A Conceptual Framework on The Design of Intelligent Supply Chain for Natural Fibre Agroindustry

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Abstract. Kenaf is a fibre-producing plants that is still highly potential to develop in Indonesia. There is a gap between supply and demand of natural fibre by 90.38%, meaning that it is only 9.62% of kenaf fibre demand met by domestic processors. The main objective of this research is designing an intelligent supply chain model of natural fibre agroindustry. Three sub-models would be developed to answer research questions, i.e.: (1) Developing a sub-model of collaborative replenishment, (2) Designing a sub-model of integrated production and inventory planning, and (3) Developing a sub-model of improvement in supply chain performance.Some approaches that would be employed in this study are Supply chain analytics, Collaborative planning, forecasting and replenishment, Particle swarm optimization, and Value chain operation reference. The concept of industry 4.0 that would be developed was an implementation scheme of Internet of Things in production optimization of dried kenaf fibre through employment of sensors and image processing.Indicators of success factor for this research that were established are: (1) Enhancement in supply chain efficiency and effectivity, (2) Enhancement in satisfaction level among supply chain actors, and (3) Achievement of level optimization and inventory cost minimization, and (4) Usefulness of a web based NFiSCA application.

INTRODUCTION

The growth of natural fibre-processing industries in the world is perceived to be more important [1]. This was said because natural fibre as a renewable raw material is abundantly available in the nature, showing a high toughness [2], potentially reducing product's weights which results in energy saving, reduced production costs, and improved appearance of product's surface [3]. Moreover, people's awareness of environmental sustainability has grown globally.

A number of researches has been conducted to develop some types of natural fibre into globally competitive products. Natural fibres such as kenaf, are processed into composite materials for an automotive component, i.e. panel door trim [4] and [5]. Sisal fibre is processed into composite [6] and textile [7]. Pineapple leaf fibre is processed into food packaging [8] and apparel [9]. Other natural fibres include rami [10], bamboo [11], abaca [12], coconut [13], sugarcane waste [14], mendong grass [15], flax [16] and hemp [17].

Kenaf fibre is derived from a plant that is easy to cultivate in Indonesia. The plant is able grow in degraded lands, not requiring a lot of water [2], able to absorb waste up to 40%, and resistant to industrial waste [18]. Based on the

The 5th International Conference on Industrial, Mechanical, Electrical, and Chemical Engineering 2019 (ICIMECE 2019)
AIP Conf. Proc. 2217, 030050-1–030050-8; https://doi.org/10.1063/5.0000742
Published by AIP Publishing. 978-0-7354-1971-1/$30.00

comparison between cotton and kenaf fibres explained above, this study established kenaf fibre as its commodity. Kenaf fibre are potentially developed into composite materials [4] [19] [20] [21].

Raw material supply of kenaf board is dried kenaf fibre obtained from upstream industries. Ideally, natural fibre obtained from upstream industries comes from domestic supply, processed by processors of dried kenaf fibre and *Balai penelitian tanaman serat dan pemanis* (Balittas). Nevertheless, domestic supply has not met the existing demand, and therefore an import policy is inevitable in order to meet demands for dried fibre in kenaf board production.

In addition to uncertainty, differences in location that lead to delivery lead times are also sources of inventory [22]. Industry must think of dried kenaf natural fiber reserves as raw material that can be used while waiting for shipping to arrive. The longer time it takes to send raw materials, the more reserves needed. The impact of this condition is the increase in inventory costs

Delivery of kenaf fibre is a part of downstream industry activities in the supply chain network. In activities of supply chain management, receival is a part of source. Upstream industries are industries who process (make) kenaf fibre into dried kenaf natural fibre. This dried kenaf fibre will be distributed (deliver) to consumers, which in this case is industries who use dried kenaf fibre to produce composite materials. Industries who process these composite materials are called as an intermediary industry, which produces raw materials for industries of automotive interior components. And finally, industries who produce automotive interior components are categorized into downstream industries.

