Framework of risk priority and risk mitigation approach for palm sugar reverse supply chain

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Abstract. In the distribution of the palm sugar Supply Chain (SC) from producers to consumers, there are many palm sugar products quality damage, so a Reverse Supply Chain (RSC) activity is needed to minimize the loss and possible processed. There are some risks that occur in the RSC activities of palm sugar agricultural industry. The purpose of this study was to design a risk priority framework and risk mitigation as a reference for implementing RSC risk management in the palm sugar industry. The steps in the implementation of this research were the data and information collection, descriptive analysis, category selection, content evaluation and subsequently creating a framework. Approaches and methods for minimizing RSC risk based on the order of risk priorities and risk mitigation strategies were done by using Hybrid Interpretive Structural Modeling (ISM) - fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) and House of Risk (HOR) 2. The results showed that the risk priority framework and the risk mitigation strategy are carried out through four stages starting from risk identification, risk classification, risk priority determination, and risk mitigation strategies.

1. Introduction
Palm sugar agroindustry is a business that processes the sugar palm juice from the Arenga tree (Arenga pinnata Merr) into shell palm sugar (SPS). The sugar palm juice is containing fructose, and sucrose, and other nutrients [1]. The sweet taste of palm sugar is caused by its carbohydrate content which reaches 11.8% [2]. This shell palm sugar contains a fairly high water content of 10-11% [3], when compared to the quality requirements of palm sugar in SNI 01-3743-1995 which a maximum value of 10%.

In the distribution of the palm sugar SC from producers to consumers, a lot of palm sugar products are damaged, both due to the buildup burden at the time of distribution or the length of product turnover. From the results of interviews with retailers also producers, it was found that the damage level of palm sugar is 10% -20%, and this damage will increase even to 30% if the palm sugar is not processed immediately. The types of damage that occur in palm sugar in the form of physical damage that is, cracked, destroyed, even melted. The durability of this palm sugar product ranges from 2-3 weeks and then this palm sugar will crack, melt, and be damaged.

For this reason, a method is needed in the management of palm sugar that is not absorbed by the market and is damaged, and how the sustainability of the palm sugar product becomes a very
important issue. Returning food products into the SC for recovery or adding value, this approach is known as the RSC [4], [5]. Figure 1 summarizes a description of the condition of the existing RSC in palm sugar.

Figure 1. RSC on palm sugar

RSC is a series of activities needed to take products from consumers or other stages of the SC and reinsert them into the supply chain network to be reused, reprocessed, reproduced, recycled or even disposed of the right way efficiently and effectively [6], [7], [8]. In this way, the RSC contributes to the industry becoming more economically, socially, and environmentally sustainable. According to [9], Reverse Logistics (RL) is indispensable in the food industry due to the presence of waste products which in most cases can still be used.

Research on RSC has been discussed by several previous researchers [10], [11], [12], research on RSC Risks was carried out in the plastic industry, electronics, and glass manufacturing, but RSC risk Agri-food palm sugar has not been much studied.

While the main challenge in conducting RSC in the food industry is the risk of food safety. The smallest deviation from organoleptic characteristics can create food safety incidents [13]. Food safety assurance is a major factor as control of food products [14], for this, it requires steps in the design of methods that can be used to identify, minimize risks to the RSC in the food industry. The purpose of this study is to design a risk priority framework and risk mitigation as a reference in carrying out RSC risk management in the palm sugar industry.

The scope of this research is the identification of the types of risks from the literature study, both RSC risks and food supply chain risk, comparison of methods in determining the RSC risk, comparison of methods in determining risk mitigation, determining appropriate methods for priority risk and mitigation risks to the RSC of the palm sugar industry.
2. Method
The research method was consisted of four stages, i.e. data and information collection, descriptive analysis, category selection, and content evaluation.

