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Supply chain risk assessment using best worst method: a case study of agro-industry skipjack tuna in Ambon - Indonesia

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Abstract: One of the main issues in the agro-industry supply chain is identifying and ranking different risk factors to maintain business continuity. This study discusses the agro-food supply chain risk assessment for smoked skipjack tuna in Ambon. Related literature and expert interviews identify risk factors that arise along the supply chain. These risk factors are contained in internal risk, company external operational risk, and macro-level risk. This research aims to evaluate comprehensively the risk factors of the smoked skipjack agro-industry supply chain, which are a priority to be addressed. The decision-making framework uses the BWM (Best Worst Method) to determine each risk factor's relative weight, followed by a sensitivity analysis to determine how robust the outcome is. Experts pick the risk factor assessment, and then an optimization model is modelled to obtain the weight of each risk factor, which is calculated with the help of Lingo software. The findings show that three risk factors will be prioritized to be addressed out of the eleven risk factors assessed, namely "Quality of the final product," "Financial instability," and "degradation of fish populations." Sensitivity analysis was also carried out to see the overall robustness of the results achieved. The weight of the selected risk factor ("final product quality (R1c)") has its weight value changed from 0.1 to 0.9 with an increase of 0.1. These findings are expected to help smoked skipjack tuna agro-industry managers make decisions to reduce supply chain risks and better administration management to maintain the sustainability of their business processes.

1 Introduction

One of Indonesia's fishery commodities with quite promising market potential is skipjack tuna (Katsuwonus pelamis). Tuna and skipjack tuna fishery commodities can be exported as fresh, frozen, processed products such as smoked skipjack [1]. Smoked skipjack tuna is one of the products processed using a combination of treatment and the administration of natural chemical compounds from burning natural fuel. Currently, the skipjack tuna supply chain in the eastern region is the same as in Ambon, mainly consisting of fishermen - large traders or Fish Management Units - small traders - processors, and then consumers [2]. Even though it is a mainstay commodity, the skipjack fishery supply chain faces risks to business sustainability, such as varying quality, post-catch handling processes and handling during loading and unloading, and the use of ice for cooling, which will have an impact on the quality of the smoked fish to be produced.

In a business environment that involves many actors in the supply chain, different situations in both the time and place dimensions will create a situation of uncertainty, thereby creating risk agents. Risk can be defined as the possibility of losses arising or unexpected events due to uncertain conditions resulting in losses for the company [3,4]. Risk cannot be avoided, but its overall impact can be minimized with appropriate risk management through risk identification, evaluation, and mitigation to ensure the smooth running of the company's business processes [5]. [6] define risk identification as a systematic process for identifying and categorizing risks and the causes of risk. According to [7], Supply Chain Risk Management (SCRM) also includes risk identification and evaluation, which aims to reduce supply chain operational disruptions and their negative impacts. Risk evaluation is the stage of risk measurement and assessment that aims to assist the decision-making process in preventing risk [8].

According to [9], research on Supply Chain Risk Assessment (SCRA) for the agri-food context still needs to be improved compared to SCRA research for other contexts, such as the manufacturing sector. Several studies on Agro-food Supply Chain Risk Assessment (AFSCRA) have been carried out using several multi-criteria decision-making (MCDM) methods, including Rathore et al. [10] uses the Failure Mode and Effect Analysis (FMEA) method combined with fuzzy VIšekriterijumsko KOmpromisno Rangiranje (fuzzy-VIKOR) to determine supply chain risk priorities in the foodgrains industry. The FMEA method was also used by [11] which is integrated with fuzzy Technique for Order Preference by Similarity to Ideal Solution (fuzzy-TOPSIS) and fuzzy Analytical Hierarchy Process (fuzzy-AHP) in identifying and classifying supply chain risks in agricultural projects. Likewise Suryaningrat et al. [12] used FMEA and AHP in determining the risk weight of edamame commodities in the agricultural industry. Furthermore, [13] use a fuzzy House of Risk (FHoR) approach in identifying and mitigating agro-industrial sugarcane risks to improve supply chain performance. The AHP based on spherical fuzzy sets (SF-AHP) approach was used by [14] in investigating the impact of risks on agricultural supply chains after COVID-19.

However, to the best of our knowledge, a comprehensive review of AFSCRA research for fishery products is still very rarely carried out when compared to Horticultural products and general food and other food products classified by [15]. Several AFSCRA studies for fishery products have been carried out by [16] in assessing supply chain risks for mackerels by conducting simulations using the Colored Petri-Net (CPN) method. Furthermore, [17] carried out risk identification, assessment, and mitigation in the tuna industry in three dimensions of sustainability using the HoR method. Likewise, [18] studied the identification and assessment of risks in the operational aspect of the supply chain in the canned tuna industry using the FMEA and VIKOR methods. The current research uses the best worst method (BWM), one of the MCDM methods developed by [19], by identifying risks and assessing the supply chain risks of smoked skipjack tuna in Ambon. Therefore, this research provides novelty by contributing to the AFSCRA literature by identifying risk factors in three aspects, namely macro-level risk, operational risk external to the firm, and internal risk, as well as assessing risk factors related to offering BWM, especially the Skipjack tuna supply chain.

