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Simulation Modeling of Resilience Assessment in Indonesian Fertiliser Industry Supply Networks

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Abstract. Supply network resilience is a significant aspect in the performance of the Indonesian fertiliser industry. Decision makers use risk assessment and port management reports to evaluate the availability of infrastructure. An opportunity was identified to incorporate both types of data into an approach for the measurement of resilience. A framework, based on a synthesis of literature and interviews with industry practitioners, covering both social and technical factors is introduced. A simulation model was then built to allow managers to explore implications for resilience and predict levels of risk in different scenarios. Result of interview with respondens from Indonesian fertiliser industry indicated that the simulation model could be valuable in the assessment. This paper provides details of the simulation model for decision makers to explore levels of risk in supply networks. For practitioners, the model could be used by government to assess the current condition of supply networks in Indonesian industries. On the other hand, for academia, the approach provides a new application of agent-based models in research on supply network resilience and presents a real example of how agent-based modeling could be used as to support the assessment approach.

1. Introduction

As an archipelago and developing country, Indonesia is particularly vulnerable to changes in infrastructure of transportation and distribution, which can significantly destabilise supply networks. Indonesia consists of 17,000 (seventeen thousand) islands **Error! Reference source not found.**with geographical characteristics that, especially when combined with factors such as infrastructure and facility availability, lead to supply network risks for Indonesian industry [1]. Capacity and availability of ports is a major factor in managing product lifecycles and supply network operations in Indonesia. Delivery and transportation systems influence the quality of products and problems of logistics and inventories influence the production process adversely [2], [3].

Research on supply network resilience has focused on areas such as managing lead time and demand in order to create supply networks that are inherently resilient. This paper takes a system engineering perspective to investigate relationships between supply networks and infrastructure. Most literature focuses on designing and assessing supply chain resilience in demand fluctuation and provides little consideration of infrastructure availability. A number of authors [4],[5],[6],[7],[8],[9] propose frameworks for assessing supply network resilience but the emphasis of these papers lies in theoretical aspects rather than the use of the frameworks to support management decisions in real world supply chain operations. This stimulated the research reported in this paper which explored the provision of tools to support the management of supply networks, taking account of resilience with respect to changes

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in infrastructure availability, and used data from a real world case study to illustrate the potential value of the research.

A simulation model to assess the resilience with respect to changes in the availability of infrastructure facilities is introduced. The model uses input data from risk assessment and port availability reports that are available to managers in Indonesian supply networks. An Indonesian port, a key item of infrastructure in fertilizer supply networks, is used as a case study to illustrate and evaluate the approach. In global product distribution systems such as the Indonesian fertilizer industry supply network, physical infrastructure such as ports, are important as these affect the supply network's performance. Inefficiencies in loading or unloading of material in ports have a detrimental impact through the product lifecycle, from production process to consumer satisfaction.

2. Methodology

The case study method was applied to investigate a real world case from the Indonesian fertiliser industry supply network in order to support the development of a resilience assessment approach. A semi-structured questionnaire [10], [11] was developed as a tool for data collection. The semi-structured questionnaire was used because it provides opportunities for researchers to explain verbally and directly the main focus of the questions to research participants and other participants. This can help improve participants' understanding of the questions and so the answers they provide. Ten participants were chosen based on their job description, experience and recommendations from managers. In addition to the primary, interview, data, secondary data from relevant risk assessment and port availability reports was used to support participants' responses. This research used the Delphi method to collect information from participants to validate the approach. The Delphi method was chosen because it is considered as an appropriate technique to gain information for a particular issue in the real world and participants involved are the key people who are considered experts in their field [12]. The number of participants is slightly difficult to determine directly, since it depends on the number of managers or staff in supply network management in the Indonesian fertiliser Industry. In this research, ten participants agreed to be involved. This amount is considered sufficient, in accordance with the requirements of the Delphi method [12].

An iterative development process was used to create the simulation model presented in this paper. Early prototypes of the simulation model were informed by findings from interviews with the participants. In addition, these early versions of the model were evaluated with participants and areas for further development identified.

3. Case study: the Indonesian fertiliser industry

In 2011 the Indonesian fertiliser industry reported an issue with the availability of subsidised fertiliser for farmers during planting time due to delays in the distribution of fertiliser from industry to distributors. This problem was caused by delays in the transportation system. The main infrastructure of the transport system was the port. The fertiliser industry, which used the berth occupancy ratio of the port to measure port availability, established a target berth occupancy ratio of 70%. The target was set based on the United Nations Conference on Trade and Development-UNCTAD. This target was used to determine acceptable levels of risk iin the case study supply network. Berth occupancy ratio higher than 70% is a sign of congestion, while lower than 70% signifies under-utilization of the port.

The interviews highlighted that Infrastructure availability and changes increasingly affect the availability and timing of goods and services, energy and information, with failures in supply network operations affecting product quality and traceability. Access to reliable and affordable transport, communications, energy and information technology were seen as crucial for decision making. Another example of a supply network failure mode was strategic risks identified in the field of marketing and distribution such as decreasing of agricultural fertiliser absorptive capacity, busy activity of loading and unloading at the dock, congestion (long queues at the port), and overstocking in the warehouse production. The participants stated that risk assessment is an increasingly important stage to achieve targets and to improve the fertiliser industry resilience and performance.

