Intelligent Decision Support System Modelling for Agri-Supply Chain Risk Balancing on Price Determination

SUHARJITO1, MACHFUD2, SUKARDI3, BAMBANG HARYANTO4, MARIMIN5

1) Magister of Information Technology, Binus University, Jakarta, Indonesia
4) Center for Agro-Industry Technology, Agency for Assessment and Application of Technology, Jakarta, Indonesia
2,3,5) Faculty of Agricultural Technology, Bogor Agricultural University, Bogor, Indonesia. suharjito@binus.edu; http://www.binus.ac.id

Abstract: - Generally, it is found that farmers have no bargaining power in price determination. Thus, they have to bear all the risks compare to the others. In addition, price exchange at farmer level tends fluctuate significantly. Therefore, it is required to develop a mechanism for price negotiation, which distributes the risks fairly for each stakeholder in the supply chain. In addition it is necessary to identify and evaluate supply chain risks in order to avoid continuing problems that can occur at any point in the supply chain network. The objective of this study are to describe the model of identification and evaluation for corn supply chain risks, to formulate a fair pricing mechanism for corn supply chain using risk balancing model, and to develop intelligent decision support system for supply chain risk management. Risk identification was conducted using fuzzy AHP approach and risk evaluation was done by using fuzzy logic with data input derived from the opinion of several experts of maize supply chain. A fairly pricing model at farmer level was developed by using stakeholder dialogue approach based on a balanced fuzzy risk utility preference that faced by all stages of the supply chain. In addition, fuzzy risk utility optimization was used to get a consensus of the supply chain stakeholder dialogue, where basic risk utility function was derived using fuzzy regression approach. Risk mitigation for each stage of supply chain was developed using fuzzy inferences based on the risk that has been evaluated. Based on the verification results, the model could identify the level of risks for each party of the supply chain and the action that must be taken for minimizing its impacts using appropriate strategies. The model can shift the risks from the farmer to the other parties to determine the fair benefit distribution on the price negotiation.

Key-Words: - supply chain, risk balancing, intelligent, DSS-modeling.

1. INTRODUCTION
1.1. Background
Corn is a type of cereal crops that have a strategic role in national economy, given the multipurpose functions. Corn can be used for food, feed, and industrial raw materials. Corn is the main staple food in Indonesia, which has a very important position after rice. With the rapid development of the livestock industry, corn is the main component (60%) in feed rations. It is estimated that more than 55% of domestic demand of corn used for feed, while food consumption is only about 30%, and the remainder for other industrial needs and seeds [17].

However, in the development of national maize still found some problems including: 1) The production is uneven every month, so that at certain times of feed shortage of raw materials plant corn. 2) Lack of capital of farmers, mainly for the provision of agricultural inputs and at a certain time some means it is difficult to obtain. 3) Production of maize are mostly produced in the rainy season, while the dryer and warehouse equipment is very limited, causing many who suffered damage to corn production. 4) Not a guaranteed price at the time of harvest. 5) Weak institutional corn farmers, so the price determined by consumers, traders, and collectors. 6) Limited hybrid seeds at farm level is one of the problems in the efforts to accelerate the increase in production [23].

Farmers generally sell their maize to traders only or to the market (merchant city dealer or retailer in the public market). Thus, prices received by farmers is relatively low
and volatile. The situation is less profitable for farmers, because there is no guarantee a decent price [26]. This raises a number of issues are not smooth supply, not proportional risk sharing, added value and benefits between actors, the low quality and product safety, inefficiencies along the supply chain costs and product price increases. Farmers, as a provider of raw materials is the main actor who suffered losses in these distortions, which bear the greater the risk portion and receive portion of the benefits and added values are smaller. Therefore, it needs a model that can be used to determine prices together in the corn supply network so as to create a balanced distribution of risk with a fair negotiation. One mechanism is to do a balancing the risk of corn supply chain management, so as to create a balanced distribution of benefits between the levels of the supply chain.

Risk management of supply chain is different form general risk management, because of those special characteristics of supply chain risk, it still has some aspects needed to be paid attention to, such as complex interactions within numerous business partners, which is the main reason why supply chain risks are more difficult to identify and manage [20]. There are many types of risks faced by the supply chain such as risks resulting from: demand problems, problems in fulfilling customer deliveries, cost management and pricing, and weaknesses in resources, development and flexibility, so it requires joint effort to mitigate them [12].

Consensus is a form of shared decision-making among multiple stakeholders who have a conflict of interest in achieving a goal [14]. Conflict resolution to make decisions together or group has been widely described by several studies [21] and [25]. While the used of stakeholder dialogue for conflict resolution has been presented by [7] and [29]. But a resolution of conflict in decision-making of supply chain risk management has not been done yet, based on some literatures review, especially on Agricultural Products Supply Chain Management (Agri-SCM).