Based on the explanation above, the formulation of the problem presented in this study is how to identify and assess risk factors for the smoked skipjack supply chain and how priority risk factors help provide practical insights for company managers. By realizing the importance of SCRM, the firm can arrange, execute, and manage the SCM process to maintain the SC and the sustainability of the smoked skipjack agro-industry. This research aims to identify risk and evaluate the risks of the smoked skipjack tuna SC using BWM.

2 Research methodology

The methodical processes taken to accomplish the intended aims are known as research methodology. This study examines the identification and risk evaluation in Ambon's supply chain for smoked skipjack tuna. This research has gone through several stages, including:

Stage 1. *Identify initial supply chain mapping.* At this stage, an initial mapping of the smoked skipjack tuna supply chain was done through interviews and previous research literature studies.

Stage 2. *Identify potential risk factors.* At this stage, risk factors are identified in three categories, namely macro-level risk (MR), operational risk external to the firm (OR), and internal risk (IR), which were adapted from [5]. The identification process was taken out through literature studies and deep discussions with experts (marine and fisheries office of Ambon, industry and trade office of Ambon, academics, smoked fish agro-industry groups, and fishermen groups) and validated to obtain risk factors (Table 1), which will then be used in preparing a paired comparison assessment questionnaire with a scale from 1 to 9 as input to the BWM model.

Table 1 Risk factors in the smoked skipjack tuna supply chain

Categories	Risk Factor, Codes and Reference	Definitions
Internal Risk	Lack of skilled workers (R1a) [18]	Agroindustry faces a shortage of skilled workers.
	Financial instability (R1b) [20]	Circumstances that describe the company's financial condition in an unstable condition
	Final product quality (R1c) [17,18]	Decrease in final product quality that does not comply with Indonesian National Standard 2725:2013, namely > 60%, histamine levels > 100 mg/100g
Operasional Risk	Demand uncertainty (R2a) [21]	Uncertainty in demand that causes demand to suddenly increase or decrease
	Supply quality (R2b) [4,20]	Quality of raw materials supplied from suppliers
	Supplier delivery delays (R2c) [5]	Not being able to deliver raw materials on time causes many problems

Macro Level Risk	Regulations and policies (R3a) [22]	Unsupportive regulations and policies, for example, regulations limiting operational hours for catching during a pandemic, managing fishing permits, increasing fuel prices.
	Conflicts between fisherman groups/agro-industry groups (R3b) [17]	Conflict between members of society that is comprehensive in life
	Fish population degradation (R3c) [23]	Reduction in fish populations as a result of overfishing
	Damage and contamination (R3d) [18]	Product damage and contamination during production and transportation
	Natural disasters (R3e) [5]	Potential losses caused by natural disasters such as bad weather, power outages

Stage 3. BWM Application. In this phase, risk factors are assessed by experts through a questionnaire and will be ranked by calculating the average optimal weight for each risk factor resulting from BWM. Dr. Jafar Rezaei developed BWM in 2015, a relatively new MCDM technique. BWM uses two pairwise comparison vectors in determining the weight of criteria; the first is the one that is "best," the most important or most desirable of the other criteria, and the second is the "worst," such as the least desirable or least necessary of the other criteria [19]. BWM consists of several steps, namely:

i. **Set of relevant risk factors.** In this phase, risk factors are identified from the aspects of and macro-level risk (MR), operational risk external to the firm (OR), internal risk (IR), which experts then validate, and there are eleven relevant risk factors (see Table 1)

ii. **Selected the best and the worst risk factors.** The expert will select the "best" risk factor and the "worst" risk factor from the risk factors that have been identified. It can be decided randomly whether the risk factor is the best or worse if there is a tie. The decision-maker's judgment is wholly responsible for this.

iii. ***Determine the preference of the best risk factor over all the other risk factors***. In this phase, a pairwise comparison assessment is carried out between the "best" risk factor (*B*) and other factors (*j = 1,2,...,n*). Then created in a row vector as in equation (1).

$$A_B=(a_{B1},a_{B2},...,a_{Bn}) \quad (1)$$

Where a_{Bj} shows the best preference for risk factor *B* compared to risk factor *j*.

