Supply Chain Risk Analysis for Organic Vegetable Farm in Indonesia

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***Abstract*—This research focuses on risk mitigation strategies in organic farming to achieve sustainable agriculture that considers profit, people, and environmental aspects. Various mitigation actions are proposed covering agricultural irrigation techniques, increasing the competence of farmers' human resources, procedures and management, and waste management. Risk analysis is carried out by identifying risks that arise in achieving key performance indicators and mitigating risks. Risk analysis using the house of risk method. A case study on an organic farmer in Indonesia was conducted. This study identified risk events that appear in the supply chain in organic farming based on 3 factors, namely 8 economic factors, 6 social factors, and 5 environmental factors.**

***Keywords*—sustainable agriculture, risk, supply chain, house of risk**

I. Introduction

The agricultural-based industrial sector (agro-industry) is the backbone of the national economy and the livelihood source for most people [1]. Agricultural products originating from local production will make it easier for agro-industry producers to obtain them. It can be said that the agro-industry grows along with the availability of relatively sufficient raw materials [2]. One of the largest agro-industry products in Indonesia is vegetable farming products. Organic vegetable farming products are the people's choice for now as an awareness of the importance of health and an environmentally friendly lifestyle. Organic farming is an agricultural cultivation system that relies on natural ingredients without synthetic chemicals [3]. The importance of organic farming is promoted worldwide to address environmental problems [4] due to the use of chemical fertilizers and pesticides [5–7]. Organic agriculture is also a solution for farming because the increasingly narrow land in Indonesia is driven by industrialization factors (agricultural services). The concept of environmental-based agriculture is growing rapidly along with the increasing standard of living and environmental awareness. The ecological farming systems developed include LISA (Low Input Sustainable Agriculture), integrated ecological farming systems, and organic farming systems [8].

The need for human resources is one of the important factors for agro-industry development to face future challenges in the era of globalization and free trade. Farmers and owners of organic farming are aspects that need to be considered for the sustainability of agriculture. Sustainable development has been the centre of attention worldwide for over a decade. Sustainable agriculture is needed to achieve sustainable development goals [9]. Comprehensive sustainable agriculture includes three basic functions of sustainable agricultural development. These functions are social, economic, and environmental. These functions are represented by agricultural systems that apply chemical reduction compared to traditional farming systems, uncontrolled soil erosion and weed control, maximum efficiency of activities (on-farm) and input materials, maintenance of soil fertility by adding plant nutrients, and the use of the basics of biology in the implementation of agriculture [10].

Sustainable agriculture is an effort to fulfil economic needs. The key factors influencing consumer demand for organic food are health awareness and people's willingness to pay for high-priced products [11]. The results of organic agricultural products prioritize high nutritional quality and are healthy for consumption. The increasing demand for organic vegetables is indicated by the development of organic farming in Indonesia. The development of organic agriculture in Indonesia from 2007 to 2011 experienced an increase of more than 180,000 ha, with a percentage increase of 49.9%. The increase in the area of organic agricultural land from 2017 until 2018 was around 17.3% [12]. Agriculture faces a major challenge in meeting the soaring demand with limited resources. At the same time, agricultural production must reduce the negative impact on the environment.

Manuscript received September 17, 2022; revised October 24, 2022; accepted April 14, 2023; published August 18, 2023.

Good practical strategies regarding organic farming supply chains are needed to achieve sustainable agriculture. Thus, the sustainability of various types of agricultural production must be measured to identify the best way to meet these challenges [13]. Risk analysis can help improve the performance of organic farming production processes. This analysis begins with identifying KPIs, then risk classification using fishbone diagrams, and the risk analysis stage.

There are several research studies on sustainable supply chain performance indicators, such as lead time indicators [14]. This study shows that supply lead times are vulnerable in resilient supply chains. Hale *et al.* [15] identified social sustainability indicators as performance. Another research was conducted by Moons *et al.* [16] by selecting logistical indicators for improving hospital operational performance while maintaining a high quality of patient care. Sun *et al.* [17] measured the performance of environmental sustainability indicators in South Asia. Moreover, Senante *et al.* [18] measured the productivity of wastewater treatment plants to improve performance from an economic and technical point of view.

Based on the literature review above, many indicators exist to improve sustainable supply chain management. However, studies to identify risks that hinder the achievement of KPI targets are still limited. Therefore, this study will identify risks and propose mitigation of these risks. This research takes a case study of Yogyakarta, Indonesia's organic agriculture supply chain. According to Adamek, Mossmer, and Hauber [19], there is an increasing demand for organic crops. Therefore, this research can help farmers to promote their agricultural products.

