DOI 10.18551/rjoas.2019-12.08

RISK MITIGATION OF SUSTAINABLE SUPPLY CHAIN FOR FOOD PRODUCT BASED ON APPLE COMMODITY

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ABSTRACT
The sustainability of the production of food products based on apples as an icon of Batu City needs attention because of the decline in apple production that has occurred in recent years. Thus, this study aims to analyze the risk of sustainable supply chains for apple-based food products in terms of production and procurement of raw materials. The study uses primary data by conducting interviews and filling out questionnaires by informants from businessmen, farmers, related academics, and the local government of Batu City. Fuzzy Failure Mode and Effect Analysis (FFMEA) technique is used to determine the priority of risk mitigation efforts. The findings indicate the risk to the sustainability of the supply chain of food products derived from apples is low to moderate, while the risk at the level of apple farmers is higher than the risk of processed apple products. Therefore, increased farmer adaptation to climate change is needed to maintain the sustainability of apple supply as a risk mitigation effort.

KEY WORDS
Sustainable supply chain, risk mitigation, Fuzzy FMEA.

Good risk management is started from the identification of risks that might occur along with the factors that cause it from the entire chain. Risk measurement is then carried out on the potential risks that have been identified to determine mitigation efforts (Mishra and Shekhar 2011). Over the past decade, company management has been responsible for the sustainability of its production and supply chains. The concept of sustainable supply chains encompasses a broad range of activities, such as sustainable procurement, sustainable production, eco-design, sustainable distribution, and investment recovery (Esfahbodi et al. 2016). While research related to risk mitigation is mostly done using the Failure Mode and Effect Analysis (FMEA) method to rank risk priorities, thus appropriate preventive measures can be formulated (McDermott et.al., 2009; Kumru and Kumru, 2012; Feili et.al., 2013 ; Sutrisno et al, 2015). FMEA is now much more developed, one of which is by integrating fuzzy logic to support appropriate decision making actions in effective, efficient and responsive supply chain management at every level of the supply chain (Wang et al, 2009; Suharjito et al, 2010; Feili et al, 2013; Yang and Wang, 2015).

Apple is one of the iconic commodities in Malang, especially in Batu City. Various processed apple food products are increasingly popular with increasingly diverse variants. In the last decade, tourism in Batu City has increased sharply with the entry of private companies that manage various rides and lodgings for families. This also increases the number of local and foreign tourists visiting Batu City. Recorded in the last 5 years, tourist visits increased especially at the end of the year (BPS, 2018). When visiting, tourists will do shopping (Kinley, et al, 2012), and become a common activity undertaken by tourists (Hu & Yu, 2007; Kemperman, Borgers, & Timmermans, 2009). Some studies suggest that tourists will spend quite a lot of expenses during visits to shopping activities, especially souvenirs (Hu & Yu, 2007). It can be concluded that the higher the visit activity in Batu City, the more will be learned from typical souvenirs of Batu City, namely apple-based processed products.

The sustainability of apple-based processed products as icons of Batu City is strongly influenced by the sustainability of the supply of apple raw materials. Unfortunately, the local apple raw material in Batu City has experienced a production decline and is projected to continue to decline. Changes in the value of production are caused by various factors, including climate change and land conversion (Ifanina, 2017). Alim et al (2018) in their research stated that the supply chain performance of small apple processing industries in Batu City currently still needs improvement in the preparation of raw materials. This fact needs to be the focus of the local government in order to maintain the characteristics of Batu City and increase the creative economic activities of its people.

The sustainability of the production of apple-based food products is highly dependent on the continuity of apple supply in Batu City and its surroundings. The decline in apple production that has occurred in recent years (BPS Kota Batu, 2018) is a factor that needs to be considered in the formulation of policy scenarios for the development of apple agro-industry. In an effort to maintain the availability of processed apple products as iconic Batu City souvenirs, a supply chain system is needed that is able to guarantee the supply of raw materials. There are several factors that affect supply chain performance, such as the flow of raw materials, the flow of funds, to the flow of information that must be integrated with each other from each stakeholder involved. The sustainability of the production of apple-based food products is expected to be guaranteed with an adaptive supply chain. Therefore, preventive action is needed for the risks that may occur in the supply chain.