Key performance indicators were identified based on six socio-technical system perspectives [13] as decribed on Table 1.

Table 1. The value of the key performance indicators in the level of risk

Key performance Indicators	Level of risk				
	Very low	**Low**	**Moderate**	**High**	**Very high**
Goal	0%	0.1% - 0.2%	0.2% - 0.3%	0.3%- 0.4%	>0.4%
Procedure	2 hours	2-4 hours	4-6 hours	6-8 hours	>8 hours
People	4 hours	4-8 hours	8-12 hours	12-24 hours	>24 hours
Culture	0-20%	20-40%	40-60%	60-80%	80-100%
Infrastructure	0-20%	20-40%	40-60%	60-80%	80-100%
Technology	1 per month	2 per month	3 per month	4 per month	5 per month

4. Design and Implementation of simulation model

The research reported in this paper used NetLogo 5.0.4 to build a resilience assessment model to represent the effect of infrastructure changes in supply network resilience. NetLogo includes both an agent-based and dynamic systems modeller, allowing the combination of these two types of model in the simulation model. Inputs of simulation model adopt from risk assessment and port availability report from the industry. Inputs to the simulation model are: (a) The type of infrastructure facilities used; (b) The level of risk impact in each department; (c) the level of probability of occurrence in risk assessment; and (d) Mitigation strategy and facilities, Avoid, Transfer, Reduce, and Exploit. The simulation model assists the decision maker to assess resilience by analysing risk and identifying key performance indicators of resilience assessment on the supply networks. The simulation model included both agent-based and dynamic systems elements. Inputs to the model were formulated for variables code in level of risk. These variables were imported into the system dynamic modeller through an interface model.

Figure 1 presents the output of the simulation model that describes the effects of the four mitigation strategies on the level of risk assessment and key performance indicators.

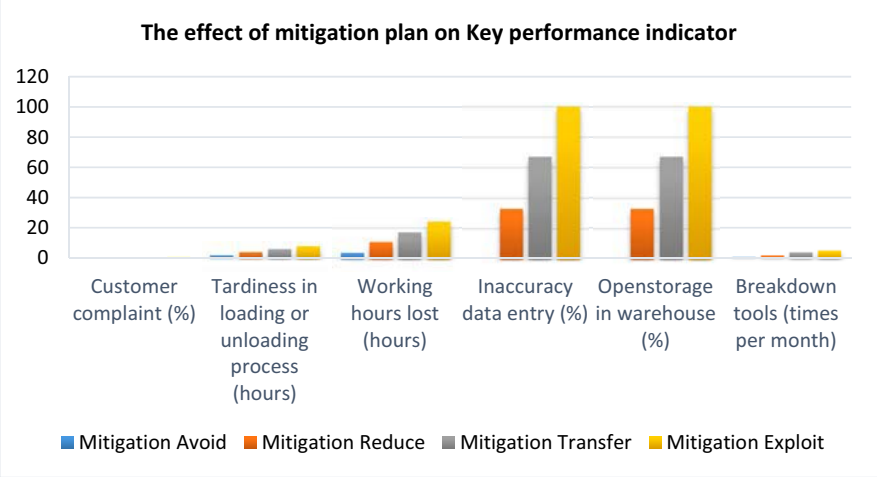

Figure 1. Output of design experiments and the effect of the mitigation plan on key performance indicators

The simulation results identified that “Avoid” is the best the mitigation plan because it generates the lowest level of risk in all six perspectives. However, the participants in the risk management department argued that if the Indonesian fertiliser industry implements “Avoid” as the mitigation for

risk, that means there are no operational and production activities in the industry. For this reason, the Indonesian fertiliser industry never carries out "Avoid" as a mitigation plan in real activity. So for the optimum result in mitigating risk, the second scenario, Reduce, is the most ideal scenario. Analysis of resilience assessment on the fertiliser supply networks can be determined based on key performance indicators that were obtained from the output of the simulation results. For example, if the berth occupancy ratio is 90%, the interoperability dimensions: the number of customers to complain is 0.27% or level 3 and inaccurate data entry is 68% or level 4. This shows the level of collaboration within the system supply networks is still low. Next on the dimensions of Safety: loss of working hours was 18 hours or level 4 and breakdown loading or unloading machinery is 4 times per month or level 4. In addition, the dimension of reliability: tardiness in the process of loading and unloading is 6 hours or level 4. This indicates that there remains potential for improvement in the resilience of the fertiliser industry. The fourth dimension, Availability: the availability of open storage for storing excess stocks of fertiliser also reached 68% or level 4 which means there was still plenty of fertiliser stock that had not been distributed due to the level of the port utility is low.

