Multiple Criteria Decision Support for Mitigating Seaweed Supply Chain Risks in Indonesia

Heti Mulyati[1] and Jutta Geldermann[2]

1. *Ph.D Student of Chair of Production and Logistics, Georg-August-Universität Göttingen, Germany and A Scholar of Japan Indonesia Presidential Scholarship, World Bank Institute*
2. *Professor of Chair of Production and Logistics, Georg-August-Universität Göttingen,Germany*

E-mail: [1]heti.mulyati@wiwi.uni-goettingen.de, [2]geldermann@wiwi.uni-goettingen.de

Abstract

Indonesia has a great challenge as one of the seaweed producer in the world. Nevertheless, seaweed supply chains face a dynamic business environment with complex disturbances in both supply and demand aspects. Long-term solutions should be prepared to ensure a sustainable seaweed industry in Indonesia. This paper will attempt to design a model of seaweed supply chain risk management in Indonesia to reach sustainability and a competitive advantage using multi-criteria decision analysis (MCDA). This will generate and consider alternative scenarios and solutions with a robust analytical tool to support decision makers in the seaweed supply chain. The PROMETHEE method, a new approach in MCDA, will be applied for mitigating seaweed supply chain risks.

Keywords: Multi Criteria Decision Analysis, PROMETHEE, Risk Management, Supply Chain Management, Supply Chain Risk Management, Seaweed Industry

1. Introduction

Indonesia has a big opportunity to become one of the seaweed producer in the world that has large areas for seaweed cultivation (1,110,900 million ha). The biggest producers of seaweed are spread across South Sulawesi (31.89%), Central Sulawesi (18.64%), East Java (9.96%), East Nusa Tenggara (8.90%), Maluku (6.66%), West Nusa Tenggara (4.16%), Bali (2.55%), Gorontalo (1.64%), and Banten (1.34%) (Ministry of Marine Affairs and Fisheries, Republic of Indonesia, 2010).

Seaweed is widely used for raw materials in food (human and pet food) and nonfood industries (pharmacy, cosmetics, bioenergy). Seaweeds or marine macro algae were classified into three main groups based on their pigmentation: *Phaeophyceae* (brown algae), *Rhodophyceae* (red algae) and *Chlorophyceae* (green algae), respectively (FAO, 2003). Brown and red algae are the most useful for development of food industry because they have polysaccharide content. They produce three hydrocolloids: agar, carrageenan, and alginate. A hydrocolloid is *a non-crystalline substance with very large molecules and dissolves in water to create a viscous solution* (Glickmans, 1987). Several types of green algae are used as salad ingredients.

The seaweed industry has many advantages for development in Indonesia, such as potential export commodities, simple cultivation technology, and short cultivation cycle (45 days) across the whole year, no substitute commodity and absorption of many areas of labor. But, development of the seaweed industry faces many problems such as low seaweed quality, gap targets between seaweed cultivation (on-farms) and production (off-farms), the fact that increased seaweed cultivation is not being followed by increased seaweed industry, and production has been limited to semi-finished industry such as sheet (chip) and powder.

A seaweed supply chain consists of seaweed farmers, local collectors and traders, Indonesia and overseas traders, manufacturers and solution providers, end users, distributors and export markets. Seaweed supply chains face a dynamic business environment with complex disturbances in both supply and demand aspects. Disruptions of raw materials supply, such as volatility of raw material supply, can lead to downtime and consequent failure to satisfy the customer's requirements on time. Volatility in terms of price may result in difficulties in passing on price changes to the customer and potentially have the consequence of lost profit. Poor quality of seaweed product may impact on the level of customer satisfaction, with consequences for future outcomes. The industry also faces vulnerable conditions or temporary competitive advantages

caused by uncertain conditions such as economic disruption and both natural and man-made disasters. Long-term solutions should be prepared to create a sustainable seaweed industry in Indonesia. This ideal condition requires comprehensive research through the seaweed supply chain which considers its risks. Furthermore, the development of the seaweed supply chain may introduce a move from the national market to international supply chain. The scope of this paper focuses on food processing in the seaweed industry (agar and carrageenan)