LITERATURE REVIEW

The main activities in the sustainable supply chain consist of three main activities, namely sustainable procurement, sustainable distribution and sustainable production. The raw materials applied by the company are raw materials with ecological attributes, can be recycled, non-toxic materials, minimize hazardous waste materials and reusability. This requires collaboration with suppliers to develop products or services that are environmentally sustainable (Carter and Rogers, (2008). According to Vachon and Klassen (2008) that there is strong collaboration between suppliers and companies in the adoption and development of innovative environmental technologies. Whereas distribution with environmental issues is related to sustainable transportation, storage, inventory control, warehousing, packaging, and facility decisions that have the least negative impact on the environment. Meanwhile, sustainable production is a production process that uses inputs that have an impact on reducing waste and pollution. Eco-design plays an important role in the efficient production process. In implementing a sustainable production system, it requires cross-functional cooperation within the company units and also collaboration between organizations involved in the supply chain.

To minimize the occurrence of risk, managers should carry out the stages in the Supply Chain Risk Management which consists of 5 stages, namely:

1. Risk identification: this is the first step where all possible supply chain sustainability related to risk is identified with tools such as risk checklist, taxonomy and risk mapping (Chapman, 2006).
2. Risk assessment: assessment of all identified risks, characteristic of likelihood regulations, of their effects on supply chain performance. Commonly used methods such as intuition (Brainstorming), inductive (Checklist, Preliminary Hazard Analysis, Event and Fault Tree Analysis and FMEA) or deductive (Accident Investigation, Controlled Experiments). (Chapman, 2006).
3. Risk Analysis: after risk assessment, risk is prioritized into conditions of relative importance. Methods that can be used to analyze the causal effects of risk include using the AHP (Analysis Hierarchical Process) method, correlation analysis, experimental control or stimulation of the causal relationship between risks. With this analysis, root

causes and potential impacts of risks can be obtained, so that they can be used as a basis for developing strategies for treating two or more possible risks.

4. Risk Treatment: there are four main responses suggested to address supply chain risks. Responses related to sustainability include:
    - Avoid: involvement by avoiding some activities that lead to the possibility of opening a risk, for example: eliminating or not choosing suppliers who use technology or processes that do not implement a sustainability system
    - Control: form of delays by preventing risk through reducing the likelihood of risk, for example: establishing a supplier development program to reduce the possibility of environmental damage
    - Allocation: a form of engagement by working with suppliers to share risks, for example: supply chain multilateral agreements in terms of the level of carbon emissions and the use of insurance against potential risks.
    - Holding: a form of involvement by accepting potential damage that can occur in a risk related sustainability, in matters where the actual costs of other strategies will be higher than the costs of potential damage.
5. Continuous involvement by monitoring the impact and response of strategies for some risks, identification of changes in the nature of supply chains or changes in regulations or operational regulations and the proportion of new solutions.

METHODS OF RESEARCH

The research location is Batu City as the region that has the largest apple agroindustry production and center in Indonesia. Batu City has been known for its iconic apple commodity and is expected to maintain its sustainability. While informants are needed to identify variables and stakeholders in the system, verify the system that was built and provide justification for the risks faced in the sustainable supply chain of the apple-based food product industry. The informant selected has to have comprehensive knowledge related to the procurement of raw materials to the production of processed apples. The informants will be represented by several parties, including decision makers in the agro-industry, academics, and the local government.

Risk assessment on sustainable supply chains is carried out using the Fuzzy FMEA analysis method. Fuzzy FMEA method is used to obtain priority level results from risks in variables from the results of scoring that have been done. Fuzzy Logic in categorizing problems or causes of risks in the supply chain uses 3 criteria considerations, namely Severity (S), Occurrence (O), and Detection (D). Occurrence to indicate the likelihood of failure occurring is indicated on a scale of 1 to 10, where the scale starts from (1) shows events that almost never happened, to the scale (10) which shows the events that are most likely to occur or are difficult to avoid.