iv. *Determine the preference of all the risk factor over the worst risk factors*. In this phase, a pairwise comparison assessment is carried out between the "worst" risk factor (*W*) and other factors (*j = 1,2,...,n*). Then created in a column vector as in equation (2).

$$A_W=\begin{pmatrix} a_{1W} \\ a_{2W} \\ ... \\ a_{nW} \end{pmatrix} \quad (2)$$

Where a_{jw} shows the level of preference for the worst risk factor *W* compared to risk factor *j*.

v. *Modeling the optimization model and calculating the optimal weight of each risk factor.* This stage will create an optimization model to calculate each risk factor's weight, represented in equation (3). The calculation of the weight of apiece risk factor using Lingo software. The formulation to find the optimal weight is modeled as follows:

$$min\ max_j \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_B}{w_j} - a_{Bj} \right| \right\} \quad (3)$$

Subject to,

$$\sum_J w_j = 1$$

$$W_j \geq 0, \text{ for all } j$$

Then converted into a linear model as follows (4):

$$min\ \xi^L \quad (4)$$

Subject to,

$$|W_B - a_{Bj} w_j| \leq \xi^L, \text{ for all } j$$

$$\sum_J w_j = 1$$

$$W_j \geq 0, \text{ for all } j$$

3 Result and discussion

3.1 *Smoked skipjack tuna supply chain*

The fish supply chain in Ambon starts with fishermen who catch skipjack tuna. The number of skipjack tuna caught by fishermen ranges from 250-1000 in one go to sea. Furthermore, the skipjack tuna is sold to collectors or wholesalers, and some are also sold to the Fish Management Unit (UPI) / cold storage to be used as frozen products. After the fish is distributed to collecting traders, the fish is then sold directly to consumers or to agro-industry to be made into smoked fish. Fish that will be used as smoked fish products are processed by smoking (3-4 hours) using hardwood or coconut shells to maintain the quality of the product. Next, the smoked fish is directly distributed to retailers to be sold to consumers and processed into other food products. In general, the smoked skipjack tuna supply chain is shown in Figure 1.

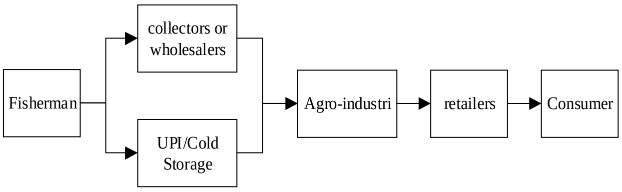

Figure 1 Smoked skipjack tuna supply chain

3.2 Best worst method application

BWM will be used to assess risk factors identified from various literature and verified by experts. The results of expert identification and verification through literature studies and interviews can be seen in Table 1.

Selected the best and worst risk factors

In this phase, five experts determine the "best" and "worst" risk variables once given a set of pertinent risk factors. Experts were drawn from the provincial fisheries and maritime service, city industry service, academics, smoked fish agro-industry group, and fishermen group, based on years of involvement and work experience. Interviews were conducted with experts directly to assess risk factors on the questionnaire that had been designed. The selection of the "best" and "worst" risk factors from the five experts is shown in Table 2.

Table 2 The best and worst risk factors determined by experts

Risk factors	Best risk factor	Worst risk factor
Lack of skilled workers (R1a)	Expert 1	
Financial instability (R1b)		
Final product quality (R1c)	Expert 2, 4, and 5	
Demand uncertainty (R2a)		
Quality of supply (R2b)		
Supplier delivery delays (R2c)		
Regulations and policies (R3a)	Expert 3	
Conflict between fishermen/agro-industry groups (R3b)		Expert 4 and 5
Degradation of fish populations (R3c)		Expert 2 and 3
Damage and contamination (R3d)		
Natural disasters (R3e)		Expert 1

Determine the preference of the best risk factor over all the other risk factors

In this phase, by using pairwise comparisons on a 1–9 rating scale, the five experts were asked to rate their propensities for the best risk factor that had been chosen relative to the other risk factors. Table 3 illustrates how Expert 4 chose the best risk factor compared to other risk factors.

Table 3 Best risk factor in comparison to other risks (expert 4)

Best to others		R1a	R1b	R1c	R2a	R2b	R2c	R3a	R3b	R3c	R3d	R3e
Expert 4	Best risk factor (R1c)	7	5	1	7	7	9	5	9	3	5	5

Determine the preference of all the risk factor over the worst risk factors

In this stage, using pairwise comparisons and a rating scale from 1 to 9, five experts were asked to rate their judgment of their propensity for other risk factors about the worst risk factors. Table 4 is an illustration of a matrix that Expert 4 evaluated.

