Risk measurement of supply chain for soy sauce product

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Abstract. Soy sauce is one of the fermented-soybean product that is widely used as a food flavoring. The high demand of soy sauce requires Company X, as producers, to ensure that consumer needs are always met. Therefore, it needs the help of many stakeholders, including suppliers and distributors to support the continuity of production. Since many members are involved, Company X needs to maintain the optimal performances. One of which is by applying supply chain risk management. This study aimed to identify and analyze supply chain risk in the soy sauce production process. Firstly, all activities carried out by supply chain members were mapped using Supply Chain Operational Reference (SCOR) approach. Secondly, the potential risk of these activities was analyzed using House of Risk Phase 1 (HOR-1) method. 16 risk events and 19 risk agents were identified based on SCOR approach and HOR-1 method. Following the risk identification stage, the priority rank of risks was analyzed using Aggregate Risk Priority (ARP). The results showed that there were 5 priorities of risk agents required to be mitigated, i.e. human error, misorder of product, power outage, raw materials variants, and disruptions during product transportation. This study suggests risk mitigations as follows: to give rewards, punishments, and work motivation to workers; to alter and enhance SOP of ordering, storing, distributing, and supplier cooperations; to use electricity generator during the production process; to control the quality of raw materials; and to regularly maintain the distribution vehicle.

1. Introduction

Soy sauce is a seasoning agent with a salty taste and a distinct aroma suggestive of meat extracts. The sauce is made by fermentation of a combination of soybeans (Glycine max L.) and wheat in water and salt [1]. For Indonesians, soy sauce is usually used as a flavoring food because it can provide a unique taste and aroma for the food. The demand of soy sauce was quite high as shown by the production of soy sauce reaching 81,709,271 liters in 2018, and kept increasing along with the population growth, consumer purchasing power, and culinary variations in Indonesia. In addition, soy sauce contains a variety of nutritional substances, such as carbohydrates, proteins, amino acids (AAs), fats, vitamins, nicotinic acid, and a variety of minerals. AAs, which account for 50%-75% of total nitrogen contents, are important nutrients in soy sauce [2].

One of the companies producing soy sauce is Company X with a production capacity of 7,500 bottles everyday, with a volume of 625 mL per bottle. The product is distributed to some regions in Indonesia, especially East Java, include Trenggalek, Tulungagung, Kediri, Nganjuk, Blitar, and Surabaya. Company X was one of the soy sauce producers with high demand in East Java, with total sales in 2018 reached IDR 5,000,954,400. The high demand and sales of the product indicate that Company X is a
producer of soy sauce with good quality so that it is favored by consumers throughout Indonesia. In order to produce good product to consumers, Company X involves many parties, i.e. suppliers, manufacturer, and distributors. Therefore, good cooperation is needed between these parties in a supply chain system.

The supply chain system of Company X consists of (1) suppliers as provider of raw materials, (2) manufacturer as transformer of raw material into product, (3) distributors as supplier of product to consumers. Each supply chain member potentially causes risks or failures that can affect product conditions and harm other supply chain members [3]. Non-standard product quality, financial loss, and the tarnished company's image are the consequences of such risks or failures [4]. Therefore, risk analysis in the supply chain system needs to identify and analyze the possible risks that can occur to each member of the supply chain. Priority risks obtained from the results of the analysis must be controlled and managed to minimise the impact and find the strategies to improve them [5].

A well-managed and well-risk analyzed company can minimize the incurred losses. In addition, good risk management is also an added value for the company to survive and compete in the industrial world. Hence, the aims of this research were to analyse the supply chain risk of soy sauce product, and to provide mitigation advices so that the company X can minimise risks and improve the quality of service, product, and product expansion.

2. Research Methods

The method used to analyse supply chain risk was divided into several stages. The first stage was to identify each actor activity using Supply Chain Operational Reference (SCOR) approach [6]. The next stage was to identify the risks in each actor activity using brainstorming methods, interviews, and discussions with experts i.e. suppliers, head of production, Quality Control and Assurance supervisors, and distributors. The risks obtained were, then, analyzed using House of Risk Phase 1 (HOR-1) [7].