Each process in source, make, and deliver sections have to perform well in order to produce products in an optimal condition, which means that they fit with number demanded by consumers and with time expected by consumers. Downstream industries have to ensure the number of automotive interior products targeted to allow intermediary industries to receive information of their demands, and prepare production planning according to targets expected by consumers. Likewise, intermediary industries should provide information related to requirement of dried fibre as a raw material to produce composite materials, so that the products are manufactured as planned.

An information flow certainly requires an intelligent system device in an internet-based computation application that is easy to access by industries (upstream, intermediary, downstream), and is able to optimally accommodate execution of supply chain management in natural fibre agroindustry. The information flow runs optimally when collaborative prediction planning and replenishment is established (CPFR) along the supply chain network of natural fibre agroindustry. CPFR is an important business process to manage uncertainty of demands, promotion planning, and replenishment [23]. CPFR-implementing industries do not only reduce stocks, costs, and period, but also increase accuracy of demand prediction, consumer service, and sales volume [24]. CPFR is able to improve efficiency in fulfilling consumer's demands, stocks, and transportation costs [25].

In the era of industry 4.0 with advances in digital and information technology, an information flow that occurs along the supply chain network of natural fibre agroindustry which consist of upstream, intermediary, and downstream industries, definitely requires management of big data analysis to allow business processes in the supply chain network to work efficiently.

In order to facilitate industries to achieve a better supply chain performance, a big data analysis and supply chain analytics were carried out in this research. This supply chain analytics would facilitate Balittas and kenaf natural fibre-using industries in transforming data into information that is able to support an intelligent decision making. Through implementation of supply chain analytics, Balittas and kenaf natural fibre-using industries both in upstream and downstream are able to work and run the business intelligently, flexibly, and efficiently.

Based on the above explanation, question generated are as follows: (1) What does a supply chain model of natural fibre agroindustry?, (2) How does collaboration among supply chain actors in natural fibre agroindustry work?, (3) What does a model of integrated production and inventory planning?, (4) How is supply chain performance of natural fibre agroindustry?

The main objective of this study is designing an intelligent supply chain model of natural fibre agroindustry. In order to achieve the goal, 3 sub-models would be developed as answers to the research questions, i.e.: (1) Developing a sub-model of collaboration among actors in supply chain of natural fibre agroindustry, (2) Designing a sub-model of integrated production and inventory planning in supply chain of natural fibre agroindustry, and (3) Developing a sub-model of improvement in supply chain performance of natural fibre agroindustry.

Novelty claimed in this research includes: (1) An intelligent supply chain analytic model of natural fibre agroindustry, (2) An intelligent decision support system from a sub-model of collaboration among supply chain actors in natural fibre agroindustry, (3) A sub-model of integrated production planning and stock based on particle swarm optimization for natural fibre agroindustry, and (4) A user interface system of web-based natural fibre supply chain analytics (Web-Based NFiSCA).

INTELLIGENT SUPPLY CHAIN

Intelligent supply chain is an open, flexible network. This system will supply networks from each group member and corporate member with an intelligent technology and coordination of supply chain management, attempting to reach a goal of being transparent and intelligent [26]. In its management, an intelligent supply chain employs a system developed from studies of artificial intelligent, expert system, genetics algorithm, imitative nervous system, knowledge-based system, and fuzzy logics [27]. Intelligent supply chain is an integration between an intelligent supply chain and a management system based on a concept of Cloud of Things (CoT) [28].

Furthermore, [29] claimed that management system of an intelligent supply chain is an approach that combines advantages of Internet of Things (IoT) and cloud to distribute right products to the right destinations at the right time using right transportations, in order to reach an efficiency. This system provides a real-time monitoring, which aims to create an interactive supply chain ecosystem, such as location of products, location of packing process, types of packaging, and vehicles responsible for transportation that will notify users regarding product locations, product quality statuses, and selected routes. An intelligent system ensures the supply chain management operates efficiently, in order to enhance quality control, cost efficiency, and consumer satisfaction.

CONCEPTUAL FRAMEWORK

Framework used in this study was generated based on problems arising in the supply chain network of natural fibre agroindustry. Some problems have been successfully described based on scientific literature searching, expert interview, and secondary data observation. A research framework was developed from the existing supply chain analytics model [30]. This model elaborated an analytic framework of dynamic supply chain, presented in Figure 1.