II. METHODS

This research takes the object of research in one of the organic agricultural agro-industry in Yogyakarta, Indonesia. The House of Risk method is used to identify and mitigate risks. According to ISO 31000, the risk is the impact of uncertainty on achieving organizational goals. Risk is often defined as a function of the probability and consequences of an uncertain outcome [20]. A risk is a form of uncertainty about what will happen in the future, with decisions made based on various considerations at this time [21].

House of Risk is a method for analyzing risk. The FMEA (Failure Mode and Error Analysis) principle to measure risk quantitatively is combined with the House of Quality (HOQ) model to prioritize risk agents that must be prioritized first and then choose the most effective action to reduce the potential risks posed by risk agents [21]. The calculation is simple. Still, the HOR method considers things not taken into account in the FMEA, for example, the possibility of a risk agent causing more than one risk agent or, conversely, a risk event caused by several risk agents.

The HOR method pays more attention to risk agents, whereas mitigation plans (preventive actions) are based on priority risk agents. After that, the sequence of preventive actions will be calculated as a direction for the company to improve the system. Therefore, the House of Risk method is a renewable method for conducting risk mapping and risk mitigation plans within the company that are appropriate for observing operational activities. The use of the HOR model aims to identify, analyze, measure, and mitigate potential risks. Risk analysis using the HOR model is used to formulate risk mitigation actions from several risk sources (agents) previously identified [21].

A. House of Risk 1

This model connects a set of needs (what) and a set of responses (how) that indicate one or more needs/needs. Each need has a certain gap to fill each response which will require resources and costs. The degree of correlation level is specifically classified: there is no relationship with giving values (0), low (1), moderate (3), and high (9). Adopting the above procedure, HOR 1 is developed through the following stages:

(1) Identify risk events (E_1) that may occur through mapping the sustainable supply chain (Social, Economic, and Environmental) and then identify what is lacking/wrong in each indicator.

(2) Estimating the impact of the risk event (S_i). This case uses a scale of 1–10, where 10 indicates an extreme impact.

(3) Assess the probability of occurrence of each risk source (O_j). In this case, a scale of 1–10 is set where 1 means that it rarely happens and a value of 10 means that it often happens.

(4) *Develop* a matrix relationship between each risk source and each risk event (R_{ij}), (0, 1, 3, 9) where 0 indicates no correlation and 1, 3, 9 indicates a low, medium, and high correlation, respectively.

(5) *Calculate* the aggregated Risk Potential of Agent *j*=ARPj, which is determined as a result of the probability of occurrence from the source of risk *j* and the set of impact causes of each risk event caused by the source of risk *j* as in the following equation:

$$ARP_j = O_j \sum_i S_i R_{ij} \tag{1}$$

(6) Rank risk sources based on a collection of potential risks in descending order (from largest to lowest value).

House of Risk 1 is shown in Table I.

TABLE I. HOUSE OF RISK 1

Risk Event E_i	Risk Agent (A_j) A_1	A_2	A_3	A_4	Severity of Risk Event (S_i)
E_1	R_{11}	R_{12}	R_{13}	R_{14}	S_1
E_2	R_{21}	…	…	…	S_2
E_3	R_{31}	…	…	…	S_3
O_i	O_1	O_2	O_3	O_4	
ARP_j	ARP_1	ARP_2	ARP_2	ARP_3	
Ranking					

where:
E_i: Risk Event
A_j: Risk Agent
R_{11}, R_{12}, R_{ij}: Relationship among risk event dan risk agent
S_i: Severity of Risk
O_j: Occurrence of agent
ARP_j: Aggregate Risk Potential of Agent

B. House of Risk 2

HOR 2 determines the first action/activity to be taken, considering the difficulty level in its implementation. Companies should ideally choose an action that is not difficult to implement but can effectively reduce the likelihood of a source of the risk occurring. The steps are as follows:

(1) Select/select a number of risk sources with a high priority ranking that may use the Pareto analysis of ARP_j.

(2) Identification of relevant action considerations for prevention of risk sources. One risk source can be implemented with more than one action, and one action *can* simultaneously reduce the likelihood of the occurrence of more than one risk source.

(3) Determine the relationship between each preventive action *and* each risk source (E_{jk}). This relationship (E_{jk}) can be considered as the level of effectiveness of action k in reducing the likelihood of the occurrence of the risk source. The values (0, 1, 3, 9) show no correlation, respectively, a low, medium, and high correlation between measures *k* and source *j*.