In the Agri-SCM, farmers as one of the perpetrators of the supply chain of agricultural products do not have enough bargaining power in price determination because agricultural products are perishable and seasonal, so the risk at farm level is higher than the risk at other levels in the supply chain network [28]. Therefore, there should be a mechanism to balance the risks faced by each level of the supply chain to improve their bargaining position at the farmer level. Improving their bargaining position is often done by consensus through stakeholder dialogue among supply chain actors [20]. This paper described a mechanism for determining the price at farm level with fuzzy risk utility optimization approach to help geting a resolution of conflicts of interest in a systematic approach using stakeholder dialogue among supply chain actors.

1.2. Research Objectives

Generally, the purpose of this research is to produce intelligent decision support systems for supply chain risk management products or commodities of corn an effective and efficient and responsive in order to assist stakeholders at all levels of the supply chain to make smart decisions quickly. While specifically aim of this research are:

a) To develop a risk management model, especially in terms of balancing the risk of supply chain corn product or commodity.
b) Develop the knowledge base of supply chain risk management systems or corn products with a focus of study is comprehensive, cross-sector and multi-disciplinary, so that identified the dominant supply chain risk and risk management priority.
c) Develop models for decision-making intelligent supply chain risk management products or commodities of corn through the development of models that can process knowledge of quantitative and qualitative techniques by exploiting the ability of multiple criteria decision making and multi-hierarchy and soft computing including fuzzy techniques inferences and fuzzy logic.
d) Create a prototype intelligent decision support system for supply chain risk management products or commodities of
corn in various strata of decision makers and supply chain levels.

While the benefits of this study is the existence of this model was expected to be useful for stakeholders to make supply chain management planning with consideration of minimizing risk and optimizing profits. Besides, with this model could give an idea of maize supply chain risk measurement to farmers, collectors, agro-industries and distributors, and provide alternative strategies and actions on risk management supply chain of the commodity and products, as an alternative solution for every stakeholder in addressing the risk of supply chain.

1.3. Related Works
Supply chain risk management by [2] defined as the identification and risk control of the supply chain and external risks through a coordinated approach among members of the supply chain to reduce overall supply chain disruption. Supply chain risk management focuses on how to understand and overcome the influence of the chain when a major or minor accidents that occur at a point in the supply network. In general, supply chain risk management process consists of risk identification, risk analysis, risk evaluation and mitigation of risk. Risk identification is recommended as a fundamental stage in the process of risk management [12]. Supply chain risks can result from one company in the supply chain, or connectedness between organizations in the supply chain, or between network supply and the environment, which will cause financial loss as a whole or even lead to cessation of business activities. Therefore, the need for supply chain risk management to avoid a risk that can continuously occur at any point in the supply network [16].

Research related to supply chain risk management is [11], [13], [1], [5], [6], [30]; [19] and [18]. But most of these studies discuss risk management in manufacturing supply chain. Several studies of risk management areas of agro-industry supply chain is [10], [9], [15], and [8]. But these studies have not identified any level of supply chain risk and risk balancing between tiers. Therefore in this study will focus on the issue.

Stakeholder negotiation is usually used to generate a consensus of a conflict. There are some researches on developing negotiation. [6] who has examined a formal bilateral negotiation in a supply contract where the buyer’s revenue and the seller’s cost are uncertain. The advantage of fuzzy logic and develops a hybrid negotiation-based mechanism, that combines both cooperative and competitive negotiations has been studied by [20]. An online negotiations have been proposed by [21] who used a reservation price reporting mechanism to reduce the number of negotiation rounds before reaching an agreement. Chen dan Kang [3] has developed an integrated inventory model which enables delay in payment and price negotiation under collaboration of two-level trade credit policy. [4] provided an automated negotiation on e-marketplace the user’s utility function for autonomous intelligent agents. Most of the literature used bilateral negotiation mechanism, in this paper will be used a multilateral price negotiation mechanism to balance the risks of Agri-SCM.

2. RESEARCH METHODOLOGY
2.1. Research Framework
A supply chain risk management corn product was a complex process. The complexity of the environment in which strategic decisions are made is a major consideration for using the intelligence system in intelligent decision-making system that will be developed. There are several reasons for the existence of this complexity are: (1) lack of information and knowledge that supports the decision was incomplete, uncertain or imprecise or even inconsistent, (2) there are different goals and even conflicting objectives and there are many different types of restrictions; (3) there are time limits for decision making in a changing environment, and (4) there is a tendency in group decision-making in which various types of consensus occurred in the process.

