Disaster risk mitigation design for supply chain activities in Aceh: a case study

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Abstract. Indonesia is a country located between three tectonic plates thus very vulnerable to natural disasters. Ensuring that supports for disaster victims arrive on time and precisely in quality and quantity is the responsibility of all the supply chain elements, particularly government board which handled the logistic support. The activities of the supports supply chain when a disaster occurs have several risks that must be assessed and the most prioritized risk will need the mitigation design to minimize the impact of these risks. This study aims to investigate risk events and risk agents in the supply chain activities in relation to disaster management in Aceh. This study employs three government boards at the key stakeholder's group who play a significant role in the disaster risk mitigation in Aceh. Data obtained from questionnaires are used for analysing the supply chain activities using the SCOR model and Fuzzy-Based House of Risk method. The study reveals that there are 25 risk events and 27 risk agents which might occur in the supply chain activities during disaster in Aceh. The mitigation strategy is proposed in mind map models with a long term solution for each risk agent related to the potential risk events.

Keywords: Disaster, Supply Chain Risk, A Fuzzy-Based HOR Assessment Method, Mitigation Modelling

1. Introduction
Disaster-related issues are tend to be popular talks in society today. Indonesia which located at the meeting of three tectonic plates (Australia, Eurasia, and the Pacific) thus very vulnerable to natural disasters. The mitigation related to the impact of disaster needs to be known by all of Indonesian. The demand of the basic necessities such as food, beverages, clothing, medicines and medical equipment for disaster victims will increase sharply after the disaster. The uncertainty in demand and supply environments in the disaster have a potential to affect delivery quality and reliability both in terms of delivering the right product as well as the right time [1]. Disaster management as the guarantor of the implementation of prompt and adequate support for disaster victims is done to achieve a quick and effective recovery [2].

Risk is something might yield loss, in applying supply chain management some risks could be influence the flow of supply chain and will inhibit the supply chain [3]. Risk itself in the supply chain could be managed with supply chain risk management. Supply chain risk management is an important process within SCM and has the main goal of identifying the sources of potential risks, suggesting suitable measures to mitigate them and increasing the supply chain’s resilience [4]. The mapping of the supply chain activities can be built using SCOR model. SCOR also provides a common supply chain
framework, standard terminology, and metrics that can be used for evaluating, positioning and implementing SC processes [5, 6].

One of the methods in risk mitigation is House of Risk (HOR). The idea is to prioritize the significant cause of supply chain risk and the most cost-effective mitigation measures. It also focuses on prioritizing the proactive actions for those prioritized risk agents by comparing the cost-effectiveness of the action before and after the proactive actions built [7, 8, 9]. The mitigation strategy can be built from a fuzzy-based house of risk assessment method which is a combination of House of Risk method and fuzzy logic. Fuzzy logic uses approximate instead of precise reasoning [10, 11, 12]. Researchers used a combination of fuzzy applications on another method which capable to solve more problem in research [13, 14]. In short, modelling of HOR in a fuzzy-based approach can ease the qualitative decision by simply using linguistic words [9]. This method expects to assess the risks and give the output for mitigation design for risk in the supply chain of support for disaster victims.

Disaster management in Aceh over the past 15 years became a concern by the government due to many natural disaster occurring which causing resulting in many deaths and losses. So the demands support should be channelled to disaster victims in the most effective timeframe. The support for disasters victims are coming from three large departments in the province scale which are the Aceh Province Department of Social Services, Aceh Province Bureau of Logistics and Aceh Province Board For Disaster Management. In a natural disaster event, communication between all of the different entities involved in the disaster response is absolutely critical, yet unfortunately, failure in communication frequently happens [15].

The observations and interviews to stakeholders in the Aceh Province Department of Social Services, Aceh Province Bureau of Logistics and Aceh Province Board For Disaster Management conclude that it took a long time to process the status of a disaster until the support is given to victims. Where actually the disaster response period is 24 hours but the government needs to respond to disaster status can take several days not to mention the time that will be taken for the distribution. The expected result of this research is to provide recommendations or good improvement proposals of policy in a mitigation strategy modelling to minimize risks in supply chain of disaster victims support in Aceh to save both time and costs.

2. Methods
The data used in this study consist only of primary data. Primary data were obtained from the results of observations and interviews with stakeholders carried out at the research site. The next is the list of Risk Event and Risk Agents which potentially appear. Furthermore, based on the series of activities, supply chain activities will be mapped using supply chain operations reference (SCOR) Model. The activities that occur are divided into five steps: plan, source, make, delivery and return.

The next step is to identify risk events and risk agents that have probabilities to occur by looking at previously mapped activities. The one who will help in this identification are stakeholders from research site who understand the flow of disaster supply chain. The risks that have been successfully identified are then developed into questionnaires. The selection of respondents will be conducted using judgmental sampling. In this study, the questionnaire will be a questionnaire based on the HOR method where the assessment consists of severity, and correlation to calculate Aggregated Potential Risk (APR) but will be filled using fuzzy expressions in linguistic words.

