Design Mitigation and Monitoring System of Blood Supply Chain Using SCOR (Supply Chain Operational Reference) and HOR (House of Risk)

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Abstract. Blood supply chain manages the flow of blood product from donors to patients. One of the service provider is PMI which contributes 92% of blood national donation. In fact, demands and supplies of in a blood supply chain are often unpredictable. They contribute to the occurrence of risks which have direct impacts on human life. Thus need a risk management to mitigate such impacts. One way to do so is by using Supply Chain Operational Reference (SCOR) model for mapping the activities of blood chain. Thus, it can facilitate the identification of risk events and risk agents. Further risk events and risk agents are processed using House of Risk (HOR). While the aim of HOR1 is to identify priority of the risk events, the HOR2 arranges necessary mitigation strategies. Moreover, in this work, there are 9 risk agents chosen from HOR1 and 8 preventive actions for the mitigation. Additionally, this research develop a monitoring system that may assist to monitor the occurring risks.

1. Introduction

The blood supply chain manages the flow of blood products from donors to the patients through 5 stages: donors, mobile collection sites, blood centre, demand nodes, and patients [1]. The concept of blood supply chain is to distribute blood products safely, inexpensively, and accessible to the patients [2]. One of the blood service providers in Indonesia is Unit Donor Darah (UDD). UDD PMI (Unit Donor Darah Palang Merah Indonesia) takes a significant role in blood service in Indonesia since it contributed 92% of national blood donation in 2016 [3].

The demand and supply of blood supply chain are hard to be predicted. That uncertainty causes risks which have direct impacts on human life [2]. A few examples of risks in blood supply chain are the sudden change in blood demands, the delay in product delivery from the supplier, errors in the process of taking blood, and damaged blood [4]. The potential risks of blood supply chain may affect the overall performance of the healthcare network. Therefore, it is important for a risk management to be conducted in order to generate the risk mitigation [2].

One of the methods that can be applied to the risk management is House of Risk (HOR). HOR1 can identify the risk and the cause of it, as well as setting up the mitigation strategy and decreasing the possibility of a risk using HOR2. The identification of risks is done using a Supply Chain Operational Reference (SCOR) model [4]. HOR model has been used in managing the blood supply chain in Regional Blood Centre 5, Thailand [2]. It has also been used to set up the risk mitigation of blood supply chain in PMI of Sleman regency [4].
The risks integrated in the monitoring system will be useful to observe the actual condition that is compared to the target so that it is easier in making a decision [5]. The purpose of this research is to set up the mitigation plan and design a monitoring system in order to minimize the risks of blood supply chain in UDD PMI of Klaten regency.

2. Theoretical Basis

2.1. Supply Chain

Supply chain consists of all parties that contribute directly and indirectly in meeting the demands of the consumer, including manufacturers, suppliers, transporter, warehouse, retailer, and consumer. The main object of every blood supply chain is to fulfill the consumer demand [6]. According to Council of Supply Chain Management, the management of supply chain consist of planning, management, and a good coordination on stocking, manufacturing up to distributing process [7].

According to Xanthopoulos and friends’s point of view, main principle of supply chain risk management is to identify, to assess, and to prioritize supply chain risks in order to minimize, to monitor, and to control the occurrences and the impacts of uncertain risk events [2]. Three phases on supply chain risk management are identification phase, risk assessment phase and risk mitigation [8].

Supply Chain Operational Reference (SCOR) is a reference model in operating supply chain [9]. It is useful for describing and analyzing the supply chain [10]. SCOR model has a hierarchal characteristic. There are three levels in SCOR, namely the type of process, process categories, and process elements [11].

2.2. House of Risk (HOR)

HOR is a modification model of Failure Mode and Effect Analysis (FMEA) to quantify risks and adapting House of Quality (HOQ) model in order to choose which risk agent is more influential. Quantifying process is done to define the process of supply chain based on Supply Chain Operation Reference (SCOR) [12].

2.2.1. HOR1. HOR1 has the aim to decide which risk agent is more influential. The followings are the steps done in HOR1 [12].

- Map the blood supply chain activity based on the SCOR model that is categorized into 5 categories: plan, source, deliver, make, dan return. The HOR1 Framework is displayed in Figure 1.

| Business processes | Risk event | Risk agents (A) | Severity of risk event (S) |
|--------------------|------------|-----------------|---------------------------|
| Plan               | E1, E2     | A1, A2, A3, A4, A5 | S1, S2, S3, S4, S5 |
| Source             | E3, E4     | A6, A7          | S6, S7                  |
| Make               | E5         | A8              | S8                      |
| Deliver            | E9         | A9              | S9                      |
| Return             | E10        | A10             | S10                     |

Figure 1. HOR1 Framework

- Identify the risk event (E) and the risk agent (A). Risk event is a negative unexpected event. Risk agent is the cause of risk event occurrence.
- Assess the severity (S) of every risk event. This assessment shows how big the effect of risk event. The assessment uses scale of 1 – 10. The bigger the number of the scale is, the bigger the effect of risk event it will have.
Assess the possibility of risk agent (O_j) occurrence. The assessment uses scale of 1 – 10. Scale 1 shows that a risk agent never happens, while scale of 10 shows that a risk agent almost always happens.

