Supply Chain Risk Management on Wooden Toys Industries by using House of Risk (HOR) and Analytical Network Process (ANP) Method

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Abstract. Good risk management will reduce the impact and risk of an event. In this study discussed the risks that may arise in the wooden toy industry supply chain and how to manage these risks. The calculation divided into three phases; there are risk mapping, risk assessment, and risk management. House of Risk (HOR) is used in calculating potential risks and Analytical Network Process (ANP) is used to choose the best strategy for supply chain risk management. Followed by HOR calculation, risk that has the greatest value and selected as potential risk is the risk of price/cost fluctuations with an ARP value of 432. The strategy of this risk is grouped based on 2 causes, namely raw material price fluctuations and poor management. With ANP calculations, the strategy for raw material price fluctuations are understanding and determining the quantity of material used (28.14%) and combining woods with various commodities (23.23%). Then the alternative for poor management are doing strategic financial accounting (54.48%) and doing financial planning (33.07%).

Keywords: risks, strategy, supply chain risk management, house of risk, analytical network process

1. Introduction
The more intense competition requires companies to be able to compete in their fields. This has triggered the company to reduce the mistakes and prevent risks in any sector. One of the most important sectors of the company in the continuity of its business processes is their supply chain sector. The supply chain is a network of companies that work together to create and deliver a product to the end user [14]. Supply Chain Management (SCM) is a systematic and strategic coordination of traditional business functions within and across companies in a supply chain to develop the company's long-term performance and overall supply chain [13]. In another way, SCM was defined as an activity of managing activities in order to obtain the raw material into goods in process or semi-finished goods and finished goods and then send the product to consumers through a distribution system [9]. In the supply chain process, there are various risks that can affect the supply chain flow and it's caused the processes cannot run properly. The risk to the supply chain can be defined as an event caused by an imbalance between demand and supply [7]. Therefore, risks in the supply chain also defined as disruption of information and resource
flows in supply chain networks due to uncertain terminations and variations [2]. Handling of risks that disrupt the supply chain sector in the supply chain sector must be overcome with good risk management. Risk management model, which measures the effects that will be caused by risk, is part of the risk management process, which covers the entire process of risk analysis and risk evaluation [12]. In general, the supply chain risk management process consists of risk identification, risk analysis, risk evaluation and risk mitigation. Risk identification is suggested as a fundamental step in the risk management process [6].

SCRM is a concept that is used to control and coordinate the risks that can be generated and mitigation actions on the company's supply chain. So with regard to the risks in supply chain management, SCRM plays an important role in keeping the supply chain system from being disturbed by the risks that might occur. Several studies have been conducted on the topic of supply chain risk identification and evaluation such as, hazard operability (HAZOP) analysis, FMEA and fuzzy theory, and Fuzzy FMEA [14]. Supply Chain Risk Management is a blend of the concept of Supply Chain Management with Risk Management. The risks to the supply chain can be defined as a place of events caused by an imbalance between demand and supply. Supply chain disruptions can lead to problems such as lead time, stock out, inability to meet customer demand, and increased costs [4][3]. The magnitude of risk can be measured by considering two fundamental parameters of risk, namely the possibility of risk and risk severity [3]. However, it must be realized also that the extent of certain risks is also highly dependent on many factors involved, such as human factors, workplace factors, material and equipment factors, etc. that are difficult to measure and handle in the traditional way [17].

In previous study, risks that may occur in the wooden toys industries are delays in material delivery schedules, suppliers unable to meet material needs, errors in inspection procedures when material arrives, errors in calculating material requirements, material stock out during the production process, and other risks [8]. However, to solve these problems some methods need to be developed. House of Risk (HOR) is a method that can be used in this case. HOR Model is used to identify risk agent and focused in preventive actions [2][14]. HOR is a modification of FMEA (Failure Modes and Effect of Analysis) and a quality house model (HOQ) to prioritize the risk sources which are the first to be chosen for the most effective actions in order to reduce the potential risks from risk sources [16]. After that, strategy for risk management can be done using the Analytical Network Process (ANP) method. The ANP is a generalization of the Analytic Hierarchy Process (AHP), by considering the dependence between the elements of the hierarchy. Many call issues can not be structured hierarchically as a result of they involve the interaction and dependence of higher-level components in an exceedingly hierarchy on lower-level components. Therefore, ANP is represented by a network, rather than a hierarchy [15].

2. Methods
The first stage in this study is identifying risks that often occur in the company's supply chain as be seen in Figure 1. The data used is qualitative and the data is obtained through interviews with selected experts who are considered to understand the company's supply chain. Then the identification of risks that have the potential to appear in the company's supply chain regarding the risks that occur, the source of the causes of risk, where the risk is and how the risk arises.

![Figure 1. Supply Chain Risk Management Stages](image)

The second stage is an assessment of the risks identified. Assessment is done with a 1-10 rating by experts. The assessment is in the form of severity of the risk event, the occurrence of the risk agent, and the correlation of the risk agent and risk event. Then it is calculated the value of Aggregate Risk Potential
(ARP) as a value to determine the risk of a priority agent that needs to be carried out risk management. Then the ARP calculation’s for identifying the highest ARP value. After obtaining a risk based agent on the highest ARP value can be seen in the Pareto diagram, the risk agent is managed by identifying what strategies must be carried out to mitigate the risk. Here’s the formula from ARP.

\[
\text{ARP}_j = O_j \times \sum (S_i \times R_{ij})
\]  

1

Information:

\text{ARP}_j : Aggregate Risk Potential

\text{O}_j : Occurance

\text{S}_i : Severity

\text{R}_{ij} : Corellation between Risk Event dan Risk Agent

Figure 2. HOR and ANP Methodology

The third stage, then it was identified several alternative strategies related to risk mitigation actions based on journal references and then adjusted to the situation of the company’s objects. After several alternative strategies have been identified, the best alternative strategies are chosen by using Analytical Network Process (ANP) method and the steps for all methods can be seen in figure 2.

The data needed is qualitative data obtained from the same expert to provide an assessment of each of the strategies that have been identified in the form of pairwise comparison. Then an expert assessment is done using pairwise comparison by bringing together the assessment of the three experts using Geometric Mean (GM). Here’s the formula from GM.

\[
\text{GM} = (R_1 \times R_2 \times \ldots \times R_n)^{1/n}
\]  

Information:

\text{GM} : Geometric mean

\text{R} : Value of respondents questionnaire n

\text{n} : Number of respondent

Then calculate the eigen value of the vector, choose the largest eigen vector, and calculate the consistency index and consistency ratio. If eigen vector is consistent, continued with supermatrix identification and ranking the results of the calculation of the strategy. Here's the formula from CI and CR.

\[
\text{CI} = (\lambda_{\text{max}} - n)/(n - 1)
\]  

Information:

\text{CI} : Consistency Index

\text{\lambda} : Eigen vector value

\text{n} : Number of alternative/criteria

\[
\text{CR} = \text{CI}/\text{RI}
\]  

Information:
3. Result and Discussion

3.1 Risk Identification and Assessment

Before the selection of priority risk, risk identification is carried out based on all activities in the supply chain conducted by wooden toys industries. Then the risks are classified based on sub-risks. The following is the classification and assessment of these risks.

| Symbol | Risk Event  | Severity | Symbol | Risk Event            | Severity | Risk Agent                      | Occurance | Relation RA & RE |
|--------|-------------|----------|--------|-----------------------|----------|---------------------------------|-----------|------------------|
| E1     | Demand Risk | 6        | A1     | Competitor Moves      |          |                                 |           |                  |
|        |             |          | A2     | Delays in Delivery to Customers |          |                                 |           |                  |
|        |             |          | A3     | Forecast Error        |          |                                 |           |                  |
|        |             |          | A4     | Market Saturation     |          |                                 |           |                  |
| E2     | Environment Risk | 6   | A5     | Macroeconomic Uncertainty |          |                                 |           |                  |
|        |             |          | A6     | Natural Disasters     |          |                                 |           |                  |
|        |             |          | A7     | Policy Uncertainty    |          |                                 |           |                  |
|        |             |          | A8     | Social, Culture & Politic Uncertainty |          |                                 |           |                  |
| E3     | Financial Risk | 7    | A9     | Cost/Price Risks      |          |                                 |           |                  |
|        |             |          | A10    | Exchange Rate Risk    |          |                                 |           |                  |
| E4     | Information Risk | 6  | A11    | Breakdown of IT Infrastructure |          |                                 |           |                  |
|        |             |          | A12    | Distorted Information |          |                                 |           |                  |
|        |             |          | A13    | Inadequate Information Security |          |                                 |           |                  |
|        |             |          | A14    | Information Delay     |          |                                 |           |                  |
|        |             |          | A15    | Wrong Choice of Communication |          |                                 |           |                  |
| E5     | Operational Risk | 7    | A16    | Capacity Inflexibility |          |                                 |           |                  |
|        |             |          | A17    | Design Changes        |          |                                 |           |                  |
|        |             |          | A18    | Disruption in Production |         |                                 |           |                  |
|        |             |          | A19    | Inventory Risks       |          |                                 |           |                  |
|        |             |          | A20    | Variability in Production Process |         |                                 |           |                  |
| E6     | Supply Risk | 7        | A21    | Dependency on Single Supplier |         |                                 |           |                  |
|        |             |          | A22    | Inflexibility of Supplier |         |                                 |           |                  |
|        |             |          | A23    | Poor Delivery Performance |         |                                 |           |                  |
|        |             |          | A24    | Supplier Poor Quality |          |                                 |           |                  |
|        |             |          | A25    | Supplier Bankruptcy   |          |                                 |           |                  |

Risk identification is obtained from one of the journal references [10] namely the supply chain risk category in general, then adjustments to the situation in the wooden toy industry supply chain. After obtaining an assessment from each expert, the average of the three values is calculated to get one value rounded down, it is done to make it easier to do the next calculation. As for risk assessment, a 1-10 scale is used to facilitate experts in assessing severity, occurrence and correlations. Then the Aggregate Risk Potential is calculated on the HOR method. Following are the calculations.
3.2 ARP Calculation and Pareto Diagram

Table 2. ARP calculation on the HOR Method

| Event | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | ... | A17 | A18 | A19 | A20 | A21 | A22 | A23 | A24 | A25 |
|-------|----|----|----|----|----|----|----|----|----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| E1    | 2  | 9  | 3  | 7  |     |    |    |    |    |      |     |     |     |     |     |     |     |     |     |
| E2    | 5  | 7  | 2  | 3  |     |    |    |    |    |      |     |     |     |     |     |     |     |     |     |
| E3    |    |    | 9  |     |     |    |    |    |    |      |     |     |     |     |     |     |     |     |     |
| E4    |    |    | 5  |     |     |    |    |    |    |      |     |     |     |     |     |     |     |     |     |
| E5    |    |    |    | 7  | 9  | 2  | 2  |     |    |      |     |     |     |     |     |     |     |     |     |
| E6    |    |    |    | 3  | 3  | 7  | 9  | 9  | 6  |      |     |     |     |     |     |     |     |     |     |
| Occurrence | 6 | 6 | 8 | 4 | 8 | 4 | 5 | 5 | 8 | ... | 7 | 5 | 6 | 5 | 4 | 6 | 3 | 5 | 4 |
| ARPj  | 60 | 270 | 120 | 140 | 200 | 140 | 50 | 75 | 432 | ... | 294 | 270 | 72 | 60 | 72 | 108 | 126 | 270 | 216 |

ARP calculation results can be seen in Table 2, where the calculation involves the risk events symbolized by E and the risk agent symbolized by A. Then the severity, occurrence and relations that have been obtained from the opinions of the three experts are used in this calculation. To get the ARP value, the following equation is used. Here are some examples of ARP calculations using the equation (1).

ARP₁ = 6 x ∑ [ 5 (2)] = 60
ARP₂ = 6 x ∑ [ 5 (9)] = 270
ARP₃ = 8 x ∑ [ 5 (3)] = 120

After obtaining ARP values from each risk agent, then the ARP values are ranked according to the largest ARP value. There is a pareto diagram to make it easier to see ARP calculation results visually. Here is the pareto diagram.

![Figure 3. ARP Pareto Chart](image)

Pareto diagram is obtained from the results of the plot of ARP calculation data and cumulative percentage, so that the results obtained that the largest ARP value is A9 or risk agent price or cost with 432. In other words, the price or cost risk agent is a risk that is considered urgent so that further management by wooden toys industries.
3.3 Alternative Strategies Identification and Assessment

The result of using HOR is price or cost risk, the risk is used as a reference to identify several alternative strategies for managing the risks that have been obtained. After identifying alternative strategies from journal references, adjusting the alternative strategies to the situation in the wooden toy industry supply chain. Then the best alternative strategy is chosen by using the ANP method. Based on several sources, some of the causes of risk of price fluctuations include fluctuations in raw material prices and poor management. Here are some alternative strategies that have been identified from each of the causes of the risk of price fluctuations.

ANP calculations are must be done. Then an assessment by the same expert was conducted regarding the comparison of each alternative strategy by the same three experts. The assessment is arranged into pairwise comparison matrix. To get one value from the three expert judgments, a geometric calculation is calculated to make an assessment. Following are the results of the geometric mean calculation.

**Table 3.** Pairwise Comparison Matrix of Price Fluctuations Strategies

|       | T1: Track price changes | T2: Establish clear rules with suppliers | T3: Understand and determine the quantity of material used | T4: Set a different savings goal | T5: Combining woods with various commodities |
|-------|-------------------------|------------------------------------------|----------------------------------------------------------|-----------------------------------|---------------------------------------------|
| T1: Track price changes | 1                        | 0.8434                                   | 0.3057                                                   | 0.3625                            | 0.7211                                      |
| T2: Establish clear rules with suppliers | 1.1856                  | 1                                        | 1.1696                                                   | 0.3625                            | 0.7539                                      |
| T3: Understand and determine the quantity of material used | 3.2711                  | 0.8550                                   | 1                                                        | 2.7589                            | 0.7211                                      |
| T4: Set a different savings goal | 2.7589                  | 2.7589                                   | 0.3625                                                   | 1                                 | 0.7539                                      |
| T5: Combining woods with various commodities | 1.3867                  | 1.3264                                   | 1.3867                                                   | 1                                 | 1                                           |

**Table 4.** Pairwise Comparison Matrix of Poor Management Strategies

|       | M1: Do strategic financial accounting | M2: Recruit external accountants | M3: Do financial planning |
|-------|---------------------------------------|---------------------------------|--------------------------|
| M1: Do strategic financial accounting | 1                                  | 4.2172                        | 1.71                     |
| M2: Recruit external accountants    | 0.2371                             | 1                              | 0.3625                   |
| M3: Do financial planning           | 0.584804                           | 2.7589                        | 1                        |

3.4 Geometric Mean Calculation

A study sometimes uses a geometric mean or a mean to find out the results of individual evaluations from several experts based on the questions posed in the form of comparisons (pairwise comparison) [1]. Geometric mean can be calculated by the following equation. Here are some examples of GM calculations using the equation (1).

\[ GM_{T1T2} = (3 \times 0.2 \times 1)^{1/3} = 0.8434 \]

\[ GM_{T1T3} = (0.2 \times 1 \times 0.1429)^{1/3} = 0.3057 \]

\[ GM_{T1T4} = (0.3333 \times 1 \times 0.1429)^{1/3} = 0.3625 \]

3.5 Consistency Index Calculation

A consistency ratio is a ratio that states whether the judgment provided by the expertise is consistent or not [5]. It is recommended that it should be less than or equal to 0.10. Inconsistency may be an adjustment needed to improve the consistency of the comparisons. But the adjustment should not be as
large as the judgment itself, nor small that it would have no consequence [10]. Previously the calculation of consistency index was done using the following equation (2). Here are the CI calculations.

\[
CI_{\text{poor management}} = \frac{(3,0013 - 3)}{(3 - 1)} = 0.000699
\]

3.6 Consistency Ratio Calculation

The calculation of consistency ratio by using the following equation (3). Here are the CR calculations.

\[
CR_{\text{poor management}} = \frac{0.000699}{0.52} = 0.00062
\]

3.7 Results of Alternative Strategy Selection

After calculating the CI and CR from both of these strategy assessments, the results of the two strategy experts from the three experts have a consistency level below 10%, which means that expert judgment shows consistent answers that can be used in this study. Then the determination of alternative strategies is ideal for mitigating the risk of price or cost fluctuations.

In Figure 3, an alternative strategy is obtained from the two causes of price or cost risk. In the alternative raw material price fluctuations strategy denoted by T, the largest eigenvalue or normals value is T3 (Understand and determine the quantity of material used) with 28.14% and T5 (Combining woods with various commodities) with 23.23%. As for the alternative poor management strategies denoted by M, the highest eigenvalue or normals value is M1 (Doing strategic financial accounting) with 54.48% and M3 (Doing financial planning) with 33.07%.

4. Conclusion

Based on the results of the study on the determination of priority risks from several risks that exist in the Wooden toys industries, obtained several risks that are classified based on 6 risk events with 25 risk agents. The results of data processing using the HOR (House of Risk) method are obtained by the risk agent with the largest ARP, namely A9 or price or cost risk agent with a value of 432. It can be concluded that the risk agent must be prioritized and considered urgent in the supply chain Wooden toys industries is a price or cost risk agent.

The risk management actions are selected using ANP. The strategy of price or cost risk is grouped based on 2 causes, namely raw material price fluctuations and poor management. The strategy of raw material price fluctuations consists of 5 alternative strategies notated by T, while the poor management strategy consists of 3 alternative strategies notated by M. For raw material price fluctuations, T3 is chosen (Understanding and determining the quantity of material used) with 28.14% and T5 (Combining woods with various commodities) with 23.23%. The alternative poor management strategies are M1 (Doing strategic financial accounting) with 54.48% and M3 (Doing financial planning) with 33.07%. Therefore, the alternative strategy chosen can be used as an action to manage price or cost risk in the hope of reducing or preventing the occurrence of price or cost risks in the wooden toys industries.

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