Steps taken to analyze risk factors with FFMEA using analytical techniques developed by Wang et al (2009), namely:

- Determine the scale value on O, S, D;
- Calculate the aggregation of fuzzy rating ratings for factors O, S, D scale;
- Calculate the weighting of the importance of factors O, S, D;
- Determine the value of FRPN (Fuzzy Risk Priority Number) for each failure mode based on the equation;
- The highest FRPN result will be the priority risk value that needs to be mitigated.

Severity (S) is a quantification of how serious the condition is if a failure occurs. According to the level of seriousness, severity is assessed on a scale of 1 to 10. The severity scale can be seen in Table 1.

Table 1 – Criteria and Fuzzy Number Severity

Ranking	Severity Effect	Rating	Fuzzy Number
Danger without warning (HWOW)	Severity is very high without warning	10	(9, 10, 10)
Danger with warning (HWW)	Severity is very high with warning	9	(8, 9, 10)
Very high (VH)	Very high impact on sustainability	8	(7, 8, 9)
High (H)	High impact on sustainability	7	(6, 7, 8)
Moderate (MH)	Moderate impact on sustainability	6	(5, 6, 7)
Low (LM)	Low impact on sustainability	5	(4, 5, 6)
Very Low (ML)	Very low impact on sustainability	4	(3, 4, 5)
Minor (R)	The impact is not so visible on sustainability	3	(2, 3, 4)
Very Minor (VR)	Almost no impact on sustainability	2	(1, 2, 3)
None (N)	There is no influence	1	(1, 1, 2)

Source: Wang et al (2009).

Occurrence (O) indicates the probability of failure. This is shown from levels 1 to 10 with an explanation of almost never happening (level 1) to most likely to occur or difficult to avoid (level 10). The scale of occurrence can be seen in Table 2.

Table 2 – Occurrence Criteria

Criteria	Failure Probability	Ranking
Very high (VH): Errors cannot be avoided	1: 2	10
	1: 3	9
High (H): Repeated errors	1: 8	8
	1: 20	7
Moderate (M): Errors sometimes occur	1: 80	6
	1: 400	5
Low (L): Relatively few errors	1: 2000	4
	1: 15000	3
Minor (R): An error might not occur	1: 150000	2
	1: 1500000	1

Source: Wang et al (2009).

Table 3 – Fuzzy Number Occurrence

Ranking	Criteria	Fuzzy Number
Very high (HV)	Errors cannot be avoided	(8, 9, 10, 10)
High (H)	Repeated errors	(6, 7, 8, 9)
Moderate (M)	Errors sometimes occur	(3, 4, 6, 7)
Low (L)	Relatively few errors	(1, 2, 3. 4)
Minor (R)	An error might not occur	(1, 1, 2)

Source: Wang et al (2009).

Table 4 – Criteria and Fuzzy Number Detection

Possible Detection	Criteria	Rating	Fuzzy Number
Absolute uncertainty (AU)	No chance to detect errors	10	(9, 10, 10)
Very Minor (VR)	Very small chance to detect errors	9	(8, 9, 10)
Minor (R)	Small chance to detect errors	8	(7, 8, 9)
Very low (VL)	Very low chance to detect errors	7	(6, 7, 8)
Low (L)	Low chance to detect errors	6	(5, 6, 7)
Moderate (M)	Moderate chance to detect errors	5	(4, 5, 6)
Moderately high (MH)	Moderately high chance to detect errors	4	(3, 4, 5)
High (H)	High chance to detect errors	3	(2, 3, 4)
Very high (VH)	Very high chance to detect error	2	(1, 2, 3)
Almost certain(AC)	Almost certainty to detect errors	1	(1, 1, 2)

Source: Wang et al. (2009).

Detection (D), shows the level of failure that caused the failure of the installed control. The level of this criterion is 1 to 10 where number 1 explains the possibility to pass from the control is very small (detected), and number 10 indicates the possibility to escape control is very large (not detected). This detection scale can be seen in Table 4.

DISCUSSION OF RESULTS

Risk Analysis of Sustainability of the Apple Juice Supply Chain. Severity, Occurrence, and Density (SOD) analyzes were carried out on the sources of risk that were the main concern of apple juice supply chain stakeholders. Based on interviews with key informants, a number of priority risk sources are presented in Tables 5 and 6.