2. Research Statement

Risk is the fundamental element that influences seaweed supply chain sustainability and competitiveness. Risks along seaweed supply chains should be managed, as well as members' interdependence on each other. If there are disturbances in one part of the supply chain, the effect of the disturbances affects the whole chain dynamically. The research question is "*How to mitigate seaweed supply chain risks in Indonesia using a decision support tool to achieve sustainability and competitive advantage?"*

3. Research Contributions

There are abundant theoretical studies regarding supply chain risk and supply chain risk management Supply chain risk (SCR) is a relatively new topic in the supply chain management literature and is an increasingly popular research area (Sodhi and Tang, 2012; Vanany et al.,2009; Ritchie and Brindley, 2007; Peck,2005; Jüttner, 2005). Supply chain risk is an assessment of failure by its probability of occurrence that is caused by an event within internal and external supply chain affecting the business process negatively (Zsidisin and Ritchie, 2010; Pfohl et al., 2010, Kersten et al.,2006; Tang, 2006; Norrman and Jansson, 2004). Yet limited in depth empirical research on supply chain risk in different fields has been published.

Therefore, this study will fill the gap between theoretical and empirical research in the supply chain risk field. In addition, it will contribute managerial aspects for decision makers or members of the seaweed supply chain. The strategic decision model will be used by seaweed farmers and seaweed manufacturing with MCDA. Several advantages of MCDA: help decision makers learn about the problem, provide a focus and a language for discussion, help to structure the complex problem, take the balancing of multiple factors, integrate objective measurement with value judgment, and manage subjectivity (Figuera et al., 2005; Belton and Stewart, 2002).

Previous studies of risk mitigation in supply chain used simulation, fuzzy Analytical Hierarchy Process, and stochastic programming (Yu et al., 2007; Faisal, 2009; Goh and Meng, 2009). The outranking approach 'Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) was chosen in this study for mitigating seaweed supply chain risk. The PROMETHEE approach was developed for assessing sets of alternatives mitigation of seaweed supply chain risks in Indonesia. The PROMETHEE approach was employed because of its flexibility, simple logic and understandability.

4. Research Methodology

The steps of the study comprise risk identification and categorization, risk assessment, and risk mitigation (Sodhi and Tang, 2012; Zsidisin and Ritchie, 2010; Faisal, 2009; Manuj and Mentzer, 2008; Wu et al., 2006; Khan and Burnes, 2007; Norrman and Jansson, 2004). Supply chain risks categorize into three categories: internal to the firm (process and control risks), external to the firm but internal to the supply network (supply and demand risks), and external to the network (environmental risks) (Kersten et al.,2006; Jüttner, 2005; Christopher and Peck, 2004; Jüttner et al.,2003). The framework of research shows in Figure 1.

Initial data was obtained through semi-structured interviews with key stakeholders: Ministry of Fisheries and Marine Affairs Republic of Indonesia, Ministry of Industry Republic of Indonesia, Indonesian Institute of Science, and Indonesian Seaweed Association. The data for this research will be gathered using a number of approaches:

1) Survey

This method provides opportunities for the researcher to analyze real condition of seaweed industry in Indonesia. The researcher can investigate and explore the condition of the biggest producer in Indonesia.

2) *Documentary analysis*

This method involves the study of existing documents to understand their substantive content. Documentary sources were needed when situations or events cannot be investigated by direct observation or questioning. These may be public documents such as media reports, government reports, or publicity materials. This research will collect documents from Ministry of Marine Affairs and Fisheries, Ministry of Industry, the Indonesian Seaweed Association, and literature such as journals and books, as well as information from public media.