The next step is to examine relationship matrix in order to assess the correlation between a risk agent and a risk event. Correlation assessment (R_ij) has 4 scales: 0,1,3, and 9. Scale of 0 indicates that there is no correlation, scale of 1 reveals a low correlation, scale of 3 shows an average correlation, and scale of 9 indicates a high correlation.

Calculate Aggregate Risk Potential (ARP_j) of every risk agent using the following formula:

\[ ARP_j = O_j \sum_i S_i R_{ij} \] (1)

2.2.2. HOR2. HOR2 aims to decide which action (preventive action) that needs to be done first by considering the effectiveness of an action and the difficulty level of the action. The followings are the steps in HOR2 [12].

- Choose which risk agent has a priority rank that can be assisted using pareto chart to analyze the ARP_j value.
- Identify preventive action (PA_k) or the preventive action against risk agent.
- Determine the correlation between every preventive action and every risk agent. The correlation assessment (E_{jk}) has 4 scales: 0,1,3, and 9. The scales display the effectiveness of preventive action k to decrease the possibility of risk agent j occurrence.
- Calculate the total effectiveness of every preventive action using the formula:

\[ T_{ek} = \sum_j ARP_j E_{jk} \] (2)

- Assess the degree of difficulties (D_k). There are three scales: scale of 3 means easy, scales of 4 means average, and scale of 5 means difficult.
- Calculate the total effectiveness to difficulty ratio using the formula:

\[ ETD_k = T_{ek} / D_k \] (3)

- Classify the rank of every preventive action. The one with the biggest ETD_k becomes the first in rank. The HOR2 framework is displayed in Figure 2

![Figure 2. HOR2 Framework](image)

2.3. Monitoring System
According to Council of Supply Chain Management, monitoring is an activity to observe the reality and the targeted condition. Monitoring can be applied in a system to help in the decision-making process since a monitoring process shows the report, for example figures of data chart [5].

3. Discussion

3.1. Risk event and Risk Agent Identification
In order to identify risks, the mapping of blood supply chain is conducted previously using SCOR model. Supply chain activity mapping is conducted by discussing the matter with the head of blood service in UDD PMI of Klaten regency. There are 28 risks in the supply chain that are categorized in plan, source, make, deliver, and return. Table 1 is the summary of blood supply chain risk event.

| Code | Risk Event                                      | SCOR Stage | Code   | Risk Event                                     | SCOR Stage |
|------|------------------------------------------------|------------|--------|------------------------------------------------|------------|
| E1   | Error in demand forecasting                    | Plan       | E15    | Error in blood-typing diagnosis                | Make       |
| E2   | Excessive blood stocks                          | Plan       | E16    | Serology test failure                          | Make       |
| E3   | Shortage in blood stocks                        | Plan       | E17    | Production failure                             | Make       |
| E4   | Blood donation failed to meet requirement       | Plan       | E18    | Bloods are damaged during the production process| Make       |
| E5   | Supporting material shortage                    | Plan       | E19    | Data input error                               | Make       |
| E6   | The sudden change in production schedule        | Plan       | E20    | No matching blood type                         | Make       |
| E7   | Blood demand cancellation                       | Plan       | E21    | Blood damaged in the storage                  | Make       |
| E8   | Failed negotiation                              | Plan       | E22    | Damaged blood and good blood mixed up          | Make       |
| E9   | Order specification failure                     | Source     | E23    | Failed in meeting blood demand                 | Deliver    |
| E10  | Delayed delivery from supplier                  | Source     | E24    | Difference in between the inventory system and the actual condition | Deliver    |
| E11  | Damaged supporting material                     | Source     | E25    | Blood product labelling error                  | Deliver    |
| E12  | Damaged supporting material passed the selection process | Source | E26    | Blood damaged during delivery process          | Deliver    |
| E13  | Supporting material damaged in the storage      | Source     | E27    | Blood product failed to be delivered to the customer | Deliver    |
| E14  | Error in blood-taking process                   | Make       | E28    | Late in filling complaints to suppliers        | Return      |

After identifying risk event, risk agent is identified. Risk agent is the cause risk event. There are 23 risk event identified in the blood supply chain in UDD PMI Klaten regency. Table 2 is the summary of risk agent in blood supply chain. The process of identifying risk event and risk agent are conducted by applying literature study which verified by expert(s) afterwards.