2.1. Data and information collection
The secondary data was collected through literature search from Google Scholar search engine and other libraries such as in Emerald, Springer, Elsevier, Scopus, Wiley, Taylor & Francis, Inderscience, IEEE. Keywords used in article search are "Palm sugar agro-industry", "RSC", "Reverse Logistic (RL)", "RSC Risk", "The risk of Reverse Logistics in the agricultural industry ", Green Supply Chain (GSC) ", " Agricultural industry SC "and" Agricultural industry SC risks", as summarized in Table 1 and Figure 2. Based on the search results using the 7 keywords above, 54 articles were obtained with the distribution of years from 2009 to 2019. From the results of 54 articles, only 53 articles that fit the topic to be studied, while one article is used as a reinforcement only.

Table 1. List of articles in the main research

| Group                        | Reference |
|------------------------------|-----------|
| Palm sugar                   | [1], [2], [3] |
| RSC                          | [4], [5], [6], [7], [8], [9], [13], [15], [48], [49] |
| RSC Risk                     | [10], [11], [12], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33] |
| SC                           | [36], [40], [41], [50], [52] |
| SC risk                      | [14], [37] |
| Agricultural industry SC risks | [34], [35], [38], [39], [53], [54] |
| GSC                          | [43], [44], [45], [46], [47] |

Figure 2. Mapping research articles

2.2. Descriptive analysis
Literature articles that have been obtained are then analyzed quantitatively, a description of the contents of the article, information about the distribution of the year the article was published,
information about the distribution of the journal in which the article was published as described in Table 2,3,4 and Figure 3,4,5.

![Publication of RSC, SC, RSC Risk, SC Risk](image)

**Figure 3.** Distribution of research publication through the years

**Table 2.** The sum of articles published by major journals

| Article Publish by Journals                                      | Number of articles |
|-----------------------------------------------------------------|--------------------|
| American Journal of Engineering and Applied Sciences            | 1                  |
| Applied Mathematical Modelling                                  | 1                  |
| Applied Sciences                                                | 1                  |
| Applied Soft Computing                                          | 1                  |
| Benchmarking                                                    | 2                  |
| Business Process Management Journal                             | 1                  |
| Computer Aided Chemical Engineering                            | 2                  |
| Computers an Industrial Engineering                            | 2                  |
| Computers and Chemical Engineering                             | 3                  |
| Decision Science Letters                                        | 1                  |
| Environmental Development                                       | 1                  |
| European Journal of Operational Research                       | 2                  |
| International Journal of Supply Chain Management               | 2                  |
| International Journal of Applied Decision Sciences              | 1                  |
| International Journal of Integrated Supply Management           | 1                  |
| International Journal of Production Economics                   | 3                  |
| International Journal of Production Research                    | 2                  |
| International Journal of Research in Engineering and Technology | 1                  |
| International Journal Supply Chain and Operations Resilience    | 1                  |
| International Strategic Management Review                       | 1                  |
| Optimization                                                   | 1                  |
| Proceedings of the palm sugar National Seminar                 | 1                  |
| Renewable and Sustainable Energy Reviews                        | 1                  |
| Sugar Tech                                                      | 1                  |
| Supply Chain Forum                                             | 1                  |
| The Scientific World Journal                                   | 1                  |
| Transportation Research Part D: Transport and Environment       | 2                  |
| Journal Cleaner Production                                      | 8                  |
Table 3. The number of articles published by books

| Article Publish by Book | Number of articles |
|------------------------|--------------------|
| CRC Press Taylor & Francis Group | 1 |

Table 4. The number of articles published by proceedings

| Article Publish by Proceedings | Number of articles |
|-------------------------------|--------------------|
| MATEC Web of Conferences      | 2                  |
| IOP Conference Series : Materials Science and Engineering | 2 |
| IPTEK Journal of Proceedings Series | 1 |
| Transportation research procedia | 1 |

Figures:

4. Articles published by journals

5. Articles published by proceedings

6. Index journal
2.3. Category selection
At this stage, articles are classified by topic. Referring to the main topic of this research on risk priority and risk mitigation, the articles obtained are classified on the topic, distribution of agro-industry supply chain articles, distribution of RSC articles, types of risks occurring in RSC, industry sectors, and the methods used. Based on this classification we can get the main flow of publications and research gaps.