The framework in this study refers to the framework that has been developed by [24], with some adjustments in supply chain risk management and use of agricultural products and categories of risk variables that have been identified by [31]. In this study the identification and analysis of risk will be conducted on every
offender supply chain to get the level of risk for each stage. Then the value of total risk be calculated by aggregating each risk in the supply chain in order to obtain the level of global supply chain risk and how risk management can be done thoroughly to make distributions and balancing the risk of supply chain.

2.2. Research Stages

Step-by-step development of intelligent decision support systems of risk supply chain management for corn products in this study are as follows: identification of the perpetrator, the goal of every actor and risk factors of agricultural product supply chain, risk identification and impact on every level of the supply chain, measuring and evaluate the risk of supply chain, development of supply chain risk management model with multiple objectives programming approach, developing a knowledge base and risk management models with a fuzzy inference system approach, analysis of various scenarios of risk management with multiple criteria, the selection of risk management scenarios with respect to profit sharing and minimization optimum risks of global and local as well as balancing the risk of supply chain with fuzzy utility function and stakeholder dialogue, decision-making support system intelligent supply chain risk management and making recommendations for action and conclusions.

Expected output of this research is the mapping of sources of risk and its impact on every level of corn products supply chain from upstream to downstream, the availability of information and ways of handling the level of risk in supply chain risk and risk measurement models at every level of supply chain network, the model collaborative supply chain risk management planning, the optimization model of risk management with multi-objectives programming approach to the criteria of risk minimization and profit maximization. Availability of mechanisms for the distribution of risk at every level with the concept of balancing risk in the supply chain. The availability of a web-based intelligent decision support system of risk management supply chain of corn products that can be accessed by any supply chain stakeholders, so as to raise awareness of the risks in the supply chain and available methods to anticipate them.

3. RESULT AND DISCUSSION

3.1. Configuration Model

Intelligent decision support systems of risk management supply chain maize products developed using the computer software named IDSS-SCRM (Intelligent Decision Support System Supply Chain Risk Management). The model was developed using a web-based systems approach in order to be able to help each stakeholder in the supply chain network to make decisions in supply chain risk management of corn products. In addition to the model is expected to obtain a mechanism of communication between tiers in the supply chain network, either directly or indirectly in decision making so that supply chain risk management will create a sustainable supply chain and can balance the level of risk that is borne between levels of actors, especially for enhance the capability of the farmer level in tackling or minimize the risk as a principal or a party that is quite weak in the face of risk.

Decision support system was developed using web-based programming that is PHP and uses MySQL Database Management System. The main components of the IDSS-SCRM system is divided into four main components namely a Model Base Management Systems, Database Management System, Knowledge Base Management System and a Dialogue Management System.

Risk identification is done using fuzzy AHP approaches and risk evaluation is done using fuzzy logic with data input expert opinion of some maize supply chain practitioners. Model of a mutually beneficial price negotiation at the level of farmers was developed using the stakeholder dialogue approach based on balancing the utility of fuzzy risk preferences faced by all levels of the supply chain. In addition, optimization of the fuzzy risk utility is used to gain consensus in the stakeholder dialogue, in which the utility function of the basic risk is obtained by using fuzzy regression approach. Mitigation of risk for each level of the supply chain is developed using fuzzy inference based on the risks that have been evaluated.
3.2. Corn Supply Chain Risk Analysis

Based on the results of the identification of risk factors and variables of each level of corn products supply chain is obtained that the highest risk factors at farm level is a risk of quality, followed by the price risk, environmental risk, and supply risks. The main risk factors faced by the traders are price risk, followed by the risk of supply and quality risks. While the dominant risk factor faced by agro-industry is the risk level of quality, followed by the supply risk, price risk and environmental risk. Then at the highest risk factor levels of distributors is price risk, followed by supply risks, the risk of quality and storage risks. Furthermore, the dominant risk factor at the consumer level is the quality of risk, supply risk, price risk and environmental risk.

In the supply chain of corn products, farmers have the highest risk when compared to risk at the level of traders, agro-industry risk, the risk of distributors and consumers’ risk. Farmers and agro-industry risk level is almost same that is moderate, but based on the weighting of risk, risk weight at the farmers level is higher than agro-industry risk weight. While the level of risk traders, distributors and consumers about the same that is low. A supply chain risk aggregation value corn product is moderate.

In the maize supply chain, critical risks that need to be addressed is the risk of low quality of raw material supply, the risk of price fluctuations and supply of raw materials, as well as the risk of information distortion in supply chain network. To cope with and anticipate the risks of commodity corn supply chain management can be done through cooperation contract between the parties with an interest in sharing the risks and benefits are balanced between supply chain actors.