HOR-1 was used to determine priority risk agents based on Aggregate Risk Potential (ARP) value for prevention. The stage processes from HOR-1 were to:

1. Identify risk events (Ei) occurred in each supply chain activity. Risk identification was conducted through supply chain mapping using SCOR method. It divided business activities into plan, source, make, deliver, and return [6].
2. Determine the level of impact/severity (Si) of a risk event which showed how much interference caused by a risk event to the supply chain process (Table 1).
3. Identify the risk-causing agent (Aj), namely the factors causing the occurrence of a risk event that has been identified.
4. Measure the probability value of the occurrence of a risk agent. Occurrence stated the probability level of the frequency of occurrence of a risk agent. Probability level is the magnitude of the probability of failure occurred which potentially causes a risk event (Table 1).

| Impact Level | Probability (%) | Scale | Frequency Level | Probability (%) | Scale |
|--------------|-----------------|-------|-----------------|-----------------|-------|
| Very High    | ≥ 80            | 5     | Very Often      | ≥ 80            | 5     |
| High         | 45 ≤ - < 80     | 4     | Often           | 60 ≤ - < 80     | 4     |
| Moderate     | 15 ≤ - < 45     | 3     | Occasionally    | 40 ≤ - < 60     | 3     |
| Small        | 5 ≤ - < 15      | 2     | Rarely          | 20 ≤ - < 40     | 2     |
| Very Small   | < 5             | 1     | Very Rare       | < 20            | 1     |

5. Measure the value of the correlation between risk events and the risk-causing agents. If there is a risk agent that causes a risk to arise, then it is correlated. Correlation value (Rij) consists of (0, 1, 3, 9) where 0 indicates there is no correlation, 1 indicates a small correlation, 3 indicates a moderate correlation, and 9 indicates a high correlation.

6. Calculate the risk priority index or ARP. ARP calculations used several elements i.e. the impact level of a risk event (Si), the probability level of the occurrence of a risk agent (Oj), and the level of
correlation between risk agents and risk events (Rij). ARP calculation was obtained using the following formula [7].

\[
ARP_j = O_j \sum S_i R_{ij}
\]  

(1)

The next step was to develop risk mitigation based on risk priority rank garnered from the HOR-1 and ARP assessments. The method used in developing risk mitigation was a qualitative descriptive method, namely brainstorming and interviews with experts. Risk mitigation garnered can, then, be implemented for suppliers, manufacturer, and distributors as a suggestion for improvement.

3. Results and Discussion

3.1. Mapping of supply chain activities, risk identification and risk agents

The supply chain members in this research were suppliers, manufacturer, and distributors. The mapping results of supply chain members activities are illustrated in Table 2.

Table 2. Supply chain members activities

| Supply chain member | Factor  | Activity                             | Risk Event                                      |
|---------------------|---------|--------------------------------------|-------------------------------------------------|
| Supplier            | Source  | Purchasing raw materials             | 1. Misorder of raw materials (E1)               |
|                     | Make    | Repackaging raw materials            | 2. Quantity misorder of raw materials (E5)      |
|                     |         |                                      | 1. Imprecision packaging weight of raw materials (E8) |
|                     |         |                                      | 2. Dirty packaging (E10)                        |
|                     |         |                                      | 1. Raw material damaged during transportation (E14) |
|                     | Deliver | Shipping raw materials to the company |                                                |
| Manufacturer        | Plan    | Planning raw material purchases      | 1. Production delay (E2)                        |
|                     |         | 2. Planning production schedules     | 2. Sudden changes in production plans (E3)       |
|                     | Source  | Receiving raw materials              | 1. Misorder of raw materials (E1)               |
|                     |         | 2. Checking raw materials            | 2. Quantity misorder of raw materials (E5)      |
|                     |         | 3. Storing raw materials in warehouses | 3. Raw materials damage during storage (E6)     |
|                     | Make    | Mixing and cooking processes         |                                                |
|                     |         | 2. Cooling and dilution processes    |                                                |
|                     |         | 3. Viscosity and organoleptic testing processes | 1. Nonstandard viscosity and organoleptic product (E9) |
|                     |         | 4. Filling and packaging processes   | 2. Imprecisions volume of product (E11)         |
|                     |         | 5. Storing processes                 |                                                |
|                     | Deliver | Shipping product                     | 3. Product damaged during storage (E13)         |
|                     | Return  | Accepting and checking the returned product | 1. Damaged packaging (E12)  |
|                     |         |                                      | 2. Product transportation error (E15)           |
|                     |         |                                      | 3. Late of product transportation (E7)          |
|                     |         |                                      | An increase in the number of non-quality product returned by consumers (E16) |
| Distributor         | Plan    | Planning product orders              | Sudden changes in production plans (E3)         |
|                     | Source  | 1. Purchasing product                | 1. Misorder of product (E4)                     |
|                     |         | 2. Receiving the ordered product     | 2. Late of product transportation (E7)          |
|                     | Deliver | Delivering product to consumers      | Damaged packaging (E12)                        |
|                     | Return  | Receiving and checking the returned product from consumers | An increase in the number of non-quality product returned by consumers (E16) |

