MODELLING OF SUPPLY CHAIN RISK MANAGEMENT FOR SAGO STARCH AGRO-INDUSTRY

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AGRO-INDUSTRIAL ENGINEERING
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Bogor, July 2021

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RINGKASAN

SYAMSUL ANWAR. Pemodelan Manajemen Risiko Rantai Pasok di Agroindustri Pati Sagu. Dibimbing oleh TAUFIK DJATNA, SUKARDI, and PRAYOGA SURYADARMA.

Sistem rantai pasokan dewasa ini semakin terpapar terhadap berbagai risiko yang dapat menghambat kelancaran aliran produk, dana, dan informasi di antara aktor-aktor yang terlibat. Risiko rantai pasok memberikan kerugian bagi para pelaku yang terlibat dalam rantai pasokan. Kerangka Manajemen Risiko Rantai Pasok perlu diterapkan untuk bisa mengatasi risiko rantai pasok secara efektif. Sagu merupakan komoditas strategis di Indonesia sebagai produsen sagu terbesar di dunia. Namun beberapa permasalahan krusial dihadapi oleh rantai pasok pati sagu termasuk segi keandalan pasokan, konsistensi kualitas, dan harga. Persoalan ini bisa dikaitkan dengan adanya risiko di sepanjang rantai pasok pati sagu.

Penelitian ini mengembangkan model Managemen Risiko Rantai Pasok untuk agroindustri sagu. Secara khusus ada tiga tujuan yang dicapai dalam penelitian ini yaitu (1) mengidentifikasi risiko-risiko di rantai pasok pati sagu, (2) memodelkan ketidakpastian dan interdependensi risiko rantai pasok di agroindustri pati sagu, and (3) memodelkan strategi koordinasi dengan skema berbagi risiko untuk memitigasi risiko ketidakpastian pasokan di rantai pasok pati sagu. Penelitian ini mengambil studi kasus rantai pasok agroindustri pati sagu yang ada di Kabupaten Kepulauan Meranti, Provinsi Riau, sebagai produsen pati sagu terbesar di Indonesia. Penelitian ini fokus menyelidiki rantai pasok pati sagu kering.

Identifikasi risiko adalah tahap pertama dari kerangka SCRM, sebagai basis untuk untuk tahap penilaian and mitigasi risiko. Pada tahap ini, karakteristik sistem rantai pasokn agroindustry pati sagu diidentifikasi and dianalisis. IPO (input-proses-output) dari sistem digambarkan termasuk kebutuhan-kebutuhan dari aktor rantai pasok. Selanjutnya, identifikasi risiko diawali dengan melakukan survei literatur untuk mengenali jenis-jenis risiko yang mungkin terjadi di agroindustri pati sagu. Selanjutnya, kandidat risiko dikonfirmasi ke pakar industri terkait. Pada akhirnya, daftar risiko-risiko yang relevan di rantai pasok agro-industri pati sagu diperoleh and diklasifikasikan atas risiko pasokan, operasi, logistik, permintaan, harga-keuangan, lingkungan, and eksternal.

Tahapan penilaian risiko difokuskan untuk mengevaluasi dampak risiko rantai pasok terhadap kinerja agroindustry pati sagu. Sifat ketidakpastian dan interdependensi risiko dimodelkan dengan *Bayesian network* (BN), yang merupakan salah satu tipe dari model grafis probabilistik. Untuk penerapannya, variabel risiko and kinerja dipilih untuk dimodelkan. Pengetahuan dari pakar industri dimanfaatkan untuk membangkitkan dataset melalui simulasi Monte Carlo and basis kaidah (*rule bases*). Struktur *directed acyclic graph* (DAG) dari pada BN dibangun dengan menerapkan metode *hybrid* yaitu metode pencarian berbasis skor dengan algoritma *Hill-climbing* dengan diberikan pengetahuan sebelumnya terkait aturan garis hubungan antar variabel. Pada langkah selanjutnya, inferensi Bayes diterapkan untuk skenario-skenario risiko dengan

analisis sensitivitas untuk mengetahui kekuatan dampak dari berbagai risiko terhadap ukuran kinerja. Hasil simulasi menunjukkan bahwa faktor-faktor risiko yang bersifat alam and eksternal, pasokan and kualitas tual sagu, logistik *inbound* and *outbond* dapat memberikan pengaruh terhadap kinerja agroindustri pati sagu. Penelitian ini juga merekomendasikan strategi-strategi mitigasi risiko untuk mengeliminasi atau setidak-tidaknya meminimisasi dampak risiko rantai pasok yang merugikan tersebut.