Table 4 Worst risk factors compared to other risk factors (expert 4)

Others to worst	Expert 4 (Worst risk factor R3b)
Lack of skilled workers (R1a)	3
Financial instability (R1b)	3
Final product quality (R1c)	9
Demand uncertainty (R2a)	5
Quality of supply (R2b)	7
Supplier delivery delays (R2c)	7
Regulations and policies (R3a)	5
Conflict between fishermen/agro-industry groups (R3b)	1
Degradation of fish populations (R3c)	1/3
Damage and contamination (R3d)	5
Natural disasters (R3e)	7

Modeling the optimization model and find the optimal weight

By completing the optimization model and the restrictions in Equation 4, this phase finds the ideal weight for each risk factor. The following describes the optimization model for Expert 4:

$$
\begin{aligned}
&\min \xi^L\\
&\text{Subject to,}\\
&|w_{R1c}-7w_{R1a}|\le \xi^L;|w_{R1c}-5w_{R1b}|\le \xi^L;|w_{R1c}-1w_{R1c}|\le \xi^L;|w_{R1c}-7w_{R2a}|\le \xi^L;\\
&|w_{R1c}-7w_{R2b}|\le \xi^L;|w_{R1c}-9w_{R2c}|\le \xi^L;|w_{R1c}-5w_{R3a}|\le \xi^L;|w_{R1c}-9w_{R3b}|\le \xi^L;\\
&|w_{R1c}-3w_{R3c}|\le \xi^L;|w_{R1c}-5w_{R3d}|\le \xi^L;|w_{R1c}-5w_{R3d}|\le \xi^L;\\
&|w_{R1a}-3w_{R3b}|\le \xi^L;|w_{R1b}-3w_{R3b}|\le \xi^L;|w_{R1c}-9w_{R3b}|\le \xi^L;|w_{R2a}-5w_{R3b}|\le \xi^L;\\
&|w_{R2b}-7w_{R3b}|\le \xi^L;|w_{R2c}-7w_{R3b}|\le \xi^L;|w_{R3a}-5w_{R3b}|\le \xi^L;|w_{R3b}-1w_{R3b}|\le \xi^L;\\
&|w_{R3c}-0.33w_{R3b}|\le \xi^L;|w_{R3d}-5w_{R3b}|\le \xi^L;|w_{R3e}-7w_{R3b}|\le \xi^L;\\
&w_{R1a}+w_{R1b}+w_{R1c}+w_{R2a}+w_{R2b}+w_{R2c}+w_{R3a}+w_{R3b}+w_{R3c}+w_{R3d}+w_{R3d}=1\\
&w_{R1a},w_{R1b},w_{R1c},w_{R2a},w_{R2b},w_{R2c},w_{R3a},w_{R3b},w_{R3c},w_{R3d},\ w_{R3d}\ge 0
\end{aligned}
\tag{5}
$$

Other mathematical models for experts 1,2,3, and 5 are carried out the same way for expert 4. This optimization model is completed with the help of Lingo software. The data processing results with Lingo software obtained optimal weights for each relevant risk factor from experts 1,2,3, 4, and 5 and are shown in Table 5. Additionally, as stated by [19], the value of ξ^{L*} for this model may be directly regarded as an indication of the consistency ratio of pairwise comparisons, with a value of ξ^{L*} near to zero denoting a high level of consistency. The value of ξ^{L*} is close to zero based on the output results, so the consistency of the pairwise comparisons is reliable.

Table 5 Optimal weight for each risk factor

Risks Factors	**Optimal weights (w_j*)**				
	Expert 1	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**
R1a	0.118	0.046	0.038	0.057	0.037
R1b	0.193	0.107	0.132	0.080	0.112
R1c	0.028	0.322	0.029	0.330	0.336
R2a	0.064	0.046	0.029	0.057	0.048
R2b	0.096	0.064	0.132	0.057	0.067
R2c	0.064	0.036	0.029	0.045	0.048
R3a	0.048	0.064	0.264	0.080	0.067
R3b	0.048	0.036	0.038	0.045	0.037
R3c	0.219	0.107	0.088	0.086	0.067
R3d	0.096	0.064	0.088	0.080	0.067
R3e	0.024	0.107	0.132	0.080	0.112
ξ^{L*}	0.075	0.000	0.000	0.071	0.000

The simple average of the optimal weights produced by the model for the five experts is computed to provide the final results. Table 6 and Figure 2 show each risk factor's ultimate ideal weight and ranking.