3.2. Risk evaluation

All risk events identified in Table 2 were, then, analyzed using severity and probability levels [3]. Based on Table 3, there were 8 risk events with impact level 2. It indicated that the impact caused had a little
effect on the supply chain activities [5]. E1 resulted in the depletion of the company's raw material stock if the replacement of raw materials took a long time.

Table 3. Assessing the level of impact of risk events and the level of probability of risk agents

| Risk Event | Risk Impact | Impact Level | Risk Agent | Code | Frequency Level |
|------------|-------------|--------------|------------|------|-----------------|
| E1         | Product quality does not meet the standards | 2 | Unclear specification on the list of purchases | A3 | 2 |
| E2         | Production output cannot meet market demand and the company's loss | 3 | 1. Malfunctioning machines, 2. Power outage | A4, A5 | 2, 3 |
| E3         | The production process is interrupted, causing both shortages and excess inventory, impacting production costs | 2 | Sudden orders | A6 | 3 |
| E4         | Returned product and decreased level of consumer satisfaction and trust | 2 | Unclear specification on the list of purchases | A3 | 2 |
| E5         | The output of production does not match with the production scheduling and market demand and financial loss | 3 | Human error | A1 | 4 |
| E6         | The raw materials cannot be processed into final product, causing the output quantity decreases and financial loss | 3 | 1. Disattention of storing procedures for raw materials, 2. A prolonged storage of raw materials | A7, A8 | 2, 2 |
| E7         | Unable to provide product on time and decreased level of consumer satisfaction | 2 | Disruption during transportation | A17 | 2 |
| E8         | Returned product and decreased level of consumer trust and satisfaction | 3 | Human error | A1 | 4 |
| E9         | Product quality does not meet the standards and decreased level of consumer trust and satisfaction | 2 | Raw material variants | A9 | 4 |
| E10        | Decreased level of consumer trust and satisfaction | 2 | uncleaned of spilled product | A10 | 2 |
| E11        | Decreased level of consumer trust and satisfaction | 3 | Human error | A1 | 4 |
| E12        | Returned product, and financial loss due to product repacking | 3 | 1. Human error, 2. Wet packaging label, 3. Disattention of packaging procedure, 4. Nonstandard handling of product | A1, A11, A12, A19 | 4, 4, 2, 2 |
| E13        | Returned product and financial loss | 3 | 1. Disattention of product storage procedures, 2. Roof leaks of warehouse, 3. A prolonged storage product in warehouse | A13, A14, A15 | 2, 3, 1 |
| E14        | Returned product and financial loss | 2 | Uncertain weather | A2 | 2 |
| E15        | Returned product, decreased level of consumer satisfaction, and financial loss | 2 | 1. Error information receiving, 2. Disruption during transportation | A16, A17 | 2, 2 |
| E16        | Increased the storage cost, financial loss, and decreased level of consumer trust and satisfaction | 3 | Misorder of product | A18 | 4 |
E3 affected the process of preparing raw materials and product packaging. E4, E7, E14, and E15 reduced consumers trust and satisfaction, if they must wait for product replacement. E9 affected the quality of soy sauce produced and it can, in the long term, affect the existence of soy sauce on the market. E10 affected consumer buy decision-making.

There were 8 risks events with impact level 3. It indicated that the risk event had a moderate impact [5]. E2 posited that the specified production target did not achieve. E5 caused financial losses if the amount received was less than the total order. E6 stoped the production process because the damaged soybeans cannot be used. E8 caused financial losses on suppliers if the raw materials overweighed the standard. E11 reduced the number of packaged product when the volume exceeded the standard. E12 and E13 resulted in the returned product from consumers, and the product cannot be resold. E16 reduced consumers trust and satisfaction and increased storage costs, causing financial losses.

