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Supplier Selection Model Based on Risk in an Indonesian Healthcare Service Industry

S Indrawati¹, A ‘Azzam¹, H I Cahaya¹

¹Industrial Engineering, Universitas Islam Indonesia, Yogyakarta, 55584, Indonesia

sriindrawati@uii.ac.id

Abstract. In Indonesia, healthcare services are a priority industry sector. In the last few periods, every health care provider began to evaluate and make a performance improvement of the entire supply chain. Supplier selection is one of supply chain business process that have some risks. Therefore, this research is conducted to identify and reduce various risks in supplier selection process. The method used is Fuzzy Failure Mode and Effect Analysis (FFMEA) with three main stages, i.e. fuzzification, rule evaluation and defuzzification. The result show that there are four criteria, i.e. price, communication, quality and delivery time used for supplier selection in an Indonesian healthcare industry. Each criterion has some supplier performance risks with a total of 10 failure modes. The integration of risk factors in supplier selection model have been successfully done with one best suppliers based on the lowest risk score.

1. Introduction

Healthcare services is one of industry priorities in Indonesia. Based on financial data, 5% of budget allocation is given for health sector. The budget allocation increased by 83,2% in the period 2011-2017, the increase in budget is the second largest after infrastructure [1]. Health budget is conducted to strengthen promotive and preventive efforts and improve access and quality of healthcare services for Indonesian citizen.

By becoming a priority industry sector, the performance of a healthcare service play an important role. In the last few periods, every healthcare provider began to evaluate and strive to improve the performance of the entire business process. Supply chain system is one of the important elements of business competitiveness in improving industrial activity [1].

A good system is done to minimize the occurrence of risk to the industry [2]. If the risk is not well managed, it will degrade the industry performance. The level of risk is influenced by several factors, i.e. exposure, location, use, quantity and susceptibility of the elements involved [3]. Any risks associated with activities in the business processes of an industry must be identifiable, measurable, assessed, mitigated, and controlled to reduce potential losses [4].

One of the business processes in healthcare service industry that should consider the risk is supplier's selection process. Supplier has a considerable influence for the industry in optimizing the quality of raw materials and supporting equipment needed in healthcare services. In addition, the cost of procurement of raw materials and components can reach 70% of product cost in an industry [5]. In general, there are several criteria used in suppliers selection, i.e. quality, delivery, service, technical capabilities and financial condition [6]. However, there are still few studies that consider the risk of supplier performance failure in supplier selection process.



There are several risks that may lead to supplier performance failures in food-producing industries, i.e. shortage of raw materials, supply-quality risk, procurement risk, communication failure and collaboration with suppliers [7]. In fashion industry, the risks faced in raw materials procurement are collaboration, the excess quantity of goods, long lead time of production, delay and the use of a single foreign supplier [8]. Each industry can face different risks, therefore it is important to manage risks in supplier selection process. FMEA is the most common method used for identifying risks. FMEA is a structured procedure for identifying and preventing as many failure modes [9]. Determining the cause of potential failure on FMEA is based on the highest value of risk priority number (RPN). But the use of conventional FMEA, the input value often contains uncertainty. Factors of severity, occurrence, and detectability are not easy to evaluate appropriately. It is necessary to give the supplier performance weight by using fuzzy goal programming to overcome the inappropriate linguistic subjective factor in FMEA [10].

2. Theory

2.1. Supplier Selection

Supplier selection is an important process in the procurement cycle. Each industry will identify supplier alternatives and determine one or some of the best suppliers. If an industry chooses an improper supplier, it will lead to some potential losses within the contract period. There are seven factors that can be used as a supplier performance measurement, i.e. quality, responsiveness, delivery, financial condition, transportation costs, technical capabilities and facilities [11].

2.2. Fuzzy Failure Mode and Effect Analysis (FFMEA)

FMEA is used to identify and prevent the risks or failure modes [10]. FMEA is a method that aims to evaluate the system design by considering the various failure modes and analyzing the effects on system reliability [12]. FMEA uses a risk priority number (RPN) which is a mathematical formulation of severity (S), occurrence (O) and detection (D). The RPN value can be calculated using the following equation:

$$RPN = S \times O \times D \quad (1)$$

To minimize uncertainty in FMEA, fuzzy linguistics is used to describe the three risk factors of severity, occurrence and detection [13]. There are three major stages in FMEA fuzzy, i.e.

- a. Fuzification is the process using linguistic variables to convert three risk factors of severity, occurrence, and detection into fuzzy. Fuzzy number values for severity, occurrence and detection are obtained from Table 1-Table 3[14].
- b. Rule evaluation that contains expert knowledge regarding the interaction of failure modes and the effects in the form of fuzzy rule "if then". Such rules are more easily formulated in linguistic rules than numerical ones.
- c. Difuzification, the process of creating a rating from Fuzzy RPN to provide the priority level of failure mode. The defuzification process uses the centroid method based on Table 4.

