only a few buyers for export purposes during the November–March period when the harvest is at its peak. PO has also received cold storage assistance from the government with a capacity of around 3 tonnes to face the main harvest season, but it has not been utilised due to the constraints of high electricity availability. To operate cold storage, electricity or diesel with a large capacity is required. Therefore, the contract system in payment improves information sharing and risk management, and this strategy strengthens the resilience of the agricultural supply chain (Zhou et al. 2019; dos Santos and Guarnieri 2021).

Responsiveness. Responsiveness measures the supply chain's ability to respond to market demand quickly and on time. In this study, responsiveness is measured through the frequency of deliveries to high-value markets, the duration of deliveries from the producer organisation to the destination market, and the speed of fulfilling delivery requests. In the context of tropical fruits with a short shelf life and high market competition, the speed and accuracy of delivery are critical to maintaining product quality, meeting consumer expectations, and reducing the risk of spoilage. A responsive supply chain enables farmers and distributors to adapt to market dynamics, improve logistics efficiency, and expand access to high-value markets.

Because of the perishable nature of these products, responsiveness ranks second in importance as a criterion for assessing sustainability performance. In this regard, the best-performing criterion weighing responsiveness is the time elapsed between the executing producer organisations' delivery toward high-value markets. If deliveries are made quickly, the product remains fresh, and consumer demand is met. The lowest-performing criterion is delivery on demand, indicating that the delivery promise can hardly be fulfilled most times. A study provides evidence that responsive agri-fresh supply chains benefit from strong logistics and market access (Rodríguez Mañay et al. 2022). High frequencies of delivery from suppliers ensure consistent and rapid delivery to keep products fresh. Further, shortening the time from demand to delivery minimises the risk of damage to the product and maximises the efficiency of the supply chain.

Agility. Agility is the capability of a supply chain to effectively and rapidly respond to unforeseen events and extreme demand. Indicators for measuring agility in this study are extreme demand fulfilment, availability of safety stock, and overtime dispatch processing capabilities. System agility is critical for tropical fruits

to counter seasonal demand fluctuations and rapid distribution challenges, ensuring supply is not interrupted and quality is upheld. The agile supply chain allows business operators flexibility in making operational changes regarding production volume and delivery time. This aids supply chain sustainability by reducing risks of lost sales and wastage while simultaneously increasing the overall satisfaction of the market.

The optimal metric for the lowest-ranked agility criterion is overtime in shipment processing, requiring POs to extend working hours to cope with extreme demand. However, this approach can increase labour costs and become unsustainable over time, potentially leading to staff burnout and decreased efficiency and productivity (Mishra et al. 2022; Sahu et al. 2023). Furthermore, workforce training especially in shipment processing can improve adaptability, facilitating strategies more responsive to fluctuating demand levels, such as cross-training employees to handle multiple tasks or implementing flexible work schedules (Rahbari et al. 2023). Additionally, improved demand forecasting methodologies can enable more precise inventory management and reduce the need for overtime it can increase overall supply chain agility (Kusrini and Miranda 2021). Thus, POs can improve responsiveness and adaptability to market fluctuations, resulting in superior supply chain performance (Montanyà and Amat 2023). Consequently, improving demand management to increase agility without compromising product quality is essential. However, the least effective metric is safety stock management which indicating inadequate buffer stock to handle demand uncertainty. Over-reliance on overtime rather than inventory management may indicate a preference for management over strategic agility. Therefore, it's crucial to recognise that a balanced inventory strategy and worker adaptability are integral to improving agri-fresh supply chain agility (Kodrat et al. 2020).

Cost. Cost refers to the full measure of the supply chain, including delivery fees, costs of shipping, return costs, as well as the labour and management wages in sorting processes and packaging costs. In the context of a supply chain concerned with perishable tropical fruit, such a factor as cost efficiency becomes important in maintaining sustainability. Control over these cost elements would not only show operational efficiency but would also have competitive advantages for the product and basic welfare for the farmers.