3.3. Calculation of ARP and HOR phase 1 (HOR-1)

The calculation of ARP aimed to determine the priority risk agents to be handled. Prioritised risk agents were ordered corresponding to ARP value (Figure 1). Based on the calculation of ARP values, there were five risks agents with the highest values, namely A1, A18, A5, A9, and A17.

| Activities | Risk Event (E) | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 | A14 | A15 | A16 | A17 | A18 | A19 | Severity |
|------------|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--------|
| Plan       | E2            | 3  | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Source     | E3            | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2      |
| Source     | E1            | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2      |
| Source     | E4            | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2      |
| Source     | E5            | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Make       | E6            | 1  | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Make       | E7            |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 9      |
| Make       | E8            | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Make       | E9            | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Make       | E10           | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2      |
| Make       | E11           | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2      |
| Make       | E13           |    | 3  | 2  | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Deliver    | E12           | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Deliver    | E14           | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 3      |
| Deliver    | E15           | 3  | 9  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 2      |
| Return     | E16           |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 9      |
| Occurrence | 4  | 2  | 2  | 2  | 3  | 3  | 2  | 2  | 2  | 4  | 4  | 2  | 2  | 3  | 1  | 2  | 2  | 4  | 2  | 3  |        |
| ARP        | 258 | 12 | 24 | 18 | 81 | 54 | 6  | 18 | 72 | 4  | 36 | 18 | 18 | 18 | 3  | 12 | 72 | 108 | 18 |        |
| Risk       | 1  | 15 | 8  | 10 | 3  | 6  | 17 | 11 | 14 | 4  | 18 | 7  | 16 | 12 | 13 | 19 | 9  | 5  | 2  | 14     |

**Figure 1.** Results of HOR phase 1

3.4. Risk mitigation

The priority of risk agents that have been identified based on the calculation of ARP values need to be addressed to reduce the possibility of system failure [7]. Risk mitigation results are shown in Table 4. A1 risk agents (human error) occured in suppliers, manufacturer, and distributors. On the suppliers, the risk occured in the purchasing and repackaging raw materials, and on the manufacturer, the risk occurred in checking process of raw materials that potentially cause quantity misorder and the imprecision packaging weight of raw materials (E5 and E8). Prevention strategies can be conducted by making contracts agreements with all suppliers, and giving sanctions if the raw material supplied is nonstandards. Similarly, the manufacturer risk agent occured in the filling and packaging process which causes the risk of the imprecision volume of product (E11). Prevention strategies can be implemented by providing reward, punishment and work motivation to workers so that they are more careful and enthusiastic in carrying out their responsibilities [8]. In addition, A1 risk agents on the manufacturer and distributors also caused other risks, namely damaged packaging (E12). Imprecision volume and packaging labels damage on the manufacturer can be handled by the use of automatic packaging and
labeling machines [9], while on the distributors, the risk can be handled by arrange the product according to the storage procedure during the shipping process.

A18 risk agent (misorder of product) occurred at manufacturers and distributors in receiving and checking the returned product from consumers which causes the risk of an increase in the number of non-quality product returned by consumers (E16). Prevention strategies can be implemented by re-confirming the buyer about the number of products ordered, checking and arranging the products following the storage procedures of transportation process in order to prevent discrepancy in product quantities and damages.