2.4. Content evaluation
After the articles are collected, a descriptive analysis is performed and classified according to the research topic, then the material is evaluated for the articles by comparing the consensus between the articles by the researchers by consensus by checking the data bank spreadsheets of the articles. The content evaluation framework can be followed in Figure 7.

Figure 7. Content evaluation framework

3. Result and Discussions

3.1. Identification RSC risk
The risks of product demand uncertainty [24], production costs, volume, and evaluation of returned products need to be considered in planning multi-period and multi-product CLSC operations [20]. Some risks that occur in the plastic industry RSC activities are divided into two types, namely internal risk, and external risk. Internal risk consists of inventory risk, data management risk, time management risk, managerial risk, quantity risk, and cultural risk. While external risks are environmental and outsourcing risks, the risk of disruption [9]. According to [10], there are financial risks in the closed-loop supply chain (CLSC) planning.

According to [11], [21] In making recycled products in the plastics industry, there are risks in the form of uncertainties in raw material supply and uncertainty of consumer demand. From the results of the study [22], determining the optimal location of the RSC network also needs to consider transportation risk and the amount of product that must be transported. This study was conducted in the electronics trade. Research conducted in the automotive industry by [14] found that the purchasing patterns carried out by consumers for remanufacturing products in CLSC are influenced by the risks and benefits felt by consumers. From table 5, it can be seen the types of risk in RSC.
Table 5. Type of RSC risk

| Author | Environment | Collection of return product | Supply Uncertainty | Demand Uncertainty | Process | Management | Financial |
|--------|-------------|-------------------------------|---------------------|-------------------|---------|------------|-----------|
|        | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
| [11]   | X | X | X | X |   |   |   | X | X | X | X |   |   |   |   |   |   |   |   |   |   |
| [16]   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | X |
| [17]   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | X |   |
| [18]   | X |   |   |   |   |   | X |   | X |   |   |   |   |   |   |   |   |   |   |   | X |
| [19]   | X | X |   |   |   |   |   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [20]   | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   | X |
| [21]   | X | X | X |   |   |   |   |   |   |   |   | X |   |   |   |   |   |   |   |   |   |
| [22]   | X | X | X | X |   |   |   |   |   |   |   |   | X |   |   |   |   |   |   |   |   |
| [23]   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [10]   | X | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [12]   | X | X | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [24]   | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [25]   | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [26]   | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [27]   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [28]   | X | X | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [29]   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [30]   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [31]   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [32]   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| [33]   | X |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

A : Disruption / Disaster ; B: Environment ; C: Culture; D: Collection of return product ; E: Quantity; F: Transportation; G: Supply Uncertainty; H: Demand Uncertainty; I: Marketing; J: Treatment; K: Quality; L: Capacity; M: Facility disputation; N: Operational; O: Inventory; P: Data processing; Q: Time management; R: Managerial; S: Outsourcing; T: Financial

3.2. Method and approach in RSC risk priority

Various risks that occur in Reverse Logistics need to be arranged and sorted by priority, research conducted in the plastic recycling industry is done by sorting the risk based on the level of loss and probability [11]. The Hybrid Multi-Criteria Decision Making Approach is Used to Prioritize Risks in Reverse Logistic Projects Based on Probability and Impact of Risk [11]. The Method of the Hybrid Multi-Criteria Decision Making (MCDM) Approach. Is an Integration Between Analytical Hierarchy Process (AHP) - Fuzzy Technique for order preference by similarity to an ideal solution (TOPSIS) and AHP - Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and AHP-Digraph Matrix, can be seen in Table 6.
Table 6. Method/approach reviews on reverse supply chain risk