(4) Calculate the total effectiveness (TEk) of each action as follows:

$$TE_k = \sum_j ARP_j E_{jk} \forall k \quad (2)$$

(5) Estimate the degree of difficulty in performing each action (D_k). The degree of difficulty is indicated by a *scale* (such as a Likert scale or another scale) and reflects the funds and other resources required to perform the action.

(6) Calculate the effective total on the ETD_k difficulty ratio:

$$ETD_k = \frac{TE_k}{D_k} \quad (3)$$

(7) Priority ranking of each action (R_k) where rank 1 gives the meaning of the action with the highest ETD_k.

House of Risk 2 is shown in Table II.

TABLE II. HOUSE OF RISK 2

To be treated risk agent (A_j)	Preventive Action (PA_k)				Aggregate risk potential (ARP_j)
	PA_1	PA_2	PA_3	PA_4	
E_1	E_{11}	E_{12}	E_{13}	E_{13}	ARP_1
E_2	E_{21}	...	...	...	ARP_2
E_3	E_{31}	...	...	...	ARP_3
E_4	E_{41}	...	...	...	ARP_4
E_5	E_{41}	...	...	...	ARP_5
Total effectiveness of action (TE_k)	TE_1	TE_2	TE_3	TE_4	
Degree of difficulty performing action (D_k)	D_1	D_2	D_3	D_4	
Effectiveness to difficulty ratio (ETD_k)	ETD_1	ETD_2	ETD_3	ETD_4	
Rank priority (R_i)	R_1	R_2	R_3	R_4	

where:
A_j: The risk agent that will be mitigated
PA_k: Mitigation action to be taken
E_{jk}: Correlation relationship between risk agent *j* and risk mitigation *k*
TE_k: Total effectiveness of mitigation actions
D_k: Mitigation action difficulty level
ETD_k: Ratio of total effectiveness to difficulty
R_i: Rank of each mitigation action from the highest ETD

In this study, the first House of Risk (HOR) was conducted to identify risk agents based on the achievement of KPIs and the second was carried out on risk agents who had high risk.

III. Result and Discussions

The study was conducted on an organic farm in Yogyakarta. Organic farmers use operational standards from land, seed selection, planting process, and fertilization. The business activities of the organic farm consist of agribusiness, organic agro-tourism, general trading, and organic farming consulting services. Meanwhile, organic vegetables from agriculture include beets, carrots, beans, lettuce, chayote, broccoli, chicory, oyong, kale, scallions and celery, tomatoes, eggplant, and green okra. The target market segmentation is the modern market, direct consumers, and restaurants.

Risk analysis is identified from supply chain processes that occur in organic farming. The initiation process begins with activity mapping to make it easier to determine the activities involved in the organic farming supply chain. After the activities involved in the supply chain are known, the next step is to identify the performance indicators for each activity. Performance indicators are obtained from the results of the study of literature studies and direct interviews with farmers or parties involved in the organic farming supply chain. Supply chain performance indicators are shown in Table III.

TABLE III. SUSTAINABLE SUPPLY CHAIN INDICATORS

No	Indicators
	Socials
1	Management commitment
2	Supplier relations
3	Local procurement and supplier development
4	Increase in employee performance
5	Increase in employee commitment
6	Partnership satisfaction
	Economics
7	Production volume
8	On-time delivery
9	Customer satisfaction rates
10	Inventory costs
11	Profit / year
12	Percentage of defects
13	Distribution costs
14	Quality guarantee
	Environments
15	Innovation & improvement
16	Compliance to regulations
17	Waste management
18	Resource utilization
19	Improvement in tracking and rewarding employees for “good environmental deeds”

There are three groups of indicators, namely social, economic, and environmental, which are shown in Table III. Each aspect has indicators that are used to measure activity performance. Furthermore, in the HOR phase I, each indicator will be identified with its risk event (risk event), as shown in Table IV. The assessment of the risk event measurement uses a score scale of 1–9 based on the results of interviews with stakeholders involved in the organic farming supply chain.