3. Research Method

Research on risk factor integration in supplier selection model using fuzzy FMEA is done in an Indonesian healthcare service industry. This research consists of four main stages, i.e.

a. Variables Identification

Some variables are identified to support FMEA research which contains potential failures mode, causes and effects.

Table 1. Fuzzy severity value [14]

Ranking	Impact of Severity	Fuzzy Number
Danger without warning	The severity is very high without warning	(9, 10, 10)
Danger with warning	The severity is very high with warnings	(8, 9, 10)
Very high	Loss of primary function (do not operate, nosafety effect)	(7, 8, 9)
High	Main function decrease (operate, but reduce performance level)	(6, 7, 8)
Medium	Loss of primary function (operate, uncomfortable)	(5, 6, 7)
Low	Decrease in secondary function (operate, but reduce the comfort level)	(4, 5, 6)
Very low	Views or sounds, operate, wrong goods, and known to most customers (> 75%)	(3, 4, 5)
Small	Views or sounds, operate, wrong goods, and known to most customers (> 50%)	(2, 3, 4)
Very small	Views or sounds, operate, wrong goods, and known to most customers (> 25%)	(1, 2, 3)
There is no effect	No effect	(1, 1, 2)

Table 2. Fuzzy occurrence value [14]

Ranking	Criteria	Fuzzy Number
Very high (VH)	Mistakes can't be avoided	(8, 9, 10, 10)
High (H)	Recurring error	(6, 7, 8, 9)
Medium (M)	Errors occasionally occur	(3, 4, 6, 7)
Low (L)	Relatively few errors	(1, 2, 3, 4)
Small (R)	Error impossible	(1, 1, 2)

Table 3. Fuzzy detection value [14]

Possible Detection	Criteria	Fuzzy Number
Almost impossible (AU)	Can't be detected /analyzed	(9, 10, 10)
Very small (VR)	Very little chance of detecting an error	(8, 9, 10)
Small (R)	Small chance of detecting errors	(7, 8, 9)
Very low (VL)	Very low chance of detecting errors	(6, 7, 8)
Low (L)	Low chance to detect errors	(5, 6, 7)
Medium (M)	Medium chance to detect errors	(4, 5, 6)
High enough (MH)	High enough chance to detect errors	(3, 4, 5)
High (H)	High chance to detect errors	(2, 3, 4)
Very high (VH)	Very high chance of detecting errors	(1, 2, 3)
Almost certainly (AC)	Can detect errors	(1, 1, 2)

Table 4. Fuzzy risk priority number value [16]

Category	Curve Type	Parameter
Very Low	Trapezoidal	(0 0 25 75)
Very Low - Low	Triangle	(25 75 125)
Low	Triangle	(75 125 200)
Low - Moderate	Triangle	(125 200 300)
Moderate	Triangle	(200 300 400)
Moderate - High	Triangle	(300 400 500)
High	Triangle	(400 500 700)
High - Very High	Triangle	(500 700 900)
Very High	Trapezoidal	(700 900 1000 1000)

b. Data Collection

A FMEA questionnaire is develop and a survey is conducted to determine the risk priority number in each failure mode for each supplier.

c. Data Processing

The FMEA input is done using fuzzification, rule evaluation and difuzzification. The linguistic table sand fuzzy number used to evaluate the severity, occurrence, detection factors are tables I, II and III. Rule evaluation is done with Matlab R2013a software. Rules formed from 3 input variables consist of severity (S) of 10 categories, occurrence (O) as many as 5 categories, and detection (D) as many as 10 categories to obtain a total of 500 rules (10x5x10). Then difuzzification is performed to determine the fuzzy risk priority number (FRPN) for each failure modes using Table 4.

d. Analysis and Interpretation

At this stage, best supplier is selected with the lowest risk score. The supplier performance also being evaluated as a basis for improvement.

4. Result and Discussion

There are four criteria, i.e. price (A), communications (B), quality (C) and delivery times (D) used in evaluating and selecting suppliers as seen in Table 5. The criterias are determined based on a survey of some experts at the purchasing department of an Indonesian healthcare service industry.

Table 5. Risk identification in healthcare service industry

Code	Failure Mode	Pottential Effect	Potential Cause
A1	Too expensive than the market	Cancellation of purchase	Level of competition
A2	Price is not in accordance with product quality	The level of trust decreased	Low grade materials and production
A3	Price is not in accordance with the contract agreement	The buyer gives a penalty	Raw material price increase
B1	Hard to contact	Low response	Insufficient information system
C1	Different quality with last ordered product	The buyer choose another supplier	Raw material price increase
C2	Quality is different than promised	The level of trust decreased	Raw material replacement
C3	Many products are damaged during shipment	Buyers ask for compensation and increase delivery time	Delivery of the product is too long
D1	Unable to adjust delivery time according to agreement	Change the schedule already made by the buyer	Limitations of product delivery transport
D2	Tolerable lateness	The suppliergets a minor reprimands	Product delivery trips are constrained
D3	Intolerable lateness	The suppliergets a penalty from buyer	Product delivery trips are constrained

Each criterion has some supplier performance failure modes. The price criteria have three potential failure modes, i.e. too expensive compared to the market, the price is not in accordance with product quality and price is not in accordance with the contract agreement. For communication criteria, there is only one potential failure mode, i.e. difficult to be contacted. Product quality criteria (C) have three types of failure modes, i.e. different quality with the last ordered product, different quality than promised and many products defect during shipment. The delivery time criteria (D) have three types of potential failure modes, i.e. unable to adjust delivery time according to agreement, tolerable lateness and intolerable lateness.