| Authors | Method and approach | Sector |
|---------|---------------------|--------|
| [10]    | Hybrid dan Chance constrained programming, GA, dan Monte Carlo Simulation | Manufacturing Industry |
| [11]    | Hybrid multicriteria decision making methods | Plastic Industry |
| [12]    | MILP model, A two-stage stochastic, conditional value at risk (CVaR) | General Industry |
| [16]    | Mathematical model, CVaR multi-period multi-objective two stage stochastic programming model with stochastic parameters | Undefined |
| [17]    | Lagrangian relaxation algorithm | Glass industry |
| [18]    | Game Theory | Manufacture |
| [19]    | MILP | Engine oil |
| [20]    | MILP and solved by a mathematical programming Language, Sensitive analysis | Electronic |
| [21]    | two stage stochastic, Fix-and-Relax Algorithm (FRA) | Undefined |
| [22]    | Mathematical modeling, two-stage stochastic MILP model, CVaR | Consumer goods company |
| [23]    | MILP is utilized in the model and addressed by an optimization software | Electronic |
| [24]    | Game-theoretical models | Undefined |
| [25]    | Interval programming, Fuzzy programming | Computer |
| [26]    | MILP, Multi-objective programming Stochastic programming | Manufacturing industry |
| [27]    | Mathematical modelling, Stochastic programming, Robust optimization | Automotive industry |
| [28]    | Coordination activity | Truck engine |
| [29]    | Hybrid meta-heuristic algorithm | Refrigerator |
| [31]    | MILP formulation, expected net present value (ENPV), Pareto Optimal curve, augmented ε-constraint | Manufacturing industry |
| [31]    | MILP | Undefined |
| [32]    | Genetic Algorithm (GA) | Electrical manufacturing |
| [33]    | Mathematical programming, MAD, Var, CVaR | Undefined |

The risk ordering model in the supply chain begins with the verification and risk mapping using the Supply Chain Operation Reference (SCOR) and House of Risk (HOR) methods [53], and then identifies the relationship between the risk of risk ranking by using the interpretative structural model (ISM) integration method [34]. This method can help decision-makers in choosing which risks should be handled first and which risks are handled then adjusted according to budget and resource constraints.

In determining risk priorities for perishable food SC, it is executed using the ISM method and risk priority number (RPN) [35]. In addition, the integration of the ISM-Dematel method can be used to determine the priority of the driving factors in implementing Agrifood Supply Chain sustainability [36]. Uncertainty, relevance, and subjectivity are inherent in the supply chain risk valuation process, therefore a comprehensive method to risk management is needed that takes into account the impact and the relationship between risk agents that are mutually integrated. This approach can be done using aggregated risk scores (ARS) by adding fuzzy logic. The use of fuzzy logic predicts uncertainty or ambiguity adequately [37] [38]. The failure mode effects critical analysis (FMECA) method is a risk
valuation method for a product or activity using three valuation factors, namely severity, events, and detection. And also uses criticality analysis to rank the criticality of current risks [39].

3.3. Method and approach in RSC risk mitigation
Responsive risk mitigation strategies are carried out through a priority order of risk. According to [36], the formulation of risk mitigation strategies on perishable foods is carried out based on the risk priority number (RPN) value, then the priority of the mitigation strategy is determined by using a risk mitigation number (RMN). Risk mitigation analysis can be carried out at all levels, but by combining the RPN and RMN methods, the risk mitigation priority selection can be made, so that the risk mitigation strategy becomes more focused.

Determination of risk mitigation priorities can be done using the HOR method stage 2. HOR 2 is used to prioritize proactive actions that must be taken first, given the availability of resources, the level of difficulty in carrying out mitigation actions so that it can effectively reduce the risks that occur [52]. The combination of the balanced scorecard (BSC) tool can improve the analysis and determination of priorities of mitigation strategies in decision making, integration of risk mitigation strategies into the performance appraisal process with BSC can be used as an effective and proactive combination in strategy management [37]. Determination of risk mitigation priority strategies can also be done with the analytical network process (ANP) method [39]. The integration of HOR and ANP can be used to reduce SC risks and reduce the consequences of risks based on priorities [53], as described in Table 7.