At the level of apple farmers, the risks of sustainability consist of risks of decreasing production and prices that are not in line with farmers' expectations. Crop damage consists of risks of crop vulnerability, difficulties in obtaining labor (especially during harvest and post-harvest), pest attacks, and climate uncertainty. Risk of plant vulnerability can occur due to the use of seedlings that are not superior and lack of input capital in plant maintenance. Risks to prices that can occur are low selling prices and are not in line with farmers' expectations and selling price uncertainty.

Table 5 – Sustainability Risks and Causes of Apple Farmers

No	Risks	Causes	Effects
1	Vulnerability of plants to damage	The seeds used are not superior	Plants are easily attacked by diseases and pests
2	Selling prices do not match expectations	Product quality decreases or there is too much supply	Reducing the motivation of farmers
3	Uncertain selling prices	Prices are determined by supply and demand	Reducing the motivation of farmers towards agricultural products
4	Difficulty obtaining manpower	Lack of community interest in agriculture	Difficulties to increase capacity
5	Pests and plant diseases	Farmers have not been able to determine the right and economic treatment of pests	Reducing apple production
6	Climate uncertainty	Farmers have not been able to adapt to climate change	Reducing apple production

The risk of crop vulnerability to damage can occur due to the efforts of farmers who are less than optimal in maintaining apple crops. This happens because there are still many farmers who use subsidized chemical fertilizers that are difficult for farmers to obtain. When fertilizer cannot be obtained, farmers do not apply fertilizer to their crops. Limited capital in the procurement of production inputs in the form of fertilizers and superior seeds causes a decrease in farmer productivity. Difficulties in obtaining labor, especially at harvest time, can result in product handling activities. In addition to having an impact on cash flow, this can have an impact on the quality decline of apples which will then be related to price risk.

Risks related to prices that can cause the sustainability of apple farming are low selling prices, especially during the harvest season. This happens because the quality of the products produced is not uniform. In addition, farmers have not been able to fulfill small medium enterprise (SME) orders continuously, so far the majority of apple farmers in the Malang area still depend on middlemen to market their products. The middleman will then distribute the apple to SME at a higher price. The distribution of products through middlemen causes the selling price of the product to have high uncertainty because it follows the concept of market supply and demand. This can actually be anticipated by activating farmer groups of apple farmers and establishing partnerships with SME.

At the producer level, there are 8 risks prioritized by key informants consisting of economic, social and business environment aspects.

Table 6 – Sustainability Risks and Causes of Apple Juice Producers

No	Risk	Causes	Effects
1	Shortage of raw material supply	Apple farmer productivity decreases	Inhibited production
2	Failure to fulfill an order	Power outages, capacity limitations, product damage during production	Decreasing consumer belief
3	Discontinuities raw materials	Apple farmer productivity decreases	Inhibited production
4	Product damage when shipping	Poor handling	Reducing profit
5	Complaints from the surrounding community	Waste in the production environment and noise pollution	Triggering conflict with the community
6	Complaints from consumers	Product received is defect	Decreasing consumer belief
7	Lack of skills and workforce innovation	Labor that is used without selection	Inhibiting innovation efforts
8	Pollution of the surrounding environment	Lots of rubbish and dust resulting from community activities	Product contamination - product defects

The risk to producers associated with farmers is mainly the lack of raw material supply. Raw materials are the most important factor for apple juice producers to run their businesses. In addition to hampering productivity, the lack of raw materials causes producers to not be able to produce efficiently. Limitations and the supply of raw materials those are not continuous from the Malang area causes producers to pay higher prices for raw materials from outside the Malang area to maintain the sustainability of their production. In the long run, if this continues, it can reduce the profit received by SMEs, thereby disrupting the sustainability of their business.

Failure to fulfill orders can occur other than due to lack of raw materials, but can also occur due to internal and external factors that inhibit production such as power outages, damage to production machinery, damage to products during production, as well as the difficulty of producers to increase production capacity. If the producer cannot fulfill the customer's order, it can result in a decrease in trust and customer switching to other products.

Manufacturers use automatic machines in their production processes that depend on electrical energy. Power outages can occur at any time and cause production loss because the product cannot be processed and eventually damaged. Failures also occur in fulfilling additional orders from customers during holidays. This happens because producers have difficulty in increasing production capacity due to lack of labor.