Table 6 Optimal weight for each risk factor

Risk Factor	**Average weight (w_j*)**	**Average ξ^{L*}**	**Ranking**
R1a	0.059		8
R1b	0.125		2
R1c	0.209		1
R2a	0.049		9
R2b	0.084		6
R2c	0.044	0.029	10
R3a	0.105		4
R3b	0.041		11
R3c	0.114		3
R3d	0.079		7
R3e	0.091		5

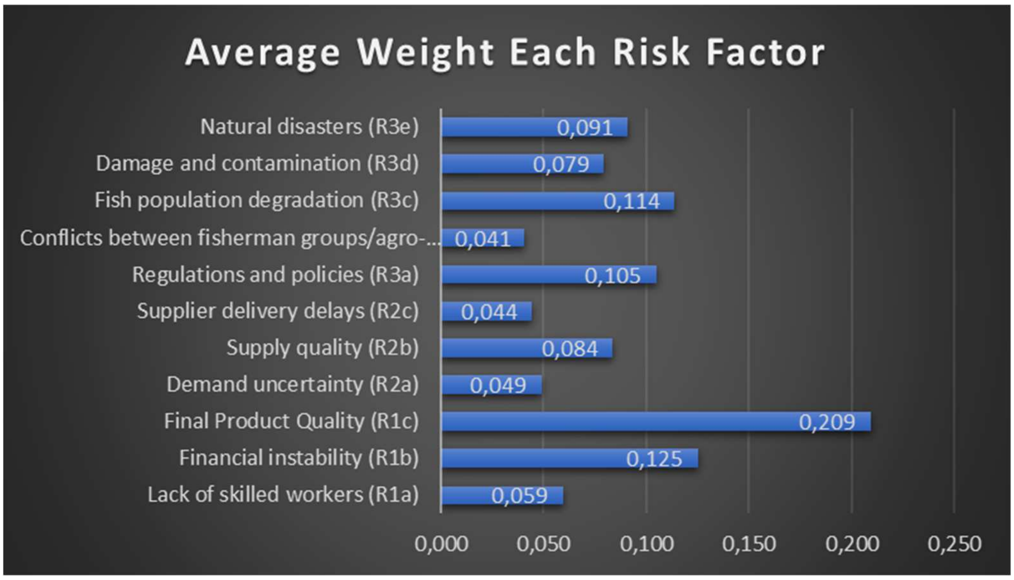

Figure 2 Smoked skipjack supply chain

The research results show that "final product quality (R1c)" is the most critical risk factor for the smoked skipjack tuna supply chain with the highest weight, 0,209. This is also reinforced by several previous studies, such as those conducted by [4,17,18] which show that the most significant risk from fish agro-industry is a decrease in the quality of the final product. The risk of "final product quality" shows that the quality management system may not function properly from upstream to downstream; this will impact business performance and pose a risk of losing consumers. Rasulu et al. (2020) state that one of the critical points of the skipjack tuna agro-industry lies in post-catch handling because it has a product that is easily damaged and contaminated with microbes. Apart from that, several factors can increase the risk of decreasing the quality of smoked skipjack tuna, including: 1) Unhygienic processing: If the fish is not processed correctly and does not meet high sanitation standards, then there is the potential for contamination by bacteria, germs or dangerous chemicals. This can hurt the quality of the fish and the risk of causing disease if consumed; 2) Lack of cooling process temperature: the cooling center temperature must be maintained between 0-4.4^0 C to prevent bacterial growth and histamine formation [25]; 3). Poor quality raw materials: The quality of skipjack tuna used as raw material also affects the quality of smoked skipjack tuna. If the fish used is not fresh or has problems, then the quality of the processed fish will also be affected; 4). Production process that does not meet standards: If the smoked skipjack tuna production process is not carried out properly or does not comply with established standards, the quality of the fish can decrease.

The following risk factor is "Financial instability (R1b)," which comes in second place with a weight of 0.125 in the final analysis. This risk element needs to be treated carefully for the smoked skipjack agro-industry in Ambon City to operate sustainably. Financial instability is an essential factor for the sustainability of business organizations because financial instability can affect the performance of business activities [20]. Smoked skipjack fish agro-industry players in Ambon City have a small capital to run their business, so sometimes the fish purchased from collectors will be paid after the product is sold out, so agro-industry development becomes difficult due to limited capital. For this reason, the government/stakeholders need a critical role in providing opportunities for agro-industry to develop [26] such as reducing burdensome regulations, helping to facilitate cooperation with financial institutions through business education, and encouraging subcontracting activities.

The third most significant risk factor, weighting 0.114, for the supply chain of smoked skipjack tuna is "fish population degradation (R3c)". This is a significant risk factor because it will impact the number of catches of skipjack tuna, which will simultaneously affect the amount of smoked skipjack tuna production. [27,28] stated that overfishing is one of the leading causes of fish population degradation. Many fishermen engage in irresponsible fishing (overfishing), such as using fishing gear that damages the marine ecosystem or catching fish still in their spawning period. As a result, the number of skipjack tuna has decreased drastically. In addition, habitat destruction also plays a role in the degradation of skipjack tuna populations. Destruction of coral reefs, mangroves, and other coastal ecosystems results in losing places to live and food sources for skipjack tuna. The degradation of skipjack tuna populations has a broad negative impact on the supply chain of smoked skipjack tuna agro-industry. Therefore, to overcome the degradation of the skipjack tuna population, the government has issued a measurable fishing policy and habitat preservation. Apart from that, collaboration between the government, fishermen, agro-industry entrepreneurs, and the community must also be engaged for the skipjack agro-industry SC to be sustainable.