Table 7. List method/approach risk priority and risk mitigation

| Authors | Risk Priority | Method/ Approach | Risk Mitigation | Sector |
|---------|---------------|------------------|-----------------|--------|
| [11]    | Hybrid multicriteria decision making methods (AHP- Fuzzy Topsis, AHP- Promethe, AHP- Digraph) | RPN | Plastic Industry |
| [34]    | HOR - ISM     | ISM and Risk priority number (RPN) | RPN-RMN | General Industry |
| [35]    | ISM- Fuzzy DEMATEL | RPN | Dairy Agro-industry |
| [36]    | Fuzzy Logic - Aggregate risk score | BSC | Agro-I |
| [37]    | Fuzzy Logic | ISM and Risk priority number (RPN) | RPN-RMN | Dairy Agro-industry |
| [38]    | Fuzzy Logic | SCOR- HOR 1 | HOR & ANP | Cassava agro-industry |
| [39]    | FMECA         | SCOR- HOR 1 | HOR 2 | Agro-Industry |
| [52]    | HOR 1          | HOR 2 | Fertilizer company |
| [53]    | SCOR- HOR 1   | HOR 2 | Cassava agro-industry |
| [54]    | SCOR- HOR 1   | HOR 2 | Cassava agro-industry |

3.4. Analysis and criticize for RSC risk priority
Based on the results and discussion, it was found that the method used to determine risk priorities in the RSC palm sugar activities be able to do with Hybrid Multi-Criteria Decision Making, but the steps in this method are too long. The method of mapping risk with SCOR and determining risk priorities using HOR and ISM. This method is a combination of assessments in which risk identification uses HOR, then the risk is re-ordered using ISM. This method works twice in determining risk priorities. The RPN method, ARS measures risk in terms of the impact and occurrence of the risk, while FMECA measures risk by three factors, severity, incidence, and detection. These three methods (RPN, ARS, and FMECA) carry out quantitative risk measurement. Quantitative risk assessment is indeed good if it is supported by the availability of data and facts, not based on assumptions. Furthermore, to sort the results of the risk assessment the previous researchers used the ISM approach and critical analysis.
Risks that occur in the RSC activity of palm sugar are very complex and involve several stakeholders, for that we need a Intelligent Decision Support System (IDSS) that is used to make decisions appropriately [40] in minimizing the risk of RSC agroindustry of palm sugar. These risks need to be sorted by probability and risk impact by integrating ISM-Fuzzy DEMATEL. This method can analyze the elements of risk, identify relationships between elements of risk, and determine the ranking of risks in the form of a hierarchy and graph in order to facilitate the determination of risk mitigation. With the ISM-Fuzzy Dematel method, it enables decision-makers to be able to understand the relationship of related attributes in decision making, which can further increase the dependability of decisions [35].

The integrated ISM-fuzzy DEMATEL method [41] was created and used to identify and classify risks in the RSC activities. ISM is a systematic and interactive technique that depends on a group of independent experts and helps in knowing the interrelation between variables [42]. Fuzzy DEMATEL method be able to reveal the relationship between elements that influence other elements in uncertain conditions [43] [44]. ISM-Fuzzy-DEMATEL techniques are excellent to interpretive modeling techniques than other decision making, such as AHP, ANP, Graph theory, SEM modeling, Interpretive Ranking Process (IRP), etc.

The incorporation of the ISM method and Fuzzy-DEMATEL in this study is due to several things including [45], [46], [41]
1. ISM-Fuzzy-DEMATEL are able to describe the complex relationship between factors observed in decision making in an unpredictable environment.
2. The integration of the ISM-fuzzy-DEMATEL can show the cause and consequence relationship between the decision factors considered.
3. Their integrated use can help in viewing the importance of the decision variables observed via well-explained diagrams (ISM-based hierarchical diagrams and cause-and-effect diagrams in fuzzy DEMATEL).
4. ISM can consider four possible relationships to analyze interactions between decision variables; however, it cannot differentiate the force of contextual relationships between decision variables using ISM. Meanwhile, Fuzzy-DEMATEL can explore more profound relationships and it moreover captures the power of contextual relationships by means of scale (from 0 to 4) under ambiguous environments.
5. ISM can be joint with DEMATEL to find out the direction and degree, in a multifaceted causal connection, thus, a complete feedback system thinks the importance and relationship between factors.