3.3. Corn Supply chain risk balancing

Balancing the risk of supply chain to get the deal price at farm level using the assumption that the risk at farm level tends to rise when corn prices fell and the risk will tend to fall when the corn price increases. However, at another level in the supply chain network, such as agro-industry or collector will have risks that tend to fall when prices fall and the risk of their raw materials at these levels tend to rise when the price of raw materials rises.

The risk balancing of supply chain is done by determining the risk utility function of each level of using fuzzy price exchange scenarios as described in [27], it will be got a risk utility function for each level in the supply chain, such as equation (1). This process is done by creating a conjoint function of each utility function of risk in order to obtain the following equation:

\[ H(x) = U_p(x) - \sum_{k=1}^{n} Q_k U_k(x) \]  \hspace{1cm} (1)

Where \( H(x) \) is the conjoint utility function of risk for price negotiations of AP-SCM, \( U_p(x) \) is the utility function of risk at farm level, \( U_k(x) \) is the utility function of risk on another level and \( Q_k \) is the weight of the supply chain level obtained from the analysis using analytic hierarchy process.

The Value \( x \) of the function above can be found by searching the minimum value of function \( H(x) \) based on linear regression equations to obtain the value of \( \alpha \) and \( \beta \).

The solution of the equation (1) above can be done by linear programming or linear interpolation to minimize \( H(x) \) as follows:

\[ H(x) = \alpha e^{\beta x} - \sum_{k=1}^{n} Q_k \alpha_k e^{\beta_k x} \]  \hspace{1cm} (2)

With constraints:

\[ X_0 < x < X_1 \]

\[ \sum_{k=1}^{n} Q_k = 1 \]

Where \( X_0 \) is the lowest offer price and the \( X_1 \) is the highest bid price in a price negotiation using the stakeholder dialogue.

The results of model verification of price negotiations with consideration of balancing the risk of supply chain value price that is greater than the forecast average price, this means that this mechanism has shown a shift from farm-gate value of risk to other parties in the supply chain in accordance with a balancing constraint risk in the supply chain of corn products. In other words, the model has shown results that can balance the risks of each level of the supply chain by providing value pricing can deliver a balanced distribution of benefits in accordance with the level of risk faced.
3.4. Managerial Implications
Managerial implications of risk management supply chain that can be proposed from this research is the need for an appropriate mechanism to be able to identify supply chain risks in order to obtain a clear picture of the possibility of risk and its causes so that management can take action or anticipation of impending risks in the process business. In addition to appropriate action can focus in analyzing the risk of supply chain is necessary to evaluate any risks that have been identified, so that it will obtain an alternative action that can be selected by management in anticipation of the risk of quickly, accurately and effectively.

Managerial Implications of balancing the risk of supply chain product / commodity corn is the need for responsible supply chain actors to be able to implement and oversee the agreement's price is obtained in the process of balancing risk, so the solution can be run properly and with a high commitment by all stakeholders chain supply. One institution that can be proposed in this surveillance is the existence of an independent agency whose members all levels of the supply chain with the initiators of the central/local government.

4. CONCLUSION
This study has successfully designed a model of intelligent decision support systems corn products supply chain risk management named IDSS-SCRM (Intelligent Decision Support System Supply Chain Risk Management). The model was developed using a web-based systems approach in order to be able to help each stakeholder in the supply chain network to make decision in supply chain risk management of corn product. System can be used to perform risk analysis, risk mitigation and risk balancing at every level supply chain and can also provide alternative solutions to control risks to any risks that have the possibility of harm in every level or supply chain networks in general. The system is modeled with a soft system approach and hard system methodologies use some combination of techniques such as fuzzy logic and inference, fuzzy AHP, fuzzy FMEA, fuzzy regression, linear interpolation, and weighted sum optimization.

The novelty of this study can be categorized into two things: the first is to have developed a model of balancing the risk of corn product supply chain to negotiate prices with the use of web-based approach using stakeholder dialogue and fuzzy utility function. The second is to have developed a system of decision support system of supply chain risk management which can be used to analyze all levels of supply chain risks and control mechanism of its risk caused.

Stakeholder dialogue on risk management of agricultural product supply chain can be done bilaterally or multilaterally to balance the supply chain risks by using risk utility function of each level of the supply chain. The utility function of risk at farm level tends to fall if the price of corn rises, the opposite risk utility function at the level of agro-industries tend to increase if the price of raw materials rises, so it can be formed a conjoint function between both of the risk utility function to get a point of mutual agreement.

References:


