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# Risk Management Analysis Using FMECA and ANP Methods in the Supply Chain of Wooden Toy Industry

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**Abstract.** Risk is a factor that has a potential to occur in every part of an industry, including its supply chain. Every industry must consider and manage its supply chain risks in order to minimize losses while improving performance. In this study, a supply chain risk management (SCRM) approach was conducted in the supply chain of wooden toy industry as a way to minimize the impact of risk. In this case, SCRM method is done by identifying risks, assessing risks using the *failure mode effect criticality analysis* (FMECA) method to determine the risk priorities that must be mitigated, and establish strategies to mitigate the risk with *analytical network process* (ANP) method. Thus, the risk priority in the wooden toy industry's supply chain is the cost/ price risk with the highest WRPN value of 33,379. In order to mitigate the cost/price risk, conducting strategic accounting practices and financial planning are recommended to be considered as its strategies.
**Keywords:** ANP, FMECA, SCRM

## 1. Introduction

Industry is a complex system consisting of various elements that interact directly or non directly with one another in the system. Every industry has a system that describes the flow of products, money and information in a supply chain. The supply chain is a series of relationships between companies or activities that carry out the supply of goods or services from the place of origin to the place of the buyer or customer [1] which activities include material procurement, product manufacturing, and forward / reversed logistics [2]. However, in the supply chain, every element and activity that exists both internally and externally is vulnerable to risk. Risk is the probability of an event that results in a loss when the event occurs during a certain period [3]. Some examples of supply chain risks are raw material shortages, supplier failures, rising in material prices, machine breakdown, uncertain demand, inaccurate forecasting, order changes, and transportation failures [4].

Competition between industries focuses not only on the percentage of profit generated but also on more critical matters: how well the company manages the risks of its internal and external supply chains. Although the profit generated is still relatively small, if the foundation of the supply chain system is good, then the company will grow more stable. Supply chain risk management (SCRM) is risk management in the supply chain by approaching and making decisions that optimally align organizational processes and decisions to take advantage of opportunities while minimizing risk simultaneously [5].

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One industry that has a significant contribution in national economic development is wooden toy industry (hereinafter WTI), which produces children's toys with a wide variety of designs and also distributes their products to major retailers. It is without exception that the supply chain of WTI is still vulnerable to risks that have the probability to emerge and disrupt the performance of the supply chain, this can result in delays in production activities, delays in distribution and ultimately delays in goods reaching customers. Responding to this, the SCRM approach was used by using the failure mode effects critical analysis (FMECA) method, which is a risk assessment method on a product or activity using three assessment factors, namely severity, occurrence, and detection. As well as using criticality analysis to sort the level of criticality of the existing risks. The result of the assessment then became the input for establishing strategies, then with Analytical Network Process (ANP) the strategy priorities would be determined. The research was carried out by conducting reference studies for the risk and strategies, then interviews on risks that could arise in the company's supply chain and interviews for taking expert judgements which were then processed into quantitative forms so that the level of risk and the recommended strategies could be identified.

## 2. Methods

The research was conducted in the wooden toy industry to indentify risk in its supply chain. For the risk identification is used the supply chain risks categorization by Jafarnejad [6], an interview was also done to check and compare the risks is obtained from the literature to the real conditions in the wooden toy industry. A risk assessment was done using three methods: AHP, FMECA, and ANP methods. The AHP method was used to obtain the risk weights which then processed further with the FMECA method to obtain the rank of the risks. In this research, three experts are chosen to judge the risks using pairwise comparison matrix, then their judgements became the input in AHP method that were calculated using Expert Choice software. Then FMECA method was done to determine the occurrence, severity, detection, and the criticality level of each risk. Criticality level helped us to filter which risks that necessary for WRPN calculation in order to rank the risks. The last step was to generate some recommended strategies for the most critical risk, strategies were obtained from literature study, and then were judged by experts before they were calculated with ANP method. The use of ANP method was necessary to help us knew which strategies to be considered for mitigation. Figure 1 shows the step of each method used for this research.

### *2.1. Analytical Hierarchy Process (AHP)*

Analytic Hierarchy Process (AHP) is a theory of relative measurement with absolute scales of both tangible and intangible criteria based on the judgment of knowledgeable and expert people [7]. In this research the use of AHP method was to obtain risk weight, not to determine priority. The weight then were used to calculate the global weight and determine the WRPN value in the FMECA method.

### *2.2. Failure Mode Effect Criticality Analysis (FMECA)*

FMECA method has a risk assessment scale [8] based on the value of the RPN that ranges from 0 to more than 324 as can be seen in table 1. The RPN is calculated by considered three factors, there are occurrence, severity, and detection. Each factor has a rating scale of 1 to 10 as in table 2.

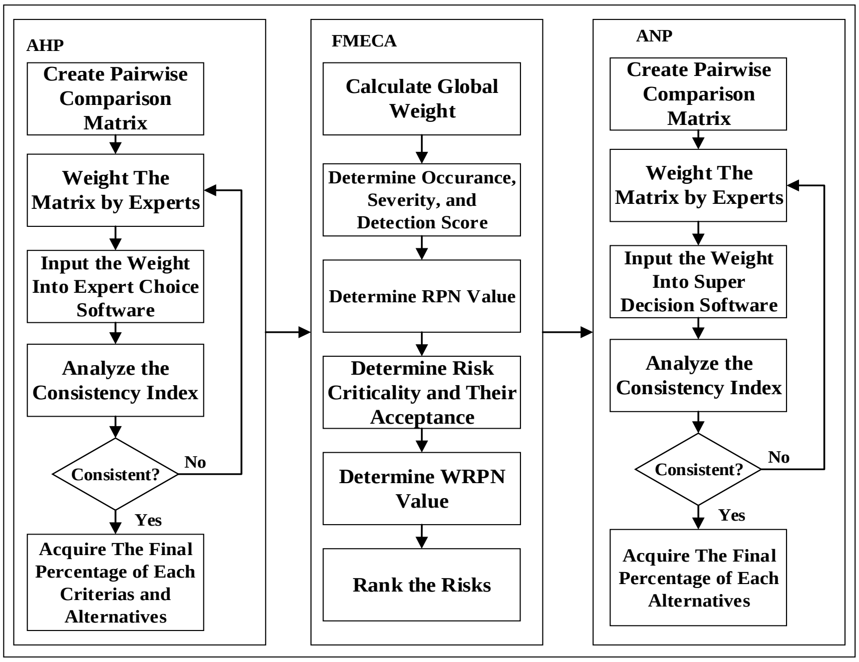


**Figure 1.** AHP, FMECA, and ANP method flowchart

**Table 1.** Criticality analysis

| Criticality | | Risk |
|---|---|---|
| **Criticality Level** | **Score** | **Acceptance** |
| Low | 0 - 30 | Acceptable |
| Moderate | 31 - 60 | Tolerable |
| High | 61 - 180 | |
| Very High | 181 - 252 | Unacceptable |
| Critical | 253 – 324 | |
| Very Critical | > 324 | |

**Table 2.** Rating scale of occurance, severity, and detection

| Skor | *Occurrence*(O) | *Severity* (S) | *Detection* (D) |
|---|---|---|---|
| 1 | Remote probability | No effect | Almost certain |
| 2 | Very rare | Very small effect | Very easy |
| 3 | Moderately rare | Minor effect | Easy |
| 4 | Slightly rare | Very low | Fairly easy |
| 5 | Rare | Low | Moderate chance of detection |
| 6 | Slightly often | Moderate | Slightly difficult |
| 7 | Moderately often | High | Moderately difficult |
| 8 | Often | Very high | Difficult |
| 9 | Very often | Serious | Very difficult |
| 10 | Certain probability | Very severe | No chance of detection |

After collecting RPN value from the experts, the next step of FMECA is to calculate global weight of each risk using risk weight we obtained in the AHP method. The equation of global weight is as shown below:

$$Global\ weight = Risk\ factor\ weight \times Local\ weight \quad (1)$$

After that, we also had to calculate Risk Priority Number (RPN) value which needed for determining risk criticality and its acceptance using the equation below:

$$\mathrm{RPN} = \mathrm{O} \times \mathrm{S} \times \mathrm{D} \tag{2}$$

The RPN value also used for calculating the Weighted Risk Priority Number (WRPN) that has an equation as shown below:

$$WRPN = RPN \times f(Wi) \tag{3}$$

*2.3. Analytical Network Process (ANP)*
ANP is a general theory of relative measurement used to derive composite priority ratio scales from individual ratio scales that represent relative measurement of the influence of elements that interact with respect to control criteria [9]. ANP method was used to assess strategies and determine which strategies that were recommended for mitigation. The ANP method began by calculating the geometric mean to get the overall value from the three experts' judgements. The equation is as shown below:

$$\text{Geometic Mean} = (\mathrm{a}_1 \times \mathrm{a}_2 \times \ldots \times \mathrm{a}_\mathrm{n})^{1/\mathrm{n}} \tag{4}$$