TABLE IV. IDENTIFICATION OF RISK EVENTS

Kode	Indicator	Sev
	Social	
E1	Lack of management commitment	5
E2	Lack of relationship with suppliers	7
E3	Lack of involvement Local procurement and supplier development	5
E4	Lack of employee performance	5
E5	Lack of employee commitment	5
E6	Partners are not satisfied	7
	Economic	
E7	Unable to fulfill request	7
E8	Uncertain delivery time	7
E9	Dissatisfied customer	5
E10	Storage cost has increased	7
E11	Company cannot reach profit target	8
E12	Number of defective products increased	5
E13	Distribution costs are not appropriate or have swelling	7
E14	Quality does not match consumer desires	7
	Environment	
E15	Unable to treat all existing waste	3
E16	Unable to comply with rules/regulations	7
E17	Waste management is not good	5
E18	Inappropriate use of resources such as fertilizer	3
E19	Some employees are not rewarded	3

19 risk events can potentially occur in organic farming supply chain activities. The risk events of each supply chain activity are then coded from E1 to E19, as shown in Table IV. After the risk event is identified, the next step is to identify the source of risk (risk agent) that can cause the risk event. Risk agents are also measured to determine the possibility of how often the risk event occurs. The measurement results of the risk agent are shown in Table V.

TABLE V. RISK AGENT

Code	Risk Agent	Oc
A1	Inability to keep up with change	7
A2	Technology and human resources	3
A3	No big impact on an organization	5
A4	Lack of practice	3
A5	Expert	4
A6	Incorrect aim	7
A7	Lack of communication	3
A8	Management error	4
A9	lack of experience	5
A10	No method development	2
A11	Facilities do not support	5
A12	Lack of data collection	5
A13	Incorrect schedule setting within the company	7
A14	Educational background	3
A15	Lack of desire to improve	5
A16	Lack of workers	3
A17	No management support	7
A18	Not according to SOP	7
A19	Document processing time	3
A20	Planning error	8
A21	Mismatch of shipping documents	4
A22	Inaccurate place information	4
A23	Data input error	1
A24	Lack of understanding of new things	3
A25	Lack of activities that do not involve customers	4
A26	Climate and weather	5
A27	New competitor	5
A28	limited land	2
A29	company policy	1
A30	Consumer demand	3
A31	The company focuses on the cultivation	7
A32	High investment cost	5
A33	Difficult to find suppliers	6
A34	Limited resources and equipment	7
A35	Hard soil texture	5
A36	Many requirements in regulation	4
A37	Consumers increase	6
A38	Just produce. organic trash	8
A39	No supervision	3
A40	Lack of socialization among farmers	5
A41	Everyone wants to get an award	3
A42	Assessment is not transparent	7
A43	there is competition in internal management	2

In HOR phase 2, ARP is calculated based on the correlation between the risk event and the risk agent, which is determined as the result of the probability of the occurrence of the risk agent and the aggregated impact of each risk event. Furthermore, the Pareto diagram prioritizes which risk agents have a cumulative percentage of more than 80% to be handled further, as shown in Fig. 1.

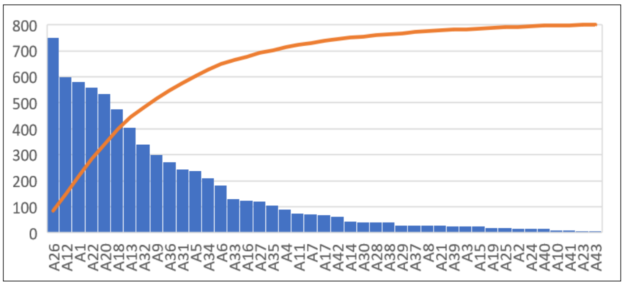

Figure 1. ARPj HOR phase 1 cumulative percentage.

TABLE VI. PROPOSED PREVENTIVE ACTION

Risk Agent Code	Preventive Action	Code
A26	Irrigation	PA1
A12	Designing a data collection program in more detail	PA2
A1	The company continuously assists employees in any changes	PA3
A22	Re-data the location of the delivery location	PA4
A20	Accumulating information and data in the planned field by utilizing resources	PA5
A18	Evaluate and revise SOPs as needed	PA6
A23	Evaluate and improve the scheduling system	PA7
A32	Implementing a rental or outsourcing system	PA8
A9	Provide training to employees regularly	PA9
A36	Prepare documents in advance	PA10
A31	Looking for outsourcing for waste treatment	PA11
A5	Adding experts	PA12
A34	Increase the capacity of resources and equipment	PA13
A6	Coordinate with partners to unify goals	PA14

14 risk agents have the highest priority, namely A26, A12, A1, A22, A20, A18, A23, A32, A9, A36, A31, A5,

A34 and A6. Each risk priority needs to be identified as a preventive measure, as presented in Table VI. For example, if the risk is caused by the risk agent A 26, namely climate and weather, then preventive measures can be taken by making irrigation lines. It is also necessary to code in identifying preventive measures; for example, irrigation prevention measures are coded as PA1.