### Table 4. Risk mitigations

| Risk Agent | Risk Event | Supply chain members | Risk impact | Solution |
|------------|------------|----------------------|-------------|----------|
| A1 E5      | Suppliers and manufacturer | 1. The output of production does not match with the production scheduling and market demand 2. Financial loss 3. Returned product 4. Increased level of consumer trust and satisfaction | 1. Provide reward, punishment, and work motivation to workers 2. Make contracts agreements with suppliers 3. Use of automatic packaging and labeling machines | 4. Arrange the product according to the storage procedure during the shipping process |
| E8 Suppliers | Decreased level of consumer trust and satisfaction | 1. Returned product 2. Increased level of consumer trust and satisfaction | 1. Confirm order 2. Check the product before sending 3. Arrange the product according to the storage procedure during the shipping process |
| E11 Manufacturer | 1. Returned product 2. Financial loss due to product repacking | 1. Confirm order 2. Make contracts agreements with suppliers | Use electricity generator |
| E12 Manufacturer and distributors | 1. The output of production does not match with the production scheduling and market demand 2. Financial loss 3. Returned product 4. Increased level of consumer trust and satisfaction | 1. Provide reward, punishment, and work motivation to workers 2. Make contracts agreements with suppliers 3. Use of automatic packaging and labeling machines | 4. Arrange the product according to the storage procedure during the shipping process |
| A18 E16 Manufacturer and distributors | 1. The output of production does not match with the production scheduling and market demand 2. Financial loss 3. Returned product 4. Increased level of consumer trust and satisfaction | 1. Confirm order 2. Check the product before sending 3. Arrange the product according to the storage procedure during the shipping process |
| A5 E2 Manufacturer | 1. Production output cannot meet market demand 2. The company’s loss | 1. Strictly check the quality of raw materials 2. Make contracts agreements with suppliers |
| A9 E9 Manufacturer | 1. Production output cannot meet market demand 2. The company’s loss | 1. Strictly check the quality of raw materials 2. Make contracts agreements with suppliers |
| A17 E7 Manufacturer and Distributors | 1. Unable to provide product on time 2. Decreased level of consumer satisfaction | 1. Put forward the schedule of the product arriving during the order process 2. Monitor the transportation process to ensure the product arrives on time 3. Maintain the distribution vehicles regularly 4. Check distribution routes to avoid traffic jam and flood areas |
| E15 Manufacturer | 1. Returned product 2. Decreased level of consumer satisfaction 3. Financial loss | 1. Put forward the schedule of the product arriving during the order process 2. Monitor the transportation process to ensure the product arrives on time 3. Maintain the distribution vehicles regularly 4. Check distribution routes to avoid traffic jam and flood areas |

A5 risk agent (power outage) occurred at the manufacturer which can cause the risk of production delay (E2). The soysauce production process at Company X is carried out 8 times a day. The delay in production due to power outage can hamper the production process, so the production target on that day cannot be achieved. Alternatively, electricity generator can be used as prevention strategy during a power outage, so that the company can still operate [10].
A9 risk agent (raw materials variants) occurred at the manufacturer during the viscosity and organoleptic testing process which can affect the product's quality (E9). Prevention strategies are: (1) to strictly check the quality of raw materials; (2) to collaborate with many suppliers and make contracts agreements with suppliers to fulfill the standard of raw materials; (3) to use raw materials from one supplier and send them on the same day in order to meet the production standard.

A17 risk agent (disruption during transportation) occurred at manufacturers and distributors. On the manufacturers, risk agent occurred in product transportation activities that can cause the risk of product transportation error (E15) and late of product transportation (E7). Such disruptions included uncertain weather condition such as rain which potentially caused flood, break down vehicle, and traffic jam. Prevention strategies are: (1) to maintain the distribution vehicles regularly to prevent the vehicle from breaking down [11]; (2) to check distribution routes before transporting the product in order to avoid traffic jam and flood areas. At the distributors, the risk agent occurred in receiving ordered product which results in the late of product arriving (E7). To cope with these risk agents, the distributor can put 1 or 2 days forward the schedule of actual date to avoid delays in the arrival of the product. The distributor can also monitor the product transportation process to ensure that the product arrived on time.

4. Conclusions
Risk analysis is carried out on supply chain members consisting of suppliers, manufacturers and distributors. The results of the risk analysis revealed that there were 16 risk events and 19 risk agents. The calculation of ARP value on HOR-1 shows 5 priority agents to be handled i.e. human error (A1), misorder of product (A18), power outage (A5), raw materials variants (A9), and disruptions during product transportation (A17). The suggested risk mitigations are (A1) to give rewards, punishments, and work motivation to workers, to make contracts agreements, and to use automatic machines; (A18) to alter SOP of ordering, storing and distributing; (A5) to use electricity generator during the production process; (A9) to control the quality of raw materials and to alter SOP of suppliers cooperation; (A17) to enhance SOP of distribution and to maintain the distribution vehicle regularly.

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