According to this study, the fourth significant risk factor, with a weight of 0.105, was "regulation and policy (R3a)". This risk factor may be a key risk factor for the smoked skipjack tuna agro-industry supply chain, as evidenced by regulations restricting fishing hours during the pandemic [4] and policies raising fuel prices [29], which have an impact on the high operational costs for fishermen in fishing. For this reason, the government, as a policymaker, needs to formulate a policy that can provide a win-win solution for all parties in the skipjack tuna supply chain.

In addition, the risk factors for “natural disasters (R3e)”, “quality of supply (R2b)”, and “damage and contamination (R3d)” are ranked fifth, sixth, and seventh with respective weights of 0.091, 0.084, and 0.079. [5], The risk factor for natural disasters is the potential loss caused by natural disasters such as bad weather as a result of the current El Nino storm, blackout of the supply of electrical energy, which affects the power source for cold storage for skipjack tuna storage. The risk factor for the quality of skipjack tuna supply for agro-industry also significantly impacts the quality of the smoked skipjack produced. The risk factor for damage and contamination is also a significant risk factor for the smoked skipjack supply chain, which requires that the final product produced be in accordance with the quality of the Indonesian National Standardization.

Finally, the risk factors "Lack of skilled workers (R1a)", "Uncertainty of demand (R2a)", "Delays in supplier deliveries (R2c)", and "Conflict between fishermen/agro-industry groups (R3b)" occupy the eighth, ninth, tenth positions. And eleventh, with their respective weights tending to be the same, namely 0.059, 0.049, 0.044, and 0.041. The lack of skilled workers can also affect the final product produced, so work experience is needed from workers. Delays in deliveries from suppliers also hurt the smoked skipjack tuna supply chain, which will further reduce the performance of the smoked skipjack tuna agro-industry. Therefore, it is necessary to look for several suppliers as suppliers of raw materials for the smoked skipjack tuna agro-industry to maintain the production process. Furthermore, conflicts between fishermen/agro-industry need to be handled by building harmonious and dynamic social interactions in building relationships through communication with the formation of fishermen or agro-industry groups [17].

3.3 Sensitivity analysis

A sensitivity analysis was performed in this study to evaluate the general robustness of the results. The risk factor with the most significant weight value in this sensitivity analysis had its weight adjusted from 0.1 to 0.9 [30,31]. Table 7 below shows the outcomes of changing the weight of the "quality of the final product (R1c)" risk factor sensitivity analysis from 0.1 to 0.9:

Table 7 Weight of each risk factor during sensitivity analysis

Risks Factors	Risk factor preference weight values									
	0.1	0.2	Normal (0.209)	0.3	0.4	0.5	0.6	0.7	0.8	0.9
R1a	0.068	0.060	0.059	0.053	0.045	0.038	0.030	0.023	0.015	0.008
R1b	0.142	0.126	0.125	0.111	0.095	0.079	0.063	0.047	0.032	0.016
R1c	0.100	0.200	0.209	0.300	0.400	0.500	0.600	0.700	0.800	0.900
R2a	0.056	0.050	0.049	0.043	0.037	0.031	0.025	0.019	0.012	0.006
R2b	0.095	0.084	0.084	0.074	0.063	0.053	0.042	0.032	0.021	0.011
R2c	0.051	0.045	0.044	0.039	0.034	0.028	0.022	0.017	0.011	0.006
R3a	0.119	0.106	0.105	0.093	0.080	0.066	0.053	0.040	0.027	0.013
R3b	0.046	0.041	0.041	0.036	0.031	0.026	0.021	0.015	0.010	0.005
R3c	0.129	0.115	0.114	0.101	0.086	0.072	0.057	0.043	0.029	0.014
R3d	0.090	0.080	0.079	0.070	0.060	0.050	0.040	0.030	0.020	0.010
R3e	0.104	0.092	0.091	0.081	0.069	0.058	0.046	0.035	0.023	0.012
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

These results, shown in Table 8 and Figure 3, demonstrate that each weight varies, and the ranking of risk factors shows minor fluctuations.