After the experts' judgement were calculated, then it was needed to also check and analyze the consistency ratio. Consistency ratio shows that the experts' judgements are consistent and can be use for further calculation. The expert's judgements are considered consistent if the CR value fall at or below 10%. CI and CR equation are as shown below:

$$\mathrm{CI} = (\lambda\mathrm{max} - \mathrm{n})/(\mathrm{n} - 1) \tag{5}$$

Information:
λmax : Maximum eigen vector
n : Number of alternative or criteria

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI} \tag{6}$$

Information:
CI : Consistency Index
RI : Ratio Index

## 3. Result and Discussion
This study aims to identify risks that have a high probability of occurrence and assess risks to determine their criticality rank. This study also aims to generate recommendation strategies that can be taken into consideration in mitigating the risk. Meanwhile, implementation and monitoring have not been carried out in real conditions.

*3.1. Risk Identification*
Risk identification was carried out with the aim of determining the risks that have emerged or have the possibility to appear in the supply chain. Identification of these risks was carried out with literature study by using supply chain risks categorization by Jafarnejad [6] and interview with experts, after which 25 risk variables were grouped based on the 6 risk factors that sheltered them:

*3.2. Data consistency and risk weight*
After the expert assessments have been done, weights for 6 risk factors and 25 local weights can be calculated. The local weight addressed a risk variable weight. The weight result can be seen in Table 4. Moreover, weight of each risk must be validated using consistency ratio (CR) value and followed the rule the CR value is 0.1 or more. The purpose of the consistency test was to find out whether the assessments of the three experts were consistent and also determine whether the data could be used for

the next calculation step or not. The results of CR obtained sequentially are: 0.04; 0.01; 0.04; 0.00; 0.07; 0.08; and 0.03. Thus, all the CR values are below 0.1 then the data was consistent.

**Table 3.** Wooden Toy Industry's supply chain risk factors and variables

| Risk Factor | Risk Variable | Risk Factor | Risk Variable |
|---|---|---|---|
| Demand | Competitor moves | Information | Information delay |
| | Delays in delivery to customers | | Wrong choice of communication |
| | Forcast errors | Operational | Capacity inflexibility |
| | Market saturation | | Design changes |
| Environment | Macroeconomic uncertainty | | Disruption in production |
| | Natural disasters | | Inventory risk |
| | Policy uncertainty | | Variability in production process |
| | Social uncertainty | Supply | Dependency on single supplier |
| Financial | Cost/price risk | | Inflexibility of supplier |
| | Exchange rate risk | | Poor delivery performance |
| Information | Breakdown of IT infrastructure | | Supplier poor quality |
| | Distorted information | | Supplier bankruptcy |
| | Inadequate information security | | |

*3.3. Calculationg Global Weight*

Here the FMECA method begun by calculating the global weight, which is the weight obtained by multiplying the local weight by the weight of the risk factor using equation (1). For example, look at the demand risk factor which has a weight of 0.22 and the competitor move risk variable which has a weight of 0.136. Using equation (1) the results are as follows, the rest of the global weight shown in Table 4:

$$\text{Global weight} = 0{,}22 \times 0{,}136 = 0{,}030$$

*3.4. Calculationg RPN Value*

The RPN value or Risk Priority Number was calculated to determine the value of the risk by considering the occurrence, severity, and detectability of risk. Furthermore, after completed the assessment of the three experts, the O (occurance), S (severity), and D (detection) scores were calculated to get the average value, so there would be only one value. The RPN was calculated with equation (2). Take an example of forecast error risk variable, the risk has a value of 8 for occurrence (often occurs), a value of 4 for severity (very low), and a value of 4 for detection (quite easily detected). With equation (2) it is produced:

$$\text{RPN} = 8 \times 4 \times 4 = 112$$

*3.5. Determining Risk Criticality and Its Acceptance*

After the RPN value had been determined, each risk variable critical level was categorized based on the RPN value, then the risk acceptance was classified based on the criticality level. Using this criticality analysis helped us to map the risk, take a look at Table 4, risk variable cost/price risk is categorized as critical because the RPN value is in the range of 253 to 324 according to table 2. This level of criticality has unacceptable risk acceptance that need corrective actions immediately.