Akhirnya, di tahapan mitigasi risiko, penelitian ini mengembangkan model koordinasi dengan skema berbagi risiko untuk meminimsasi risiko-risiko ketidakpastian pasokan antara pengepul sagu (pemasok) dan kilang sagu (agroindustri). Identifikasi sistem and telaah literatur dilakukan sebagai basis untuk mengembangkan model-model koordinasi tersebut. Model-model yang dibangun mencakup skema *non-risk sharing* (NRS), *undersupply risk-sharing* (URS), *oversupply risk-sharing* (URS), dan *hybrid risk sharing* (HRS). Permainan Stackelberg diterapkan dan nilai payoff yang optimal didapatkan untuk model-model tersebut. Hasil simulasi menunjukkan bahwa masing-masing model menghasilkan nilai payoff (ekspektasi keuntungan) yang sedikit berbeda baik bagi kedua aktor maupun keuntungan rantai pasok. Secara keseluruhan, model HRS menghasilkan nilai payoff relatif lebih tinggi dibanding model koordinasi lainnya dalam kondisi tiga skenario realisasi pasokan.
Kata kunci: agroindustri pati sagu, berbagi risiko, *Bayesian network*, koordinasi, manajemen risiko rantai pasok, pemodelan

SUMMARY

SYAMSUL ANWAR. Modelling of Supply Chain Risk Management for Sago Starch Agro-industry Supply Chain. Supervised by TAUFIK DJATNA, SUKARDI, and PRAYOGA SURYADARMA.

The supply chain system is increasingly exposed to various risks that may interrupt product, fund, and information flows among supply chain parties. Those supply chain risks (SCRs) may contribute to losses for the actors of the supply chain. In response, the supply chain risk management (SCRM) framework is employed to manage SCRs effectively. Sago is a strategic commodity in Indonesia as the largest sago producer in the world. However, the sago starch agro-industry encounter crucial issues, including supply reliability, quality consistency, and price. These issues were related to the existing risks across the sago starch supply chain.

This research aims to develop an SCRM model for the sago starch agro-industry. Specifically, it has achieved three objectives; (1) identification of risks in the sago starch supply chain, (2) modelling of uncertain and interdependent SCRs in the sago starch agro-industry, and (3) modelling of coordination strategy with risk-sharing schemes for the sago starch supply chain. This research took a case study of the sago starch agro-industry supply chain in Kepulauan Meranti Regency, Riau Province, as the largest sago starch producer in Indonesia. It focused on investigating the supply chain of dried sago starch.

Risk identification is the first stage of the SCRM framework as the basis for the risk assessment and mitigation stages. In this case, the system

characteristics of the sago starch supply chain were identified and analyzed. The IPO (input-process-output) of the investigated system was described, including the actor's requirements. Furthermore, risk identification was started with literature reviews to identify the possible risks in the sago starch supply chain. Next, the risk candidates were confirmed to the related industry experts. Finally, the relevant SCRs were listed and classified into supply, operation, logistics, demand, price-financial, environmental, and external risks.

The risk assessment stage focused on evaluating the SCR impacts on the performance of the sago starch agro-industry. The uncertainty and interdependency of SCRs were modelled into the Bayesian network (BN), a class of a probabilistic graph model. In its application, the risk and performance variables were selected to be modelled. The expert knowledge was utilized to generate the dataset through Monte Carlo simulations and rule bases. The directed acyclic graph (DAG) of the BN structure is constructed by applying hybrid methods. The Hill-climbing algorithm, a search and score-based method, was applied to learn datasets given to prior knowledge (rule of links among variables. In the next stage, Bayesian inference was applied to risk scenarios with sensitivity analysis to examine the impact strength of SCRs on the performance measures. The results of the simulation indicated that the natural and external-risk factors, supply and quality of logs and water, inbound and outbound-logistics factors might contribute to the industry performance. This research also recommended mitigation strategies to eliminate or at least minimize the adverse SCR impacts.

Finally, risk mitigation stage, this research developed the coordination models with risk-sharing schemes to mitigate uncertain supply risks between sago collector (supplier) and sago mill (agro-industry). The system identification and literature review were carried as the basis for developing those coordination models. The developed models include non-risk sharing (NRS), undersupply risk-sharing (URS), oversupply risk-sharing (URS), and hybrid risk sharing (HRS) schemes. The Stackelberg game was applied, and their associated optimal payoff values are obtained for those models. The simulation results indicated that each model generated a bit different payoff value for both actors and supply chain profits. Overall, the HRS model generated a higher payoff value than the other models under three supply realization scenarios.