Social risks to producers include complaints from customers and surrounding communities. Complaints from customers occur because of damaged products or late delivery while complaints from the community occur due to residual production waste and noise pollution that occurs due to production and transportation activities. Pollution of the surrounding environment also contributes to the sustainability of SMEs because it can contaminate products that can cause conflicts with the community.

Analysis of Severity, Occurrence, and Density of the Sustainability of the Apple Juice Supply Chain. The risks that have been identified are then assessed for their impact (severity), likelihood of occurrence, and ease of being detected (density) on the sustainability of the apple juice supply chain. The results of the assessment are presented in Tables 7, 8, and 9.

Based on Table 7 it is known that at the farmer level, the risk with the greatest impact is pests and plant diseases while the risk with the smallest impact is labor shortages. At the producer level, the biggest impact occurs on product damage while the smallest impact is also owned by labor factors. Thus, it can be concluded temporarily that based on the opinion of the informants, labor does not have a large impact on the sustainability of the apple juice supply chain.

Table 7 – Severity Risk Value of Unsustainable Apple Juice Supply Chain

No	Risks	Average Value	Criteria
1	Vulnerability of plants to damage	6.50	VMR – MR (Moderate)
2	Selling prices do not match expectations	7.08	VH (Very high)
3	Uncertain selling prices	8.00	VH (Very high)
4	Difficulty obtaining manpower	3.67	MR-L (Minor)
5	Pests and plant diseases	8.75	VH-HWW (High- Danger with warning)
6	Climate uncertainty	7.83	VH (Very high)
7	Shortage of raw material supply	7.00	H (High)
8	Failure to fulfill an order	6.00	M (Moderate)
9	Discontinuities raw materials	6.00	M (Moderate)
10	Product damage when shipping	8.00	VH (Very high)
11	Complaints from the surrounding community	7.00	H (High)
12	Complaints from consumers	7.00	H (High)
13	Lack of skills and workforce innovation	3.00	MR (Minor)
14	Pollution of the surrounding environment	7.00	H (High)

Table 8 – Occurrence Value of Sustainability of Apple Juice Supply Chain

No	Risks	Average Value	Criteria
1	Vulnerability of plants to damage	6.50	H (High)
2	Selling prices do not match expectations	7.08	H (High)
3	Uncertain selling prices	6.17	M (Moderate)
4	Difficulty obtaining manpower	3.67	L (Low)
5	Pests and plant diseases	8.75	H (High)
6	Climate uncertainty	7.83	H (High)
7	Shortage of raw material supply	3.00	L (Low)
8	Failure to fulfill an order	7.00	M (Moderate)
9	Discontinuities raw materials	3.00	L (Low)
10	Product damage when shipping	8.00	H (High)
11	Complaints from the surrounding community	8.00	H (High)
12	Complaints from consumers	2.00	L (Low)
13	Lack of skills and workforce innovation	6.00	M (Moderate)
14	Pollution of the surrounding environment	6.00	M (Moderate)

Table 9 – Density Value of Risk of Unsustainable Apple Juice Supply Chain

No	Risks	Average value	Criteria
1	Vulnerability of plants to damage	5.83	L (Low)
2	Selling prices do not match expectations	6.67	VL (Very low)
3	Uncertain selling prices	6.17	L (low)
4	Difficulty obtaining manpower	5.42	M (moderate)
5	Pests and plant diseases	4.17	MH (Moderately high)
6	Climate uncertainty	6.25	L (Low)
7	Shortage of raw material supply	6.00	L (Low)
8	Failure to fulfill an order	1.00	AC (Almost certain)
9	Discontinuities raw materials	7.00	VL (Very low)
10	Product damage when shipping	3.00	H (High)
11	Complaints from the surrounding community	3.00	H (High)
12	Complaints from consumers	10.00	AU (Absolute uncertainty)
13	Lack of skills and workforce innovation	2.00	VH (Very high)
14	Pollution of the surrounding environment	2.00	VH (Very high)

Based on Table 8, it can be seen that pests and plant diseases have the highest incidence rates. Meanwhile, constraints on labor are the least common risks among other risks. At the producer level, community complaints around the production site are the most common risk due to noise and residual waste production. The lowest risk level of occurrence is

complaints from the public regarding damaged products. This is due to a faulty product being detected beforehand at the production site or at the time of delivery.