The DEMATEL method is appropriate for exploring multifaceted causal relations and sets of interrelated problems and is inclined to find ideal solutions in solving complex system problems. DEMATEL assists to get direct and indirect influence among criteria in a multi criteria decision problem. It also assists in calculating the relationships and strengths among the factors relevant [47]. The DEMATEL approach can help in classifying elements into groups of cause and effect [48]. However, DEMATEL utilization has limitations in dealing with issues of uncertainty, inaccuracy of data and prejudice related with human judgment [49]. Thus, we would be better off using fuzzy DEMATEL in this study [50], [51].

3.5. Analysis and criticize for RSC risk mitigation
Based on the findings of a strategy for risk mitigation that can be done using RMN, this strategy can direct decision-makers to choose the priority of mitigation to be carried out so that the mitigation strategy becomes more focused, but this strategy does not take into account performance appraisal. The weakness of this method can be corrected by integrating the BSC method for performance measurement. The RMN, BSC, and ANP methods, all three do not take into account the availability of resources and the level of difficulty in carrying out risk mitigation actions.

Based on the description above, the risk mitigation strategy in the RSC of palm sugar activities is carried out by using the HOR 2 method [52]. This method prioritizes proactive actions by considering
the availability of resources and the level of difficulty so that risks can be reduced effectively [52]. HOR 2 is used to decide the initial activities that must be taken, given the different effectiveness and resources involved and the level of difficulty in carrying out a mitigation action. Companies must choose and management actions that are not so hard but can successfully decrease the possibility of risk factors happening [54].

3.6. Framework of RSC risk priority and risk mitigation of RSC

The framework of RSC risk priority and risk mitigation is depicted in Figure 8.

![Figure 8. Framework of risk priority and risk mitigation RSC](image)

The steps in determining risk priorities and risk mitigation in the RSC activities of the palm sugar agroindustry are as follows: First, identification and classification of risks that occur in the RSC activities of the palm sugar agroindustry (refer to literature studies and in-depth interviews with business actors and expert). Second, the selection of risks that occur in the RSC agroindustry of palm sugar, the risks were chosen are risks that have occurred or risks that are likely to occur. Third Determination of risk priorities using the ISM Fuzzy Dematel method with nine stages as shown in Figure 8. Finally, mitigate risk with the HOR type 2 approach.

The steps in HOR type 2 are as follows: first, determine the risk prevention measures based on the priority order of risk from highest to lowest. Note that one risk can be corrected by more than one action or one action can fix several risks, the second determines the assessment of risk prevention measures by considering the level of resource availability and the level of difficulty in carrying out preventive activities. the third calculates the total value of effectiveness against the level of difficulty ratio. Finally, determine the order of priority of actions based on the highest total effectiveness value.

4. Conclusions and Recommendations

The framework for determining risk priorities and risk mitigation strategies is carried out through four stages consisting of risk identification, risk classification, risk priority determination, and risk mitigation strategies. Risks that occur in the activity of RSC palm sugar is very complex and involves several stakeholders, these risks need to be sorted based on the probability and impact of risks,
Determination of the order of risk can be done by integrating the ISM-Fuzzy DEMATEL approach. This method can analyze the elements of risk and be able to describe the complex relationships between variables considered in decision making in an uncertain environment and can rank risks into hierarchical and graphical forms.

Mitigation strategies to minimize RSC risk based on the priority order of risk can be carried out using the HOR 2 method. HOR 2 method is expected to prioritize risk mitigation actions proactively by considering the availability of resources and the level of difficulty of risk management so that risks can be effectively reduced. The integration of the Hybrid ISM-Fuzzy DEMATEL-HOR 2 method, enables decision-makers to be able to understand the relationship of relevant attributes in decision making to determine risk priorities and risk mitigation strategies which can further improve the reliability of decisions.

For future research exploration that needs to be developed is RSC risk management in palm sugar agro-industry which is integrated with the optimization of RSC palm sugar products and sustainability of RSC palm sugar agro-industry.

Acknowledgments
This research is funded by Indonesia Endowment Fund for Education (LPDP) and Indonesia center of excellence for food security (local food innovation) University of Sultan Ageng Tirtayasa

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