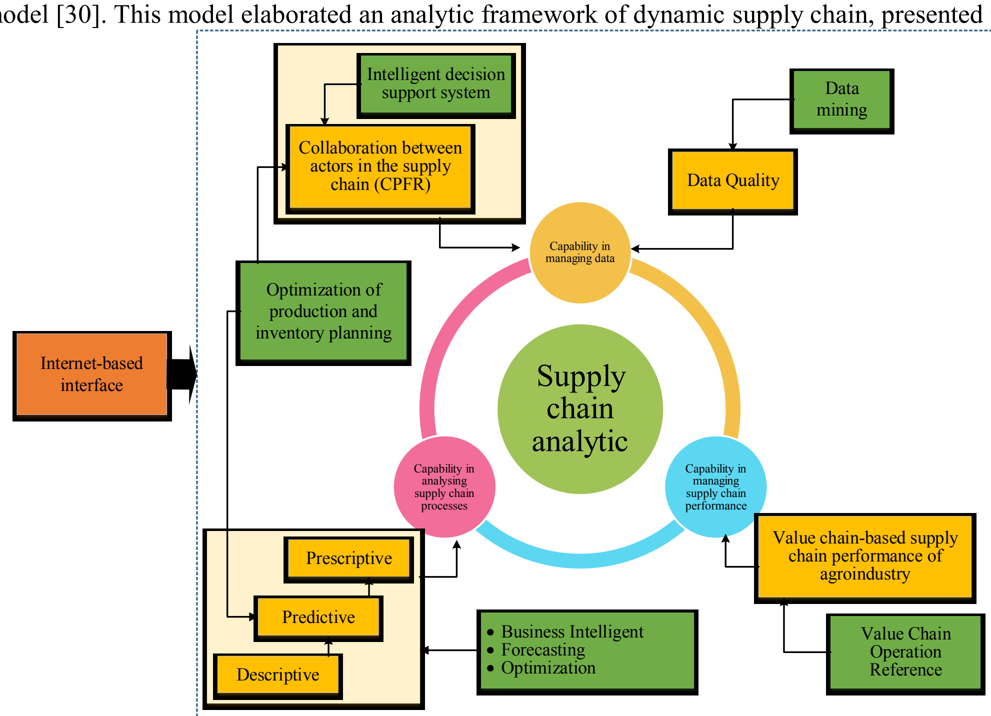


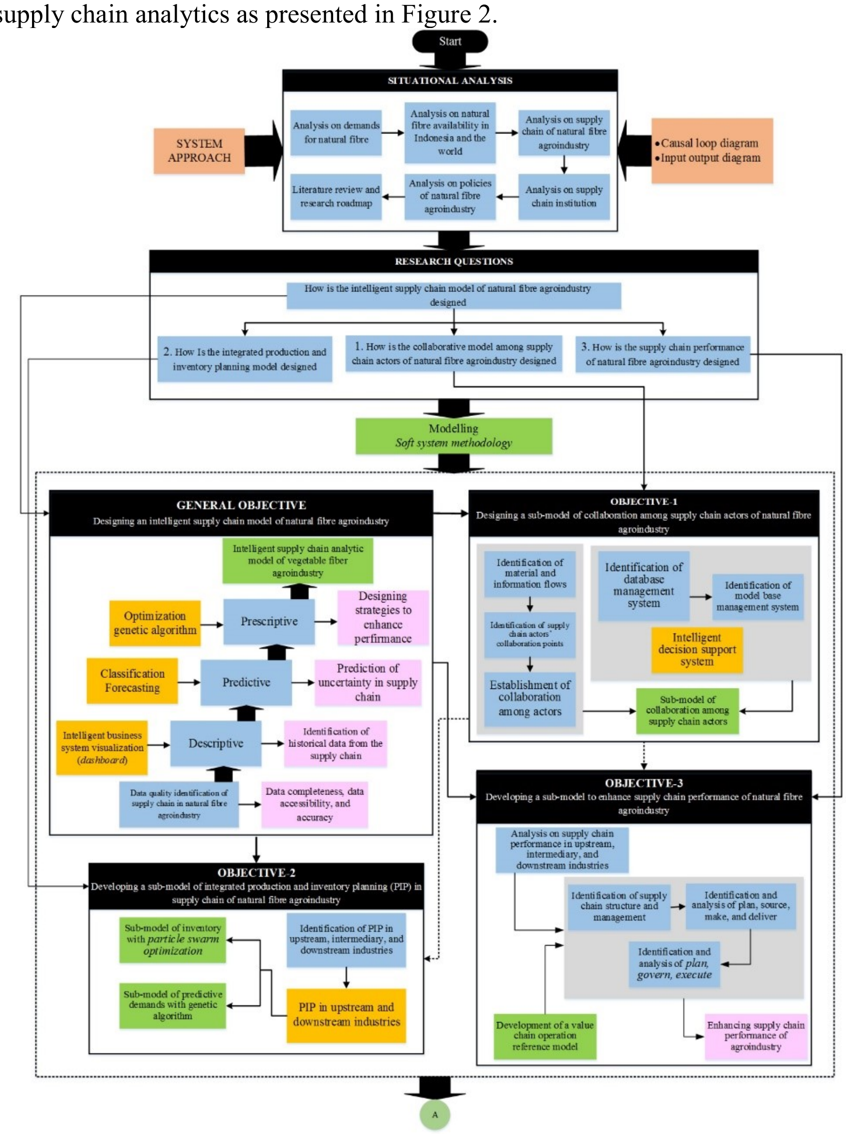
FIGURE 1. Design framework for an intelligent supply chain model of natural fibre agroindustry