Table 9 shows that selling prices are the most difficult risk to detect compared to other risks at the farm level. Meanwhile pest attacks are the most easily detected risks because they usually occur at certain times. At the producer level, complain from consumers is a risk that is almost impossible to detect while failure to fulfill orders can be detected properly.

Apple Juice Sustainability Priority Risk Analysis. The SOD value that has been obtained is then processed using the MATLABR2019 software to produce a Fuzzy Risk Priority Number (FRPN) value presented in Tables 10 and 11. The analysis was performed using 500 rules (if-then rules), which were entered into the system. The rules contained in this fuzzy FMEA are a combination of 3 input variables, namely severity, occurrence, and detection as well as the output of the fuzzy RPN itself using if-then rules. Rules that are formed from 3 input variables consist of S in 10 categories, O in 5 categories, and D in 10 categories so that a total of 500 rules (10x5x10) is obtained.

Table 10 – Value of Sustainability Fuzzy Risk Priority Number for Farmers

No	Risks	S	O	D	RPN	FRPN
1	Vulnerability of plants to damage	6,50	6,50	5,83	246,32	249
2	Selling prices do not match expectations	7,08	7,08	6,67	334,34	364
3	Uncertain selling prices	8,00	6,17	6,17	304,55	321
4	Difficulty obtaining manpower	3,67	3,67	5,42	73,00	92,1
5	Pests and plant diseases	8,75	8,75	4,17	319,27	371
6	Climate uncertainty	7,83	7,83	6,25	383,18	378

Table 10 shows that there is almost no difference in risk ranking between RPN assessments with traditional methods and with the fuzzy approach. However, the results of calculations with fuzzy logic integrations provide RPN values with a much greater range for each risk. Significant value differences occur in the risk of pest attack from the two approaches. In traditional FMEA, pest attacks have a third RPN sequence, but based on the results of analysis with fuzzy has the second highest order. The greatest sustainability risk at the apple farmer level is climate uncertainty while the risk with the smallest value is the difficulty of obtaining employment. Overall, risks at the farm level have a range of low to moderate values.

Table 11 – Value of Sustainability Fuzzy Risk Priority Number for Producers

No	Risk of SME	S	O	D	RPN	FRPN
1	Shortage of raw material supply	7	3	6	126	133
2	Failure to fulfill an order	6	7	1	42	24,5
3	Discontinuities raw materials	6	3	7	126	133
4	Product damage when shipping	8	8	3	192	208
5	Complaints from the surrounding community	7	8	3	168	208
6	Complaints from consumers	7	2	10	140	208
7	Lack of skills and workforce innovation	3	6	2	36	24,5
8	Pollution of the surrounding environment	7	6	2	84	75

Table 11 shows that the lowest risk at producer level is failure is failure to fulfill orders and labor constraints. While the highest risk is complaints from the public, complaints from customers, and product damage when shipping. The results of a risk analysis on the sustainability of the apple juice supply chain based on the informant's assessment can be concluded that the sustainability risk is low to moderate. The risk is higher at the farmer level in terms of the supply of raw materials used in the apple juice production process.

CONCLUSION

Fuzzy FMEA analysis on the apple juice supply chain results in the conclusion that the sustainability risk that needs to be a concern at the farm level is climate uncertainty and crop diseases due to climate change. On the other hand, the main risks of sustainability at the producer level are product damage when shipping, complaints from consumers, and complaints from communities around the production site. Risk mitigation that needs to be done to maintain the sustainability of apple supply is to increase farmers' adaptation to climate change. Cooperation between the two stakeholders is needed in the form of partnership. Meanwhile, the sustainability of production requires measures to prevent product defects both during production and shipping. To avoid conflicts with the surrounding community related to waste can be done by processing liquid and solid waste so that it can be used as fertilizer by partner farmers. Therefore, attention from the local government is needed through the distribution of information technology and the latest methods that can improve the productivity and capacity of both supply chain actors.

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