The evaluation results on sustainability performance show that cost management is essential for profitability. The optimal indicators for cost management performance are wages and labour management in the sorting

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and packaging process, which indicate the effective utilisation of labour resources in that section. Conversely, the lowest ranking metric is the cost of returns associated with damaged products during the tropical fruit shipping process or failure to meet consumer expectations. High return costs indicate management in shipping and can substantially increase operational costs. This statement is supported by Reklitis et al. (2021), who state that labour cost control and quality control are essential techniques for minimising supply chain costs in the agri-food business.

Asset management. Asset management in this study refers to the efficiency of managing financial assets within the supply chain system, particularly related to payment schemes. The indicators used include the payment contract system, payment period, and pay-off period. In the tropical fruit supply chain involving many actors, including farmers, cooperatives, and distributors, good asset management is crucial for maintaining cash flow and operational smoothness. Timeliness of payments and clarity of contracts can enhance trust among supply chain actors and support the continuity of long-term business relationships.

Furthermore, the payment period becomes the best measure in asset management of supply chain performance because the shorter payment cycles improve cash flow and facilitate better financial planning for producer organisations, ensuring asset utilisation. On the other hand, the lowest measure is the contract payment system, which indicates problems with payment delays that can also hinder asset utilisation. Cash flow management, which handles professional and prompt payments, is essential to improve asset performance in the agri-food supply chain (Yusianto et al. 2022). Thus, improving the payment process and shortening the payment duration can strengthen the financial health of POs and efficiently meet market demand.

GreenSCOR. Environmental sustainability performance in the tropical fruit supply chain is measured using the GreenSCOR criteria in this research. Indicators include (i) number of areas with organic certification, (ii) number of processes categorised as environmentally friendly, (iii) number of strategic plans for ecological management, and (iv) number of innovations or product diversifications targeted towards waste reduction due to the nature of the products being perishable. These criteria remain relevant because of the nature of the sensitivity of tropical fruits concerning time and temperature; hence, the consideration of minimising environmental impact in production and distribution becomes necessary. Organic certification and environmentally friendly

processes show compliance with ecological standards, while systematic adaptation in waste management and keeping products with added value is reflected in strategic planning and diversification into products.

Producer organisations rate the environmental aspect of their supply chain sustainability quite highly, as indicated by the GreenSCOR aspect. This criterion indicates that POs are committed to environmental sustainability in their supply chain operations. POs have implemented green practices and are committed to implementing ecological management for plans. In addition, producer organisations develop innovations in processed tropical fruit products through collaboration with government agencies, research, and academics targeting domestic consumers and oriented to the needs of foreign markets.

Social. The social criteria in this research reflect the social contribution of supply chain activities to the surrounding community. The indicators used include (i) job creation for the local community, (ii) attention to occupational health and safety, (iii) the quality of relationships with the surrounding community, and (iv) opportunities for professional development for actors in the supply chain, especially farmers and post-harvest workers. In the context of tropical fruit supply chains that often involve rural communities, social aspects are very important to ensure long-term sustainability. A supply chain that not only prioritises efficiency but also enhances social welfare will create an inclusive and stable production and distribution system.

POs have implemented social considerations in managing their supply chain, as evidenced by opening job opportunities that benefit the surrounding community. POs are also involved in institutional development for training with independent agricultural and rural apprenticeship methods. These efforts aim to accelerate access and application of technological information through the learning process of farmers and their families. However, PO still needs help regarding equipment/supplies, procedures, and awareness of health and safety in managing its supply chain. Health and safety are crucial in achieving sustainable performance in the supply chain, so it is necessary to increase awareness of the importance of health and safety for POs members.