METHODOLOGY

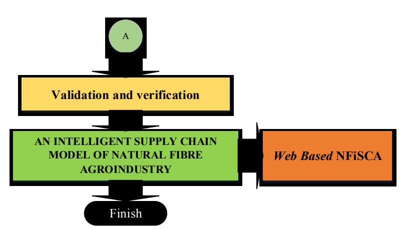
This research was initiated with modelling an intelligent supply chain using 3 levels of supply chain analytics, i.e. descriptive, predictive, and prescriptive levels [31]. An intelligence business system was used at a descriptive level in order to identify history data of supply chain and visualize it into a dashboard as an initial performance report. Classification and forecasting approaches would be used at a prediction level, while optimization and algorithm approaches would be used at a prescriptive level.

Development of an institutional model for natural fibre agroindustry would be performed using a method of Interpretative Structural Modelling (ISM) and Soft system methodology (SSM). A CPFR model design would be developed using an intelligent decision-supporting system, where collaboration of stock management developed a stock model of natural fibre agroindustry using particle swarm optimization algorithm.

Supply chain performance of natural fibre agroindustry would be formulated using a VCOR model that had been carried out by [32] in canned food industries. The last step of this research was developing a user interface system using web-based supply chain analytics as presented in Figure 2.



(a)



(b)

FIGURE 2. (a) Research procedure of an intelligent supply chain model design for natural fibre agroindustry (b) Research procedure of an intelligent supply chain model design for natural fibre agroindustry

RESULT AND DISCUSSION

System identification through a system approach started with analysis on demands and was stated according to needs of stakeholders in supply chain network of natural fibre agroindustry. The pattern of supply chain flow in natural fibre agroindustry is given in Figure 3.

It is apparent that supply chain network of natural fibre agroindustry is divided into 3, i.e. upstream, intermediary, and downstream industries. Each section implements a concept of plan-source-make-deliver. Upstream industries are industries who process natural fibre into dried natural fibre. Intermediary industries use the dried natural fibre to produce composite materials. Downstream industries are those who use these composite materials as semi-finished products to manufacture finished goods, which in this case are automotive interior products. These products are ready for direct consumer use.