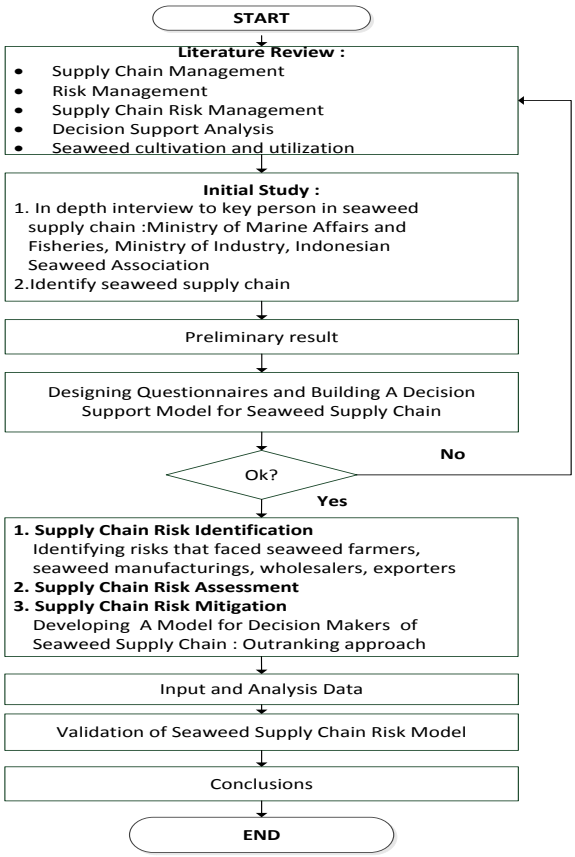
3) In depth interviews

Semi structured interviews will be undertaken, using responsive, flexible, and interactive questioning techniques. The interviews will use questionnaires to identify supply risks, operational risk, control risk, demand risk and environmental risks. The respondents include seaweed farmers and seaweed manufacturing.

4) Focus Group Discussions (FGD)

This approach involves several expert respondents from key stakeholders (national or local government, Indonesian seaweed association, and academician) to discuss the risks in the seaweed supply chain and how to manage them. The researcher provides some questions about the supply chain risk and explores the ideas put forward by participants.

Figure 1. Research Framework



The current state of this study is identifying and assessing the seaweed supply chain risks. The PROMETHEE approach will be used for assessing the strategies to mitigate the seaweed supply chain risks. We expect the final solutions with the PROMETHEE can be presented on the conference.

5. The PROMETHEE for Mitigating Seaweed Supply Chain Risks

The objective of MCDA is to create a decision support for decision makers based on their preferences due to the different problems settings. MCDA approaches generally can be categorized into two methods: Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM). The classification is appropriate for problem solving that MADM is for selection (evaluation) and MODM is for design (Hwang and Yoon, 1981). MADM focus on the assessment of a finite set of alternatives (discrete solution space), while MODM focus on alternatives restricted by constraints (continuous solution space).

MADM is suitable for this study because it can be used to assess a set of discrete alternatives. MADM has two main school of thought using in various disciplines: the classical approaches and the outranking approach (Belton and Stewart, 2002; Figuiera et al., 2005; Geldermann and Treitz, 2008). The first approaches depend on the assumption that clear judgments exist about utility values of attribute and their weightings such as Multi Attribute Value/Utility Theory or the Analytical Hierarchy Process (AHP). The second approaches assume the preferences are not visible for decision makers, and it give the consequences of different weightings. The most used method is ELECTRE and PROMETHEE (Geldermann and Treitz, 2008). As mentioned before, an appropriate approach for mitigating seaweed supply chain risks to reach sustainability is PROMETHEE.

PROMETHEE was introduced by B.Roy and developed by Brans et al. (1986). There are several development of PROMETHEE from PROMETHEE I up to PROMETHEE VI. The objective of PROMETHEE I is to find a partial ranking that it can be transformed into PROMETHEE II through complete ranking. These types are most frequently used in various fields. PROMETHEE III based on interval ranking, and PROMETHEE IV for continuous cases. A set of constraints must be identified in some purposes. The PROMETHEE V is covering for that particular case. The PROMETHEE VI (human brain) provides the decision makers with additional information on their own personal opinion (Brans and Mareschal, 2005).

The preference structure of PROMETHEE is based on pairwise comparisons (Brans and Mareschal, 2005). PROMETHEE is built on the basic notation with a set *A* of *T* alternatives that must be ranked, and *K* criteria that must be optimized (Geldermann and Treitz, 2008). The deviation between the evaluations of two alternatives on a specific criterion is considered.