Furthermore, it is necessary to know the effectiveness of preventive measures by calculating the correlation between preventive measures against risk agents. The calculation results in the total effectiveness value as presented in Table VII. The value of the difficulty of implementing preventive measures is obtained from calculating the effectiveness ratio to difficulty (ETD_k). Then the decision-making regarding which preventive action should be taken first is presented in the percentage shown in Fig. 2.

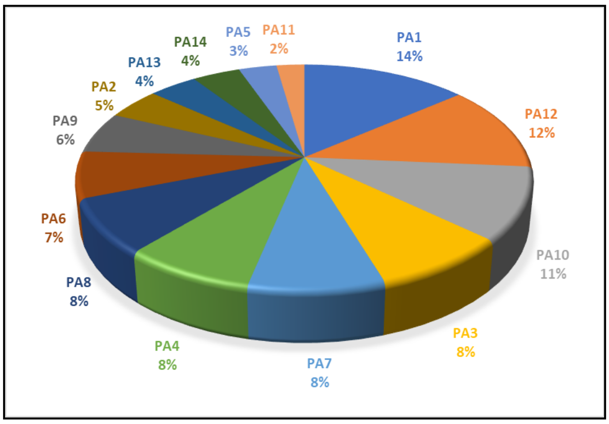

Figure 2. ETDk percentage.

TABLE VII. HOR FASE 2

Risk Agent	Preventive Action														ARPj
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12	PA13	PA14	
A16	9						3					3			750
A12		9		3			3			9		3	3	3	600
A1			9			3		3	9			3			581
A22				9		3	3			9					560
A20	3			3	9	3	3	3		3		9			536
A18		3	3			9	3	3						3	476
A23	3			3			9			3		3			406
A32	9							9	3						340
A9			9						9			3			300
A36								3		9					272
A31			3								9				245
A5						3		3				9			240
A34													9		210
A6														9	182
TE_k	12636	6828	10092	9666	4824	10035	12420	9375	8949	15714	2835	14895	3690	4866	
D_k	3	5	4	4	5	5	5	4	5	5	4	4	3	4	
ETD_k	4212	1365.6	2523	2416.5	964.8	2007	2484	2343.75	1789.8	3142.8	708.75	3723.75	1230	1216.5	
R_i	1	10	4	6	13	8	5	7	9	3	14	2	11	12	

Prevention measures PA1 (irrigation) has the largest value of 14%, while the lowest percentage is PA11 (Seeking outsourcing for waste treatment) with 2%. So that it can be seen that preventive measures to make irrigation for water distribution have high effectiveness if they are realized to reduce events that pose a risk to the sustainability of organic agriculture.

Overall, the risk events that may hinder the sustainability of the supply chain in organic agriculture are caused by three factors: the risks that occur in social, economic, and environmental factors caused by human error, processes, methods, and management. Risk measurements can be carried out to overcome this, including the House of Risk (HOR). The House of Risk combines the FMEA method with the HOQ (House of Quality) into a simple quantitative calculation to map risks based on their priorities.

The results obtained were 36 risk events and 43 risk agents. Then the ranking is carried out using a Pareto diagram where 19 risk events and 14 valid risk agents are obtained based on a priority rating of 80%.

The priority of risk agents is based on the Aggregate Risk Potential (ARPj) and Pareto Diagram, then 14 preventive actions are prepared that can be considered as solutions to problems that threaten the sustainability of organic agriculture. HOR stage 2 has provided direction regarding priority mitigation actions that must be carried out by the company based on the greatest effectiveness value (ETD_k), namely Irrigation (PA1), Adding experts (PA12), Preparing initial documents (PA10), The Company continues to assist employees in any changes (PA3) and finally seek outsourcing for waste treatment (PA11).

IV. CONCLUSION

The conclusion that can be drawn from research in organic agriculture is that company risk management using the HOR method can be executed successfully. HOR is a renewable method in risk mapping that combines the principles of FMEA and HOQ. The advantage of this method is to consider the possibility of risk events caused by several risk agents and risk agents. The identified risk events are likely to appear in the supply chain in organic farming based on 3 trigger factors, namely 8 economic factors, 6 social factors and 5 environmental factors. These paper obtained 19 risk events and 14 valid risk agents to be mitigated.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Elisa kusrini designed and directed the project; Bayu Wahyudi and Palmadi Putri Surya Negara performed the survey; Elisa kusrini and Bayu Wahyudi and Palmadi Putri Surya Negara performed the analysis; Elisa kusrini and Bayu Wahyudi and Palmadi Putri Surya Negara and Syarif Hidayatuloh drafted the manuscript; all authors provided critical feedback and helped shape the research, analysis and manuscript; all authors had approved the final version.

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