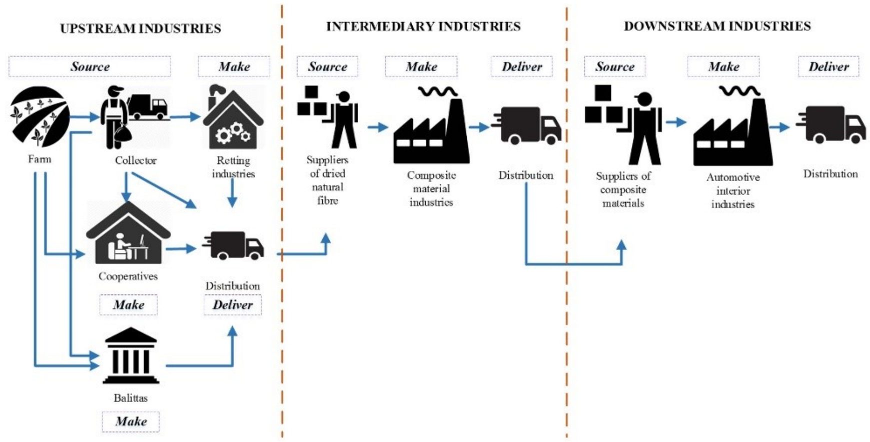


FIGURE 3. Supply chain network of natural fibre agroindustry

Material and information flows in supply chain of natural fibre agroindustry were depicted according to 3 types of industries involved in this chain. Material flows in each aspect of plan-source-make-deliver of these 3 industries. Meanwhile, information can flow both from suppliers to consumers (forward) and from consumers to suppliers (backward).

In upstream industries, farmers and collectors play a role as a source. Retting industries, cooperatives, and Balittas play a role as a make, while distributors play a role as a deliver. In intermediary industries, supplier of dried natural fibre play a role as a source, while industries who transform dried natural fibre into composite materials play a role as a make. Distributors who play a role as a delivery send the composite materials to downstream industries. Type of actors in downstream industries are similar to that in intermediary industries.

This research would implement IoT in order to take an advantage of data mining. IoT employed was sensors and image processing connected to farmer's devices to provide information to buyers. The sensors that would be employed are sensors of light and plant humidity, which aim to ensure levels of intensity and plant humidity, resulting in forecast data of kenaf plant harvest time. Likewise, image processing requires forecast data of ready-to-harvest kenaf plant according to the blossom of tenth flower.

Data in the farm would be obtained in real time and continually mined to allow farmers to predict preparation of harvest time, and to plan information sharing with buyers through cloud. When farmers notify that ready-to-sell dried kenaf fibre is available, buyers would immediately respond to this information through a dashboard built in the web-based NFiSCA. At this point, collaboration occurs more deeply. As the emphasized collaboration is related to stock, its development would be carried out with a CPFR model. The architecture system diagram that has been described above is shown in Figure 4.

Limitations of this study, first is that data retrieval is only obtained from upstream and intermediate industries, while data for downstream industries cannot be obtained properly. Second is the limitation of mining new data from IoT devices such as sensors and cameras connected to internet connections, and Android mobile phones. Last, the literature review has been unearthed from 6 data bases, even though there are still a number of databases that carry out the same research topic area.

Further research from this study, first is the evaluation of the results of implementation of intelligent supply chain model as outlined in the submodel collaborative replenishment, submodel integration of production and inventory planning, and submodel of supply chain performance. Second is to apply the intelligent supply chain model on other natural fibers that are supported to develop competitiveness in Indonesia, such as sisal, coir, and abaca.