| Code | Risk Agent                                                   | Code | Risk Agent                                                   |
|------|--------------------------------------------------------------|------|--------------------------------------------------------------|
| A1   | Fluctuating demand                                           | A13  | Difficulty in detecting blood vessels                       |
| A2   | Demand forecasting error                                     | A14  | Production employee’s inaccuracy in reading the result      |
| A3   | Uncertainty in blood donor numbers                           | A15  | Damaged machine                                              |
| A4   | Staff shortage                                               | A16  | Unsuitable temperature of the production site                |
| A5   | Sudden huge demands                                          | A17  | Blood mishandling                                           |
| A6   | The hospital has gotten blood product from another blood service | A18  | Negligence of production employee                           |
| A7   | Logistic workers’ negligence                                  | A19  | IT system disruption                                         |
| A8   | Natural disaster                                             | A20  | Empty blood stocks                                           |
| A9   | Lack of communication with supplier                          | A21  | Delays in updating stock data                                |
| A10  | Carelessness of logistic officer                              | A22  | Negligence of blood service employee                        |
| A11  | Improper handling of supporting material                     | A23  | Accidents in delivering blood products                       |
| A12  | Uncertainty in blood donor’s health                          |      |                                                              |
3.2. Aggregate Risk Potential Calculation

In order to calculate the value of Aggregate Risk Potential (ARP), the value of severity ($S_i$), occurrence ($O_i$), and correlation ($R_{ij}$) are required. The assessment of those values as well as the calculation of ARP are provided in Table 3.

### Table 3. Risk Agent Blood Supply Chain

| Bas. Process | Risk Event (Ei) | Risk Agent (Ai) | Risk of Agent | Sum | Source | Si |
|--------------|-----------------|-----------------|---------------|-----|--------|----|
| Plan E1      | 3               | 3               | 0             | 1   | 0      | 5  |
| Plan E2      | 3               | 9               | 0             | 9   | 0      | 2  |
| Plan E3      | 9               | 9               | 0             | 9   | 0      | 7  |
| Plan E4      | 0               | 0               | 3             | 0   | 3      | 0  |
| Plan E5      | 3               | 3               | 0             | 3   | 0      | 2  |
| Plan E6      | 3               | 0               | 0             | 0   | 0      | 3  |
| Plan E7      | 0               | 0               | 0             | 0   | 0      | 1  |
| Plan E8      | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E9    | 0               | 0               | 0             | 0   | 0      | 0  |
| Source E10   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E11   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E12   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E13   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E14   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E15   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E16   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E17   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E18   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E19   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E20   | 1               | 0               | 0             | 0   | 0      | 1  |
| Source E21   | 0               | 0               | 0             | 0   | 0      | 1  |
| Source E22   | 0               | 0               | 0             | 0   | 0      | 1  |
| Deliver E23  | 0               | 0               | 0             | 0   | 0      | 1  |
| Deliver E24  | 0               | 0               | 0             | 0   | 0      | 1  |
| Deliver E25  | 0               | 0               | 0             | 0   | 0      | 1  |
| Deliver E26  | 0               | 0               | 0             | 0   | 0      | 1  |
| Deliver E27  | 0               | 0               | 0             | 0   | 0      | 1  |
| Return E28   | 0               | 0               | 0             | 0   | 0      | 1  |

The assessment is conducted by handing over/distributing questionnaire to the expert. In this case, the expert is the head of blood service of UDD PMI in Klaten regency. The table provide the ranks of ARP. It can be seen that rank 1 is a risk agent which has the highest ARP.

3.3. Choosing Risk Agent

In order to choose risk agent, the pareto chart is applied. The basic concept of pareto, which is 80/20, is applied in choosing a risk agent. Therefore, the chosen one is risk agent that has ARP cumulative percentage until 80%. The chosen risk agents are: (a) the negligence of logistic employee (896), (b) sudden huge demands (798), (c) empty blood stocks (693), (d) fluctuating demands (588), (e) damaged machine (540), (f) natural disaster (420), (g) blood mishandling (351), (h) the negligence of production employee (333), (i) and forecasting error (306). The pareto chart is displayed in Figure 3.
3.4. Preventive Action Classification
The preventive action is organized based on the risk agent. There are eight preventive actions as shown in Table 4 below.