The steps of the PROMETHEE consist of construction of an outranking relation on *K* and exploitation of this relation in order to give an answer (Brans et al., 1986)

A : {a_1,…., a_t) Set of discrete alternatives, scenarios or techniques a_t *(t =1…T)*

F : {f_1,….,f_k) Set of criteria relevant for decision f_k *(k = 1,..K)*

The solutions can be stated in an optimal decision matrix is a *(T x K)* matrix

$$D := (x_{tk}) \quad \begin{matrix} t=1,\dots,T \\ k=1,\dots,K \end{matrix} \quad \text{.....(1)}$$

whose elements $x_{tk} = f_k(a_t)$indicate the value of alternative a_t with respect to criterion f_k

$$D = \begin{bmatrix} x_{11} & \cdots & x_{1K} \\ \vdots & x_{tk} & \vdots \\ x_{T1} & \cdots & x_{TK} \end{bmatrix} := \begin{bmatrix} f_1(a_1) & \cdots & f_K(a_1) \\ \vdots & f_k(a_t) & \vdots \\ f_1(a_1) & \cdots & f_k(a_T) \end{bmatrix} \text{.....(2)}$$

The algorithm for PROMETHEE is as follows:

1) Specify for each criterion f_k a generalized preference function *Pk (d)*
2) Define a vector containing the weights, which are a measure for the relative importance of each criterion, $w^T = [w_1,\dots,w_k]$
3) Define the Outranking-Relation π for all the alternatives at a_t, $a_{t'} \varepsilon A$

$$\pi: \begin{cases} AxA \rightarrow [0,1] \\ \pi(a_t, a_{t'}) = \sum_{k=1}^{K} w_k \cdot p_k(f_k(a_t) - f_k(a_{t'})) \end{cases} \quad \text{.....(3)}$$

4) As a measure of the strength of the alternatives at $a_t \varepsilon A$, *the leaving flow* (Phi plus) is calculated by :

$$\Phi^+(a_t) = \frac{1}{T} \cdot \sum_{\substack{t'=1 \\ t' \neq t}}^{T} \pi(a_t, a_{t'}) \quad \text{.....(4)}$$

5) As a measure of the weakness of the alternatives at $a_t \varepsilon A$, *the entering flow* (Phi minus) is calculated by :

$$\Phi^-(a_t) = \frac{1}{T} \cdot \sum_{\substack{t'=1 \\ t' \neq t}}^{T} \pi(a_{t'}, a_t) \quad \text{.....(5)}$$

6) Graphical evaluation of the outranking relation

6. Work Packages

The next steps of this study focus on several questions seeking to develop seaweed supply chain risk decision support:

1) What were the criteria used to choose alternative for mitigating risks of seaweed supply chain?
2) How can the research findings be validated?
3) What recommendations can be implemented of the research's findings for decision makers to mitigate seaweed supply chain risks?

References

Anonymous (2011). Ministry of Marine Affairs and Fisheries. Industri Rumput Laut Indonesia. http://www.bbrp2b.kkp.go.id/publikasi/lain/inbudkan-1.pdf

Belton, V. and T.J.Stewart (2002). Multiple Criteria Decision Analysis: An Integrated Approach. Kluwer Academic Publisher, USA.

Brans, J.P.,Mareschal, B. (2005). PROMETHEE methods. Figueira, J.,Greco, S.,Ehrgott, M. (eds.) Multiple Criteria Decision Analysis – State of The Art Surveys, pp 163 – 195; Springer, New York.

Brans, J.P.,Vincke,Ph., Mareschal, B (1986). How to select and How to rank Projects: The PROMETHEE method.European Journal of Operational Research, 24, pp.228 – 238.

Chopra, S. and Meindl, P. (2007). Supply Chain Management: Strategy, Planning and Operation. 3rd edition. Prentice Hall, New Jersey.

Christopher, M. and Peck, H. (2004). Building the Resilient Supply Chain. *International Journal of Logistics Management*, Vol. 15 No. 2, pp 1 -13

Faisal, M.N (2009). Prioritization of Risks in Supply Chains. Managing Supply Chain Risk and Vulnerability: Tools and Methods for Supply Chain Decision Makers. Wu, T and J.Blackhurst. (Eds.). Springer.