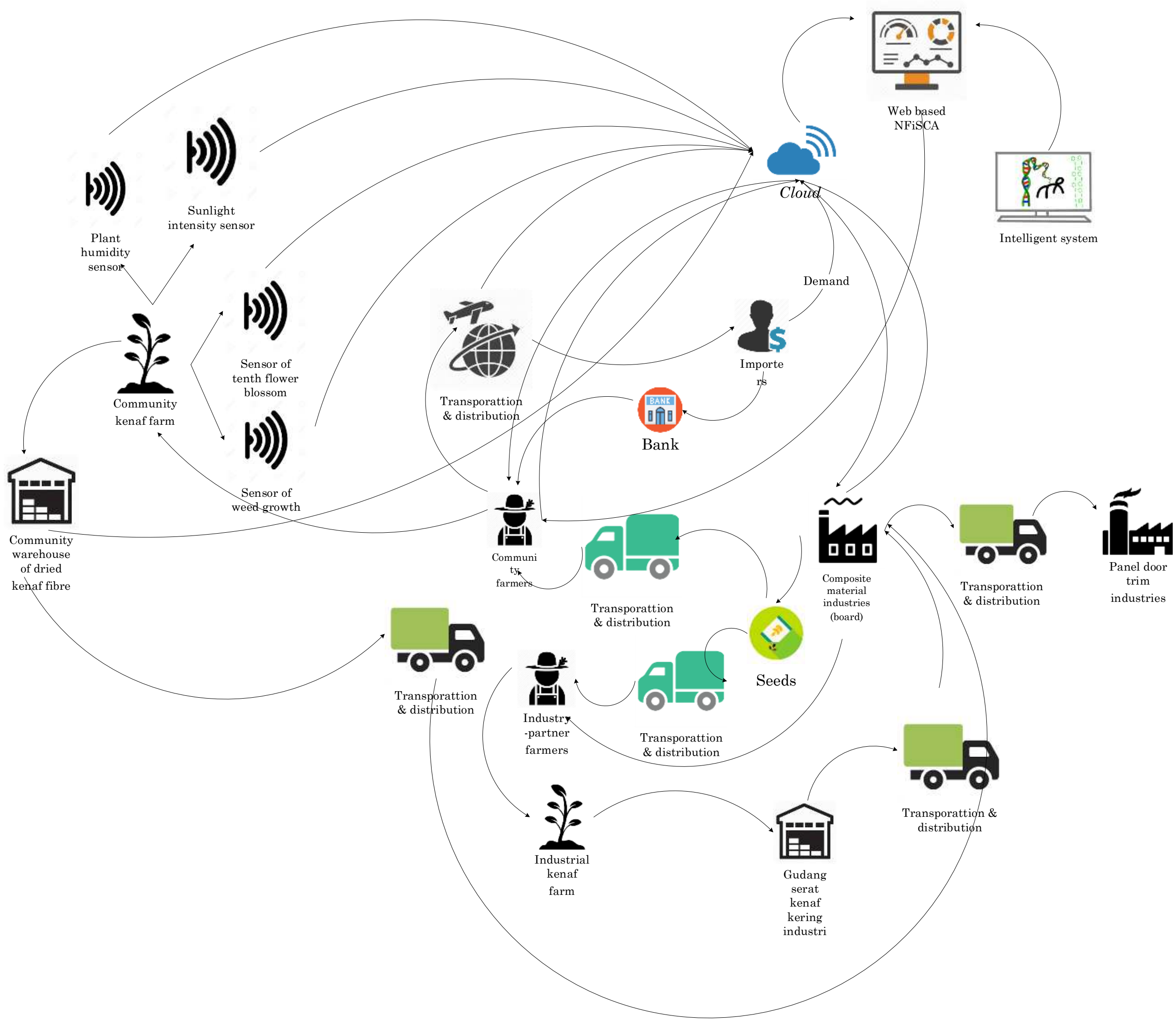


FIGURE 4. Architecture system of natural fibre agroindustry development

CONCLUSION

According to literature review and preliminary study that have been conducted, it is claimed that kenaf natural fibre is a potential type of fibre to develop in Indonesia. In addition to improving farmer welfare, it potentially increases competitiveness of kenaf fibre-based products in Indonesia through enhancement in added value of dried fibre that currently is only derived from beast kenaf fibre. Indonesia has not optimally utilized core kenaf fibre, unlike our neighbouring country has done, Malaysia. The limited land for kenaf plant, which is only 2000 Ha at the present time, is an opportunity for farmers, industry actors, exporters, and investors to develop this agroindustry, as current domestic production capability of kenaf is only 9.62% leaving an annual import of 90.38% [1] [19].

Indicators of success for this research that were summarized in critical success factor are: (1) Enhancement of supply chain efficiency and effectivity in natural fibre agroindustry, (2) Enhancement of satisfaction level among actors in supply chain, and (3) Achievement of level optimization and stock cost minimization, as well as (4) Benefits of a web-based NFiSCA application for users.

ACKNOWLEDGEMENT

We express a gratitude to BPPDN scholarship from Ministry of Research and Higher Education of the Republic of Indonesia, as well as to Universitas Al Azhar Indonesia for supports given to this work.

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