Table 8 Ranking of each risk factor throughout the sensitivity analysis

Risks Factors	Normal (0.209)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
R1a	8	8	8	8	8	8	8	8	8	8
R1b	2	1	2	2	2	2	2	2	2	2
R1c	1	5	1	1	1	1	1	1	1	1
R2a	9	9	9	9	9	9	9	9	9	9
R2b	6	6	6	6	6	6	6	6	6	6
R2c	10	10	10	10	10	10	10	10	10	10
R3a	4	3	4	4	4	4	4	4	4	4
R3b	11	11	11	11	11	11	11	11	11	11
R3c	3	2	3	3	3	3	3	3	3	3
R3d	7	7	7	7	7	7	7	7	7	7
R3e	5	4	5	5	5	5	5	5	5	5

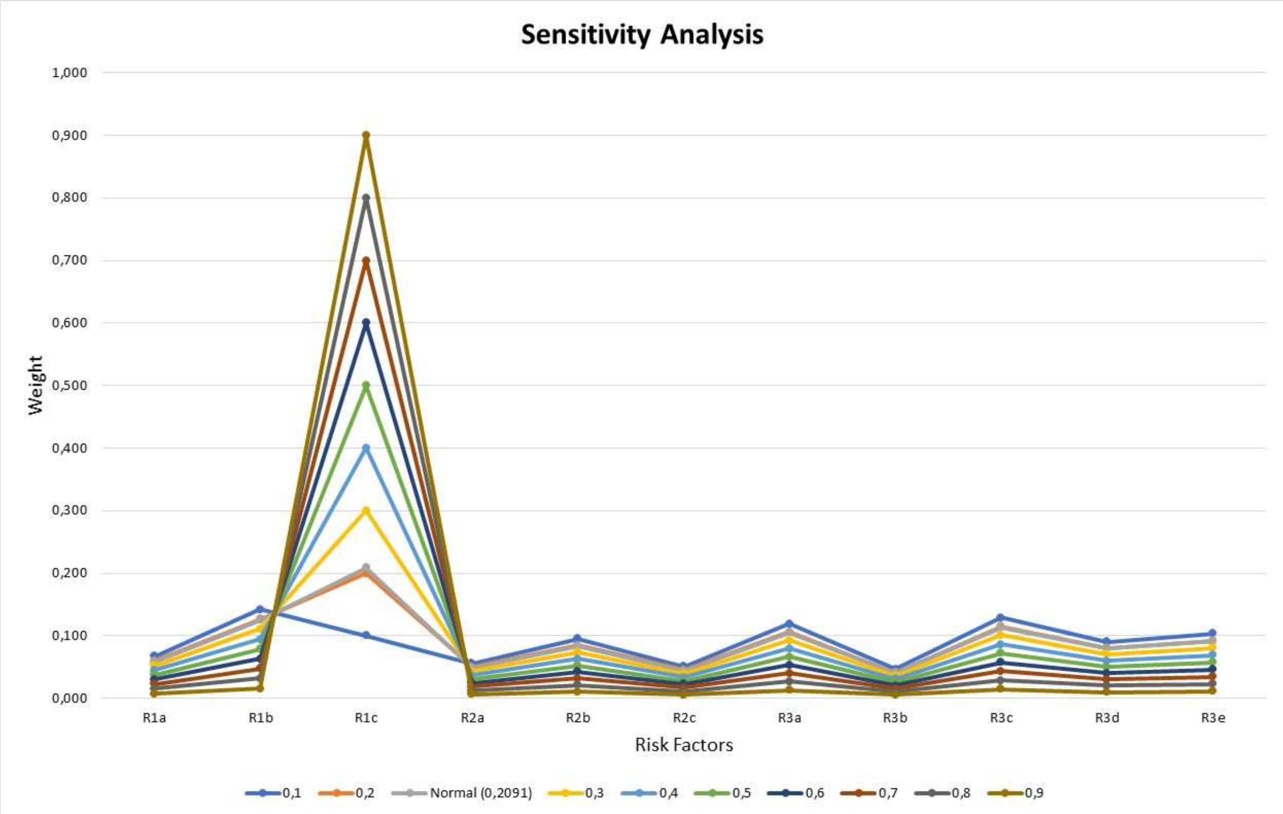

Figure 3 Graph of the weight of each risk factor during the sensitivity analysis

A little difference in the rating was discovered at a weight of 0,1 for the risk factor "quality of the final product (R1c)", with the risk factor "Financial instability (R1b)" receiving the first place, not the second., the risk factor "Government regulation (R3a)" got the position third, not fourth, the risk factor "Degradation of fish population (R3c)" is in second place, not third, the risk factor "Natural disaster (R3e)" is in fourth position, not fifth, and the risk factor "Quality of final product (R1c)" is fifth position, not first. Furthermore, no changes were noted during weight variations of 0.2 to 0.9.