Keywords: Bayesian network, coordination, modelling, risk-sharing, sago starch agro-industry, supply chain risk management

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PREFACE

First of all, the author thanks Allah Subhanahu wa ta'ala for all provided mercies so that the author's dissertation entitled "Modeling of Supply Chain Risk Management for Sago Starch Agro-industry Supply Chain" could be accomplished. Shalawat and greeting are conveyed to a messenger, Prophet Muhammad Salallahualaiwasallam. This dissertation accumulates the author's knowledge during the doctoral study for more than four years. It is one of the requirements to obtain a Doctor degree at the Agro-industrial Engineering Study Program, Graduate School, IPB University.

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Bogor, July 2021

Syamsul Anwar

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GLOSSARY

Bayesian networks	:	A probabilistic graph model consists of nodes and edges representing variables and interdependency
Bayesian inference	:	A method for deriving conclusions under uncertainty based on the Bayes' theorem to update the linked nodes' probability (variables).
BIC	:	Bayesian information criterion, a score that describes how well the model fits the data. It is a criterion for model selection in which the lowest BIC is preferred.
Bootstrap sampling	:	A random sampling technique with a replacement under the umbrella of nonparametric statistics.
Conversion value	:	A value that indicates the number of inputs required to produce an output or vice versa
Coordination	:	The coordination aims to improve supply chain (SC) performance. The coordination can be achieved when inter-dependent entities work together by sharing resources and information to achieve common objectives aligned to

		maximize customer value for the entire SC (Arshinder, 2007)
DAG	:	A directed acyclic graph consists of vertices and edges whose directions never form a closed loop.
Edge	:	Arc or link between two nodes
Hill climbing algorithm	:	A greedy local search that grabs a good (better solution) of the neighbour state by making incremental changes.
Hybrid BN	:	Mixed of expert and data-driven method
HRS	:	A risk-sharing scheme covering both over and undersupply risk situations
Inbound logistics	:	The activity involves relationships with suppliers and includes all the activities required to receive, store, and disseminate inputs (Laradi 2017)
Interdependency	:	Relationship between two variables
JPD	:	Join probability distribution
MLE	:	Maximum likelihood estimation, a technique to estimate the parameter values of a probability distribution by maximizing a likelihood function
MPD	:	Marginal probability distribution
Modeling	:	Representation of a real-world problem. It also describes a process or phenomenon by explaining or predicting through a systematic process.
Node	:	A circle that represents variable under investigation
Non-cooperative game	:	A game with competition between individual players in which the equilibrium points are derived in trade conditions
Outbound logistics	:	The activities of collection, storing, and product distribution (Laradi 2017)
Operation/operational	:	all the activities required to transform inputs into outputs (Laradi 2017)
ORS	:	A risk-sharing scheme in a situation of supply realization exceeds the estimated (e.g. order) level
Outbound logistics	:	The activities of collection, storing, and product distribution (Laradi 2017)
Payoff value	:	The outcome of a game depends on the selected strategies of the players.
Procurement	:	The acquisition of inputs, or resources, for the firm (Laradi 2017)
Risk assessment	:	The second stage of SCRM provides risk-related information in a quantitative and qualitative framework

Risk driver	:	Critical risk factor/event that significantly affect the performance of sago starch agro-industry
Risk identification	:	A comprehensive and structured determination of potential supply chain risks
Risk mitigation	:	Strategies to decrease the likelihood and impact of risks
Risk impact	:	The strength of risk in affecting the performance
Risk probability	:	The risk occurrence in a certain period
Risk-sharing	:	A risk mitigation method that involves or partners with other parties to share responsibility (e.g. cost, revenue) for activities that have risk
Sago mill	:	Sago factory that produces starch
Sago logs	:	A sago stem that cut to a length of between 100 and 110 cm for easy handling and conveying
Sago starch	:	An intermediate product from the extraction process of starch from sago trunks
SCRM	:	Supply chain risk management, a framework that adopts the risk management approach in the supply chain.
Sensitivity analysis	:	Investigating the effect of changes in input parameters on the output parameters
Sourcing	:	A business function of raw material procurement
Stackelberg game	:	A game theory model in which one player as the leader moves first and then the follower players move sequentially
Supply uncertainty	:	Quantity of raw material supply may deviate from prediction due to uncontrollable factors which depend on the industry environment
URS	:	A risk-sharing scheme in a situation of supply realization less than the estimated (e.g. order) level