After all the risk agents and risk events are identified, those variable risks will be modelled in the form of fuzzy variables. The risk event will be assessed with severity $S_i$ using a fuzzy expression which classified as very low (VL), low (L), normal (N), severe (S) and very severe (VS). Risk agents would be prioritized according to their respective occurrences $O_j$ in fuzzy expression which classified as less (L), normal (N) and frequent (F). The relationship between risk event and risk agent will use $R_{ij}$ notation that classified into low (L), medium (M) and high (H). The results of the questionnaire will be continued to be modelled for the relationship between the risk event, risk agent and relationship between risk event and risk agent as graphical form as the fuzzy input sets which will be then determined to be APR value.
The risk assessment result will be measured by doing the defuzzification of the risk agent \( j \) to a particular risk event \( i \) under the occurrence \( j \) using the centre of gravity which is widely used in the literature for fuzzy defuzzification to obtain the score of fuzzy inputs. After the defuzzification, we are able to obtain the APR value for each risk agent and prioritize them from the largest to the smallest. Then this prioritizes risk will be depicted using a Pareto diagram.

Based on the Pareto analysis, the last stage is building the mitigation strategy model. The mitigation model built in the form of schematic modelling. This mitigation model built by considering existing mitigation based on the literature review and the results of interviews with stakeholders from each department. The following are the representative of the stakeholders for discussion of mitigation strategies.

### 3. Results and Discussion

Identification is conducted based on literature study, which is then is made suitable with interview process with the company related; in order to find out the risks and risks causes that may potentially have happened in the company. After the risks are identified then they will be classified according to the activities, they are: plan, source, make, deliver and return.

The risks are then coded based on SCOR model. There are 25 risk events where there are 4 risks in the plan activity, 10 risks in the source activity, 9 risks on the make activity, 1 risk on deliver activity and 1 risk on return activity. Furthermore, table 1 shows that there are 27 risk agents that have been identified which are the causes of risk events. The risk agents will be given an assessment by the research respondents to see how influential this agent is in the risks that occur in the supply chain.

| Code | Risk Agent | Code | Risk Agent | Code | Risk Agent |
|------|------------|------|------------|------|------------|
| A1   | Changes in departments policy | A10  | Request estimate error | A19  | Long time for loading and unloading process |
| A2   | Communication disorders | A11  | Procurement and distribution delays | A20  | Rough products handling |
| A3   | New employees still in the training process | A12  | Unpredictable demand | A21  | Unstandardized packaging from suppliers |
| A4   | Data entry error | A13  | The fluctuation of supplier’s production capacity | A22  | The limited ability of employees |
| A5   | Access to the location of the disaster | A14  | The forecasting based material requirement planning only | A23  | Lack of material supply capacity in warehouses |
| A6   | The disruption of the electricity supply | A15  | Careless Employees | A24  | Late material procurement |
| A7   | The large variation of item | A16  | Communication with suppliers | A25  | Lack of transportation and Infrastructure |
| A8   | Wrong item identification | A17  | Uncertainty of logistics providers for shipping | A26  | Natural Condition |
| A9   | Management planning errors | A18  | Traffic in distribution | A27  | Human error |

The risks assessment that has been done are the severity of the risk event, the occurrence of the risk agent and given a correlation assessment between the two. After the correlation value is obtained, then the APR calculation is performed to see which risk agent is the highest which will be prioritized for mitigation. The fuzzy output result will be modelled based on the fuzzy input sets which are risk events, risk agents and correlation. For defuzzification of risk agent \( j \) to a particular risk event \( i \) under the occurrence \( j \), it will be applied centre of gravity. After the defuzzification, now the APR for each risk agent are obtained and then will be prioritized from the largest to the smallest. The recapitulation of the APR value of all risks are shown in Figure 1.
The Pareto diagram shows that 80% of the occurring events are from 20% of risk agents with the highest APR value. Accordingly, these are regarded as high-risk agents namely; New employees still in the training process (A3), Unpredictable demand (A12), and Management planning errors (A9). It requires the departments to pay attention and it is urgent to build a mitigation design strategy. The mitigation strategy model will be built based on the results of interviews with the respective stakeholders, literature review and mind mapping from the researcher.

Figure 1. Pareto Diagram for ARP Values

Figure 2 shown the mitigation strategy model for new employees still in the training process (A3). There are eleven risk events that possibly caused by A3. Figure 3 shown the mitigation strategy model for unpredictable demands (A12). There are ten risk event related to A12. Figure 4 shown the mitigation strategy model for Management Planning Errors (A9). It relates to twelve risk events which connected each other.

| Colour | Annotation |
|--------|------------|
|        | Risk Agent |
|        | Risk Event |
|        | Mitigation Strategy |
4. Conclusion

There are 25 risk events and 27 risk agents that have been identified occurring in the supply chain of support for disaster victims. The data processing using a fuzzy-based house of risk assessment method shows
that there are three risk agents that are priorities that need mitigation strategy models that are new employees still on training process with APR 580, unpredictable demands with APR 580 and management planning errors with APR 560. The mitigation strategy model has been built based on the results of the literature review and interview with the experts from each department and described in the form of the mindmap.

Acknowledgments
This research is supported by Universitas Syiah Kuala, Ministry of Research, Technology, and Education of Indonesia, in accordance with the Letter of Appointment Agreement of Laboratory Grant of Fiscal Year 2019 Number: 305/UN11.2/PP/PNBP/SP3/2019 Date May 3, 2019. Thanks and high appreciation to Rector, Head of Integrated Laboratory and Head of LPPM Universitas Syiah Kuala.

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