Table 4. Preventive Action

| Code | Preventive Action                                      |
|------|-------------------------------------------------------|
| PA1  | Punishment for PMI employee’s negligence              |
| PA2  | Regular training for PMI employees                    |
| PA3  | Cooperation with other PMIs                           |
| PA4  | Increasing the number of blood donation socialization  |
| PA5  | Analysing blood demand statistically                   |
| PA6  | Increase blood storage capacity                        |
| PA7  | Checking the blood processing machine regularly        |
| PA8  | Improve communication with hospitals                   |

Preventive action classification is conducted by calculating ETD. ETD indicates the effectiveness degree of an action to minimize a risk cause. In order to classify preventive action, the value of $ARP_i$, correlation ($E_{ik}$), total effectiveness ($Te_k$), degree of difficulties ($D_k$), and total effectiveness to difficulty ratio (ETD$_k$) are required. The assessment of correlation and degree of difficulties are conducted by distributing questioner to the head of UDD blood service in Klaten regency. The result of preventive action classification is displayed in Table 5 as follows.

Table 5. HOR 2

| Risk Agent ($A_i$) | PA1 | PA2 | PA3 | PA4 | PA5 | PA6 | PA7 | PA8 | ARP$_i$ |
|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|---------|
| A7                 | 9   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 896     |
| A5                 | 0   | 0   | 9   | 1   | 1   | 0   | 0   | 3   | 798     |
| A20                | 0   | 0   | 9   | 9   | 9   | 0   | 0   | 3   | 693     |
| A1                 | 0   | 0   | 9   | 1   | 1   | 0   | 0   | 1   | 588     |
| A15                | 0   | 0   | 0   | 0   | 0   | 0   | 9   | 0   | 540     |
| A8                 | 0   | 0   | 3   | 0   | 1   | 0   | 0   | 0   | 420     |
| A17                | 3   | 1   | 0   | 0   | 3   | 0   | 0   | 0   | 351     |
| A18                | 3   | 1   | 0   | 0   | 3   | 0   | 0   | 0   | 333     |
| A2                 | 0   | 0   | 1   | 0   | 0   | 0   | 0   | 0   | 306     |
| Total effectiveness of Action (TE_k) | 10116 | 684 | 20277 | 7623 | 11013 | 798 | 4860 | 5061 |
|------------------------------------|-------|-----|-------|------|------|-----|------|------|
| Degree of difficulty preforming action (D_k) | 3     | 3   | 3     | 4    | 3    | 3   | 3    | 4    |
| Effectiveness to difficulty ratio (ETD) | 3372  | 228 | 6759  | 1906 | 3671 | 266 | 1620 | 1265 |
| Rank                               | 3     | 8   | 1     | 4    | 2    | 7   | 5    | 6    |

Based on the table above, the order of preventive action which can be done by PMI in Klaten regency in sequence: (1) Cooperate with other PMIs, (2) analyze blood demands statistically, (3) give punishment for every negligence of employee in PMI, (4) increase the number of blood donation socialization, (5) check blood processor machine regularly, (6) improve communication with hospitals, (7) increase blood storage capacity, and (8) give a regular training routine to every employee in PMI.

3.5. Monitoring System

Monitoring system can be used in the risks observing process. Use case diagram used to understand the system behavior and the system function [8]. There are three acts in the monitoring system: an admin, a manager, and a programmer, such as displayed in Figure 4 above. The Manager has access to login and check the dashboard. Meanwhile, the admin may login and input the data. In this case, the programmer takes role in managing the database and the website.

![Figure 4. Use Case Diagram](image)

When logging in, a user should choose to login whether as a leader or as an admin as displayed in Figure 5. Then the user should enter username and password as illustrated in Figure 6.

![Figure 5. User Interface Login As](image)
If the user chooses to log in as an admin, then he may decide whether to input the risks or to do the threshold input as shown in the Figure 7. The risk input is used to add the date, risks, and the causes. While the threshold input is used to input the limit of every risk agent.

Figure 8 shows us what the system be like if the admin chooses risk input. Admin needs to add the risk date, risk event, and risk agent that may cause the risk event happen. Then the admin needs to click "add". The result then can be seen on the table under the input form.

Figure 9 shows us what the system be like if the admin chooses threshold input. Admin needs to add the risk agent and the lower limit, middle limit and the upper limit. Then the admin needs to click "add". The result then can be seen on the table under the input form.
Figure 9. User Interface Threshold Input

If the user chooses to login as the Manager, the system will open the dashboard as Figure 10. The manager needs to choose one of the risk agents to present, and then click show button. As the result, he may see how many times the risk happens. Then, it will be compared to the limit/threshold.

Figure 10. User Interface Dashboard

4. Conclusion
There are 28 risk events and 23 risk agents that have been identified in the blood supply chain of UDD PMI of Klaten regency. Those risks are tabulated using HOR method, resulting the existence of nine chosen risk agents. Those risk agents become an input in arranging mitigation strategy. In arranging the mitigation strategy, there are eight preventive actions that can be applied by UDD PMI of Klaten regency which are expected to decrease the possibility of risk. Monitoring system can be used in observing risks. Monitoring system can observe the occurrence of risks that happen by comparing it to maximum amount that is tolerated by UDD PMI in Klaten regency.

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