Figuera, J., S. Greco and M.Ehrgott (2005). Multiple Criteria Decision Analysis: State of The Art Surveys. Springer, New York.

Geldermann, J. and Treitz, M. (2008). Quantifying Eco-Efficiency with Multi-Criteria Analysis. Research paper Nr.5, Goettingen.

Glicksman, M. (1987). Utilization of Seaweed Hydrocolloids in The Food Industry. Hydrobiologia 1517152: 31–47. 12 *International Seaweed Symposium*, Netherlands.

Goh, M. Lim, J.Y.S., Meng, F. (2007). A Stochastic Model for Risk Management in Global Supply Chain Networks. European Journal of Operational Research 182, pp 164 - 173

Hwang, C.L. and Yoon, K. (1981). Multiple Attribute Decision Making : Methods and Applications: A State of the Arts Survey. Springer, Berlin.

Jüttner, U., H. Peck, and M. Christopher (2003). Supply Chain Risk Management : Outlining Agenda for Future Research. *International Journal of Logistics: Research and Applications*, Vol. 6 No.4, pp. 197–210.

Jüttner, U. (2005). Supply Chain Risk Management: Understanding to Business Requirements from a Practitioner Perspective. *International Journal of Logistics Management*. Vol.16 No.1,pp 120-141.

Khan, O. and Burness, B. (2007) Risk and Supply Chain Management: Creating A Research Agenda. The *International Journal of Logistics Management*, Vol. 18 No.2, pp. 197–216.

Kersten, W. et al. (2006). Supply Chain Risk Management: Development of A Theoretical and Empirical Framework. InKersten, W. and T.Blecker (Ed.). *Managing Risks in Supply Chains: How to Build Reliable Collaboration in Logistics*.Erich Schmidt Verlag, Berlin, pp. 3–17.

Manuj, I. and Mentzer, J.T. (2008). Global Supply Chain Risk Management. *Journal of Business Logistics*, Vol.29, No.1 pp 133 - 155

McHugh, D.J. (2003). A Guide to The Seaweed Industry. *FAO Fisheries Technical Paper 441*, Rome, Italy.

Norrman, A. and Jansson, U. (2004). Ericsson's Proactive Supply Chain Risk Management Approach After A Serious Sub Supplier Accident. *International Journal of Physical Distribution and Logistics Management*, pp. 434–456.

Peck, H. (2005). Drivers of Supply Chain Vulnerability: An Integrated Framework. *International Journal of Physical Distribution and Logistics Management*, Vol.35, No.4, pp. 210–232.

Pfohl, H.C., Köhler, H., Thomas, D. (2010). State of The Art in Supply Chain Risk Management Research: Empirical and Conceptual Findings and A Roadmap for The Implementation in Practice. Logistic Res., pp. 33–44. Springer, Verlag.

Ritchie, B. and Brindley, C. (2007). Supply Chain Risk Management and Performance: A Guiding Framework for Future Development. *International Journal of Operations and Production Management,* Vol 27 No.3,pp 303-322

Sodhi, M.S. and Tang, C.S. (2012). Managing Supply Chain Risk. Springer

Tang, C.S. (2006). Perspectives in Supply Chain Risk Management. *International Journal Production Economics*, Vol. 103 No.2, pp. 451–488.

Vanany, I. Zailani, S., Pujawan, N. (2009). Supply Chain Risk Management: Literature Review and Future Research. *International Journal of Information Systems and Supply Chain Management*, Vol. 2 No.1, pp. 16–33. January–March.

Wu, T. J. Blackhurst, and Chidambaram, V. (2006). A Model for Inbound Risk Analysis. Computers in Industry Vol.57, pp 350-365.

Yu,H., Sun, C., Chen, J. (2007). Simulating The Supply Disruption for The Coordinated Supply Chain. Journal System Science and System Engineering 16 (3): pp 323- 335

Zsidisin, G.A, and Ritchie, B. (2010). Supply Chain Risk: A Handbook of Assessment, Management and Performance. Springer.