*3.6. Calculating the WRPN value and ranking the risks*

The last stage in FMECA was risk ranking, based on criticality analysis we took only the risk that had a high criticality level to be sorted using WRPN (weighted risk priority numbers) calculation which could be obtained using equation (3), for example for policy uncertainty risk, the calculation is as follows:

$$\text{WRPN} = 150 \times 0{,}023 = 3{,}456$$

**Table 4.** Risk criticality and its acceptance

| Risk Factor | Weight | Risk Variable | Local Weight | Global Weight | O | S | D | RPN | Criticality | Risk acceptance |
|---|---|---|---|---|---|---|---|---|---|---|
| Information | 0,094 | Breakdown of IT infrastructure | 0,38 | 0,036 | 3 | 5 | 2 | 28 | Low | Acceptable |
| Demand | 0,22 | Competitor moves | 0,136 | 0,030 | 5 | 4 | 2 | 33 | Moderate | Tolerable |
| Financial | 0,234 | Exchange rate risk | 0,458 | 0,107 | 3 | 5 | 2 | 33 | Moderate | Tolerable |
| Supply | 0,191 | Poor delivery performance | 0,197 | 0,038 | 3 | 5 | 2 | 37 | Moderate | Tolerable |
| Supply | 0,191 | Supplier bankruptcy | 0,332 | 0,063 | 4 | 6 | 2 | 40 | Moderate | Tolerable |
| Supply | 0,191 | Dependency on single supplier | 0,156 | 0,030 | 3 | 5 | 2 | 41 | Moderate | Tolerable |
| Operational | 0,179 | Variability in production process | 0,157 | 0,028 | 4 | 3 | 3 | 43 | Moderate | Tolerable |
| Information | 0,094 | Distorted information | 0,221 | 0,021 | 4 | 5 | 3 | 49 | Moderate | Tolerable |
| Demand | 0,22 | Delays in delivery to customers | 0,344 | 0,076 | 5 | 5 | 2 | 50 | Moderate | Tolerable |
| Information | 0,094 | Inadequate information security | 0,183 | 0,017 | 3 | 4 | 4 | 58 | Moderate | Tolerable |
| Operational | 0,179 | Design changes | 0,151 | 0,027 | 6 | 6 | 2 | 67 | High | Tolerable |
| Information | 0,094 | *Wrong choice of communication* | 0,1 | 0,009 | 4 | 6 | 3 | 72 | High | Tolerable |
| Supply | 0,191 | Inflexibility of supplier | 0,084 | 0,016 | 5 | 5 | 3 | 76 | High | Tolerable |
| Information | 0,094 | Information delay | 0,116 | 0,011 | 4 | 5 | 3 | 77 | High | Tolerable |
| Operational | 0,179 | Inventory risk | 0,105 | 0,019 | 6 | 5 | 3 | 79 | High | Tolerable |
| Demand | 0,22 | Market saturation | 0,378 | 0,083 | 3 | 6 | 4 | 82 | High | Tolerable |
| Supply | 0,191 | Supplier poor quality | 0,231 | 0,044 | 5 | 7 | 3 | 104 | High | Tolerable |
| Environment | 0,082 | Social uncertainty | 0,169 | 0,014 | 5 | 6 | 4 | 112 | High | Tolerable |
| Demand | 0,22 | Forcast errors | 0,142 | 0,031 | 8 | 4 | 4 | 112 | High | Tolerable |
| Operational | 0,179 | Disruption in production | 0,419 | 0,075 | 5 | 7 | 3 | 122 | High | Tolerable |
| Environment | 0,082 | Policy uncertainty | 0,281 | 0,023 | 5 | 6 | 5 | 150 | High | Tolerable |
| Operational | 0,179 | Capacity inflexibility | 0,168 | 0,030 | 6 | 7 | 4 | 154 | High | Tolerable |
| Environment | 0,082 | Natural disasters | 0,268 | 0,022 | 4 | 6 | 8 | 186 | Very High | Unacceptable |
| Financial | 0,234 | Cost/price risk | 0,542 | 0,127 | 7 | 6 | 6 | 263 | Critical | Unacceptable |
| Environment | 0,082 | Macroeconomic uncertainty | 0,282 | 0,023 | 8 | 10 | 7 | 519 | Very Critical | Unacceptable |

**Table 5.** Ranked Risk

| Risk Factor | Risk Variable | Global Weight | RPN | WRPN | Criticality | Rank |
|---|---|---|---|---|---|---|
| Financial | Cost/price risk | 0,127 | 263 | 33,379 | Critical | 1 |
| Environment | Macroeconomic uncertainty | 0,023 | 519 | 11,996 | Critical | 2 |
| Operational | Disruption in production | 0,075 | 122 | 9,167 | Critical | 3 |
| Demand | Market saturation | 0,083 | 82 | 6,807 | Critical | 4 |
| Operational | Capacity inflexibility | 0,030 | 154 | 4,631 | High | 5 |
| Supply | Supplier poor quality | 0,044 | 104 | 4,576 | High | 6 |
| Environment | Natural disasters | 0,022 | 186 | 4,083 | High | 7 |
| Demand | Forcast errors | 0,031 | 112 | 3,513 | High | 8 |
| Environment | Policy uncertainty | 0,023 | 150 | 3,456 | High | 9 |
| Operational | Design changes | 0,027 | 67 | 1,807 | High | 10 |
| Environment | Social uncertainty | 0,014 | 112 | 1,552 | High | 11 |
| Operational | Inventory risk | 0,019 | 79 | 1,491 | High | 12 |
| Supply | Inflexibility of supplier | 0,016 | 76 | 1,217 | High | 13 |
| Information | Information delay | 0,011 | 77 | 0,840 | High | 14 |
| Information | *Wrong choice of communication* | 0,009 | 72 | 0,677 | High | 15 |