Simulation models need to be verified and validated to ensure that they successfully represent the real system and desired objectives. This research applied a combination of face validity [14] and subjective [15] approaches to verify and validate the simulation model based on the model and simulation result with practitioners. The results of the review of the simulation model with the practitioners from the Indonesian fertiliser industry confirmed that the model could be understood by its intended audience and it represented the process of resilience assessment in the Indonesian fertiliser industry. The participants considered the possibility of applying the approach in the industry. Through the creation of simulation models, available historical data and information on the industry was implemented into a visual model that provides output in the form of quantitative data. This assists managers and other decision makers in analysing and predicting levels of risk and resilience in the supply network. The structures of the model in computer simulations were adapted with the variables taken from the case study. Thus, the port was included in the model as the infrastructure facility as well as the elements of the key performance indicators and the dimension of resilience.

5. Conclusions

Supply network failures in the Indonesian fertiliser industry have a serious negative impact on agricultural production especially for small and medium sized farms. This failure arises from risk particularly in the transport system. Improving supply network resilience reduces the impact of risks and so improves the situation of the small and medium sized farms in Indonesia. This research introduced a new approach to assess resilience in supply network elements by considering risk assessment and infrastructure availability changes. The research was based on the premise that the risk assessment and the port management reports that already exists in the industry can be used as an information resource for resilience assessment. This premise corroborates a theory stated by Savage abd Gibson [16] that a set strategy of competitiveness, including risk management, must be defined by the organization in order to obtain supply chain resilience. By identifying the areas of highest risk in key processes of the supply network, crucial problems that influence network resilience can be identified. This is because the impact caused by the risk can be used as important information to reflect constraints in supply network activities. Moreover, mitigation plans capture the capacity of the supply network system to increase performance.

This research aids identification of key performance indicators of risk in supply networks especially for industries located in Asia in an archipelago country. The results of this study give real examples of the relationship between the risks and resilience and provide an approach containing steps using the information generated on a risk assessment to assess resilience. The simulation model considered the aspects of the managers or decision makers need, making this approach easy to adopt and applied by the managers. The use of agent-based modelling to create a simulation model also provides examples for academics on how to transform a real supply network system into the simulation model. The results of this research provide benefits for policy makers, especially the Ministry of

Agriculture and Ministry of Industry of Indonesia in analysing and assessing the supply network of subsidised fertiliser.

Simulation models such as that built in this study have the potential to be used in a wide range of industries that have characteristics and data similar to the Indonesian fertiliser industry. However, the model would need to be adjusted if it were employed in other industries that have different characteristics or supply network elements from the presented case study.

References

[1] Utami I. D 2016 *An Approach to the Assessment of Resilience in Indonesian Fertiliser Industry Supply Networks* University of Leeds

[2] SteadieSeifi M Dellaert N P Nuijten W Van Woensel T Raoufi R 2014 Multimodal freight transportation planning: A literature review. *European Journal of Operational Research* 233 1 1–15

[3] Boone C A Craighead C W Hanna J B Nair A 2013 Implementation of a System Approach for enhanced supply chain continuity and Rrsiliency: A Longitudinal study. *Journal of Business Logistics* 34 3 222-235

[4] Carvalho H Barroso A P Machado Virgínia H Azevedo Susana Cruz-Machado V 2012 Supply chain redesign for resilience using simulation. *Computers & Industrial Engineering* 62 1 329–341

[5] Carvalho H Maleki M Cruz-Machado V 2012 The links between supply chain disturbances and resilience strategies *Int. J. Agile Systems and Management* 5 (3)

[6] Revilla E Sáenz M J 2013 Supply chain disruption management: Global convergence vs national specificity *Journal of Business Research 1-13*

[7] Shuai Y Wang X Zhao L 2011 Research on measuring method of supply chain resilience based on biological cell elasticity theory *2011 IEEE International Conference on Industrial Engineering and Engineering Management* 264–268

[8] Soni U Jain V 2011 Minimizing the vulnerabilities of supply chain: A new framework for enhancing the resilience *2011 IEEE International Conference on Industrial Engineering and Engineering Management* 933–939

[9] Spiegler V L M Naim M M Wikner J 2012 A control engineering approach to the assessment of supply chain resilience *International Journal of Production Research* 50 21 6162-6187

[10] Robson C 2011 *Real Word Research* Third edition edition West Sussex United Kingdom: John Willey and Sons Ltd

[11] Yin R K 2014 *Case study research: design and methods* Fifth Edition SAGELtd. United Kingdom

[12] Hsu C C Sandford, B A 2007 The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research and Evaluation* 12 10 1-8

[13] Clegg C W Robinson M Davis A Matthew C Bolton Lucy E Pieniazek Rebecca L Mckay A 2017 Applying organizational psychology as a design science : A method for predicting malfunctions in socio-technical systems (PreMiSTS) *Design Science* 1–31

[14] Sargent R G 2011 Verification and validation of simulation models In: *Proceedings of the 2011 Winter Simulation Conference* 183–197

[15] Liu J Zhang W G W and Y Y (2012) Conceptual model for simulation and its verification and validation. *Computer Science and Automation Engineering (CSAE) 2012 IEEE International Conference 3* 622 – 626

[16] Savage C Gibson R 2013 Resilient Supply Chains in an uncertain environment In: *18th International Symposium on Logistics 7-10 July 2013 Vienna Austria*