3.4 Theoretical and managerial implications

The research's theoretical and managerial implications are evident. In terms of theory, this research has significantly advanced the field by breaking down the risks associated with the supply chain for smoked skipjack tuna into three categories: internal, operational, and macro-level risk. From a methodological standpoint, this study is the first attempt to use the BWM in risk assessment for agro-food supply chains. Using the BWM, it is possible to assess risk variables quantitatively and get the most accurate and dependable answers.

This research substantially contributes to the practice area in the managerial aspect. The results of this study can assist professionals in comprehending the risks associated with the skipjack tuna agro-industry supply chain and can direct decision-makers in creating a proactive risk mitigation strategy to manage the risks already present. Based on the research findings, which are summarized as follows, some particular management implications can be developed:

- Tightening the implementation of quality control and cold chain improvement from upstream to downstream. This effort is made to improve the quality and safety of food products involving the supply chain from the production stage (upstream) to the distribution and consumption stage (downstream), such as implementing strict hygiene and sanitation standards in processing areas, as well as using standard equipment that is kept clean.
- Easy access to capital in financial institutions with low interest. With easy access to capital from financial institutions with low-interest rates for agro-industry, it is hoped that more agro-industry will obtain capital to develop their businesses sustainably. This will have a positive impact on economic growth and improving community welfare, such as utilizing the People's Business Credit Program (KUR), microfinancing programs through Savings and Loans Cooperatives or Micro Financial Institutions (LKM), utilizing government programs oriented towards agro-industry.
- Application of measurable fishing policies and selectivity of fishing gear. Applying measurable fishing policies and selectivity of fishing gear is essential to prevent the degradation of fish populations. By paying attention to size, quota, fishing time, and fishing gear used, it is hoped that the fish population can be managed sustainably so that it does not experience a significant decline.
- Formulate a win-win solution policy for all skipjack tuna supply chain actors. This approach can be implemented as 1) Empowering Fish Supply Chain Actors: The government must also empower all fish supply chain actors through education, training, and access to the necessary information and knowledge. By providing adequate skills and knowledge, fish supply chain actors can increase their capacity to manage the fish business, obtain greater profits, and improve product quality. 2) Infrastructure and Technology Development: The government can develop the necessary infrastructure to facilitate fishing, processing, storage, and distribution activities. Improving infrastructure such as fish ports, fish markets, cold storage, and reasonable access roads will help speed up the process and reduce losses in the fish supply chain. In addition, the government must support technological innovation in fishing that is more efficient and environmentally friendly. 3) Fair Price and Profit Setting: The government can set up a fair price-setting mechanism for fishermen to ensure sustainable profits in the fish supply chain. This can be done by avoiding setting meager prices by mediators or market intermediaries.
- Accelerate the application of renewable energy technology for fishermen and agro-industry. Accelerating the application of renewable energy technology for fishermen can help increase productivity, reduce operational costs, and reduce the environmental impact of fishing businesses. The government and related institutions can provide incentives and support to accelerate the adoption of this technology so that fishermen can access renewable energy technology more widely and effectively.

4 Conclusion and future research

The AFSCRA has been carried out using the BWM so that several conclusions can be drawn, namely that there are 11 risk factors identified from the aspects of internal risk, operational risk, and macro-level risk. Using the BWM, the weight importance of each risk factor is obtained, which is a focus for proposed handling strategies. Three risk factors are taken based on ranking as priorities to be handled, including final product quality (R1c) with a weight of 0.29, financial instability (R1b) with a weight of 0.125, and degradation of fish populations (R3c). Furthermore, several managerial implications for more proactive risk mitigation are proposed, including tightening the implementation of quality control and improving the cold chain from upstream to downstream, easy access to capital in financial institutions with low-interest rates, implementation of measured fishing policies, and selectivity of fishing gear, formulating win-win solution policies for all actors in the skipjack tuna supply chain, and accelerating the application of renewable energy technology for fishermen and agro-industry.

There are a few limitations to this study. Using BWM, the eleven risk factors were examined. This study did not examine strategies for risk mitigation that would address identified risk factors. The scope of this study might be increased to examine and find risk-mitigation measures for the most critical risk variables. This research can also be developed by simulating the success of mitigation strategies for risk factors. Furthermore, this research can also be expanded to examine how different risk factors interact in the skipjack tuna supply chain using several MCDM methods such as Total Interpretive Structural Modelling (TISM), Fuzzy DEMATEL, or rough-DEMATEL. In addition, thorough handling is required to apply the suggested technique.

The BWM method is not only used in solving supply chain risk assessment. Still, it can also be applied widely in several research fields, for example, in the manufacturing sector, such as selecting production machines to be purchased, selecting suppliers to supply raw material needs for production, and in the transportation sector such as evaluate port performance measurements.

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