Then, the critical level for each risk variable was determined based on the comparison with the average WRPN, the average WRPN of the 15 risk variables at Table 5 is 5,946. So if the WRPN value in Table 5 exceeded the WRPN average, then it is categorized as a critical risk. According to Table 5, there are have four risks that are labeled as critical. But, in this research focused to develop strategies for the most critical risk which was cost/price risk.

### *3.7. Determine strategies priority*

The main risk generated is price/cost risk. In the case in the wooden toy industry it is considered as the commodity cost volatility. Commodity cost volatility risk is a financial risk which in its handling involves effective and efficient management. Therefore, there are 8 strategies proposed to be assessed and prioritized. The proposed strategy consists of strategies for the commodity cost volatility risk and also strategies for effective management. Both are different things, so that the strategy is not combined in one matrix. Determination of strategy priorities was done using the ANP method. To input the valuation, the geometric mean of the experts' judgment using equation (4) must be done. The results are as shown in Table 6.

**Table 6.** Aggregated experts assessments using geometric mean equation

| Strategies for cost/price risk | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Commodity Cost volatility | | | | | | Effective Management | | | |
| | Track commodity price movements (T1) | Establish clear terms with suppliers (T2) | Understand the true quantity used (T3) | Differentiate savings goals (T4) | Combining wood with various commodities (T5) | | Strategic accounting practices (M1) | Hiring external accountant (M2) | Financial planning (M3) |
| T1 | | 0,843433 | 0,305711 | 0,36246 | 0,721125 | M1 | | 4,217163 | 1,709976 |
| T2 | 1,185631 | | 1,169607 | 0,36246 | 0,753947 | M2 | 0,237126 | | 0,36246 |
| T3 | 3,271066 | 0,854988 | | 2,758924 | 0,721125 | M3 | 0,584804 | 2,758924 | |
| T4 | 2,758924 | 2,758924 | 0,36246 | | 0,753947 | | | | |
| T5 | 1,386723 | 1,326352 | 1,386723 | 1,326352 | | | | | |

According to Barosi and Busse [10], strategies like T1 to T4 could help on understanding exposure to raw material and how to manage the cost volatility. On the other hand, in order to achieve effective and efficient management could be done by practicing effective financial magement as Shallow [11] elaborated that strategies like M1 to M3 could be applied for financial management in a small business.

*3.7.1. Data Consistency.* This step has similarity with AHP method in part to consider the consistency expert's judgements. E*quation* (5) can be used to be found the Consistency Ratio (CR) value as an example bellow. There *is the calculation of CI for effective management:*

$$\mathrm{CI} = (3{,}00139 - 3)/(3 - 1) = 0{,}000699$$

After that, calculating the consistency ratio using equation (6), and got the result as shown:

$$\mathrm{CR} = (0{,}000699)/(0{,}52) = 0{,}00134$$

According to Saaty It is recommended that CR should be less than or equal to 0.1. Seeing that the result, the effective management factor was less than 0.1 then the experts judgements is consistent. But for commodity cost volatility factor, the experts' judgement exceeded the recommended CR and has the value of 11%, because of that the strategy priority assessment continued only with management factor.

*3.7.2. Strategies priority. I*n order to get the best strategy that were recommended, the highest percentage can be chosen as a decision. Thus, in this research, the recommended strategies for cost/price risk are strategic accounting practices (54%) and financial planning (33%).

## 4. Conclusion

Based on the risk analysis in the wooden toy industry's supply chain, it can be concluded that there are 6 risk factors and 25 risk variables in the wooden toy industry's supply chain. Those 6 risk factors are demand, environment, financial, information, operational, and supply risk. The most critical risk from the 15 risk variables is cost/price risk with the highest WRPN value of 33,379. For that critical risk, developed and assesed the recommended strategies for minimizing the cost/price risk based on ANP method which are obtained: conducting strategic accounting practices, and financial planning.

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