Theoretical contributions. This research provides a theoretical contribution to the development of sustainable supply chain management studies, particularly in the context of perishable tropical agricultural products. By extending the conventional SCOR model through the integration of environmental sustainability indicators (GreenSCOR) and social indicators,

<https://doi.org/10.17221/46/2025-AGRICECON>

this research offers a more holistic performance evaluation framework aligned with the triple bottom line principles (economic, social, and environmental). This model reinforces the findings of the study by Jain et al. (2022), which emphasises the need for a sustainable performance assessment approach that also considers social aspects, which are often less prioritised in developing countries.

From a methodological perspective, this research adopts the BWM as a multi-criteria decision-making approach suitable for application in the context of small farmers and producer organisations (PO) with data and resource limitations. This reinforces the findings of the study by de Carvalho et al. (2022), which highlights the importance of using adaptive and practical MCDM methods in sustainable supply chain systems. On the other hand, this research also enriches the methodological foundation by referring to the use of BWM for sustainable supplier selection and green innovation assessment as demonstrated by Gupta and Barua (2017) as well as Pamucar et al. (2019). By contextualising SCOR in community-based evaluations, this research presents a replicable conceptual model and directly contributes to strengthening the theoretical framework of SSCM in the tropical agriculture sector.

CONCLUSION

This study aims to measure sustainability performance using seven criteria for supply chain performance evaluation that integrates two approaches, namely SCOR and BWM. Three producer organisations operating for tropical fruit commodities have been used as sources in measuring sustainability performance. The findings indicate that producer organisations consider the main criterion in sustainability performance to be the reliability criterion. PO always commits to producing high-quality products before delivering them to the customer. The assessment revealed that agility received the lowest grade, indicating significant opportunities for improvement in handling extreme demand, overtime, and safety stock. In addition, producer organisations have considered social and environmentally friendly aspects in managing their supply chains by implementing green practices and social goods. Meanwhile, this study's most important managerial insight is the perspective on managing the tropical fruit supply chain by producer organisations in Indonesia. This perspective on improving sustainability performance in supply chain has the potential to turn risks into opportunities. By focusing on sustainability performance criteria, producer organisations can enhance consumer satisfaction

and operational efficiency. This approach also helps optimise their supply chains for increased performance in competitive marketplaces, and contribute rural development in Indonesia. This research not only provides a comprehensive assessment of the performance of the tropical fruit supply chain in Indonesia but also offers practical implications for improving farmers' livelihoods. By identifying key performance attributes such as reliability, responsiveness, agility, cost, asset management, GreenSCOR, and social aspects, this research recommends strategic areas that can be improved to generate higher farmer incomes, particularly through better coordination and reliability in more timely demand accuracy.

Although this research makes an important contribution to the development of a sustainable supply chain performance evaluation framework for tropical horticultural products, there are several limitations that need to be noted. First, the number of respondents was limited to three heads of producer organisations who acted as experts, which may affect the generalisation of the study's results. However, the selected experts hold central positions in managing the supply chain and represent key decision-makers within producer organisations, making their insights highly relevant in the context of a community-based supply chain. The use of three experts is aligned with existing literature that validates the use of small expert panels for multi-criteria decision-making. Moreover, the goal of this study was not to provide statistical generalisation but to offer a conceptual and exploratory framework adaptable to similar agricultural contexts.

Future research could explore the integration of resilience indicators and sustainable SCOR metrics into SCOR-based assessment models, as well as expand the scope of analysis to include a broader range of stakeholders such as cooperatives, distributors, and local governments. Comparative studies in various regions and commodities in Indonesia, or even in different countries in Southeast Asia, could also enrich the application and generalisation of the framework. Second, this research was conducted within a specific geographical scope and commodity context, so its application to other regions or products requires adjustments. Further research is recommended to involve more respondents with diverse backgrounds. Additional quantitative data should be used to test the model's validity, and BWM results can be triangulated with alternative qualitative approach (e.g. grounded theory data). This framework should be also applied to the supply chains of other tropical agricultural products to strengthen its generalisation and theoretical contribution.

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