Ten types of failure modes are used to evaluate supplier performance. There are five suppliers evaluated in this research, i.e. supplier 1 (S1), supplier 2 (S2), supplier 3 (S3), supplier 4 (S4) and supplier 5 (S5). Each supplier is given severity (S), occurrence (O) and detectability (D) values for each type of failure modes before defuzzification process. For supplier 1, there are three types of failure modes with high fuzzy risk priority number (FRPN) as shown in Table 6. The Failure modes, i.e. too expensive compared to market, different quality with last ordered product and quality different from promised. The total value of FRPN for supplier 1 is 1214,5.

Table 6. Defuzzification results for supplier 1

Code	S	O	D	FRPN	Code	S	O	D	FRPN
A1	5	5	9	208	C2	6	5	6	208
A2	8	7	3	133	C3	5	3	9	75
A3	5	6	5	75	D1	2	8	8	75
B1	5	8	3	24.5	D2	6	6	4	75
C1	5	7	7	208	D3	6	3	9	133

For supplier 2, there are two types of failure modes with high fuzzy risk priority number (FRPN) as shown in Table 7. The Failure modes, i.e. too expensive than the market and many products are damaged during shipment. The total value of FRPN for supplier 2 is 815,5.

Table 7. Defuzzification results for supplier 2

Code	S	O	D	FRPN	Code	S	O	D	FRPN
A1	5	4	5	133	C2	3	4	6	75
A2	4	8	3	75	C3	4	7	4	133
A3	4	8	2	75	D1	4	3	5	24,5
B1	7	3	4	75	D2	3	5	5	75
C1	5	4	3	75	D3	5	4	4	75

For supplier 3, there are three types of failure modes with high fuzzy risk priority number (FRPN) as shown in Table 8. Failure modes, i.e. prices are not in accordance with the contract agreement, difficult to contact and many products are damaged during the delivery. The total value of FRPN for supplier 3 is 823.

Table 8. Defuzzification results for supplier 3

Code	S	O	D	FRPN	Code	S	O	D	FRPN
A1	7	6	2	75	C2	7	7	2	75
A2	5	3	5	24,5	C3	5	5	5	133
A3	4	5	6	133	D1	8	3	4	75
B1	6	3	6	133	D2	4	7	3	24,5
C1	7	2	6	75	D3	6	4	4	75

For supplier 4, there are two types of failure modes with high fuzzy risk priority number (FRPN) as shown in Table 9. Failure modes, i.e. the price is not in accordance with the quality and can not adjust the delivery time in accordance with the agreement. The total value of FRPN for supplier 4 is 664.

Table 9. Defuzification results for supplier 4

Code	S	O	D	FRPN	Code	S	O	D	FRPN
A1	5	2	6	75	C2	6	2	3	24,5
A2	5	8	6	133	C3	4	6	5	75
A3	5	2	6	24,5	D1	6	8	3	133
B1	2	2	4	24,5	D2	8	3	3	24,5
C1	4	7	5	75	D3	5	9	2	75

For supplier 5, there are four types of failure modes with high fuzzy risk priority number (FRPN) as shown in Table 10. Failure modes, i.e. the price does not match the quality, difficult to contact, different quality with the last ordered product, can not adjust the delivery time in accordance with the agreement and late can not be tolerated. The total value of FRPN for supplier 5 is 963,5.

Table 10. Defuzification results for supplier 5

Code	S	O	D	FRPN	Code	S	O	D	FRPN
A1	5	4	5	24,5	C2	5	6	4	75
A2	9	5	3	133	C3	7	8	2	24,5
A3	7	8	2	24,5	D1	7	6	3	133
B1	8	4	6	208	D2	4	6	5	75
C1	3	7	7	133	D3	8	8	2	133

Supplier 4 becomes the best supplier because it has the lowest risk score 664. To improve the supplier's performance, some improvements are needed, i.e. product pricing based on quality and using the services of an external expedition to reduce product delivery lead time.

5. Conclusions

The integration of risk factor in supplier selection model is successfully done in an Indonesian healthcare service industry using fuzzy FMEA. The result shows that total FRPN value for each supplier, i.e. supplier 1 with FRPN 1214,5, supplier 2 with FRPN 815,5, supplier 3 with FRPN 823, supplier 4 with FRPN 664 and supplier 5 with FRPN 963,5. So supplier 4 is the selected supplier because it has the lowest risk score. The supplier performance can be improved through some factors with high FRPN. A further research is needed to develop a general model to improve suppliers performance among healthcare service industries in Indonesia.

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