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THE EVALUATION MODEL OF THE RISK IN EACH SUPPLY CHAIN STAGE OF THE AGRICULTURAL FOOD CROP PRODUCT

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ABSTRACT

Supply chain management of agricultural product was different from supply chain management of manufacture product, because the agricultural product was easy broken, was seasonable, had varying form and size, and was bulky therefore it was difficult to be handled. The height complexity of the supply chain network and the characteristics of this product made supply chain management of agricultural product were more susceptible to the risk emergence of loss. The risk of failure for the supply chain could be happen internally (the relations between the organization and the network of the supplier) and externally (between the network of the supplier and its environment). The risk control of supply chain to avoid the continuous loss that happened in each point in the network chain could be carried out with a right supply chain risk management. The aim of this paper was to explain an evaluation model of risk for agricultural product supply chain management. The model could identify the level of risk for each parties of the supply chain and the action that must be taken for minimizing its impacts.

Key words: *risk evaluation, supply chain risk management, food crop supply risk*

1. INTRODUCTION

One of the efforts to improve the food endurance system was by designing the system of food agro-industrial that could produce the food product with high added value for the farmer, guaranteed the smoothness of food supplies, controlled by the height quality and guaranteed the security of the food product and set the price of the food that could be accessed by the community. This could be done through the development of the supply chain management strategy that integrated the perpetrators from all the segments of the supply chain both vertically and horizontally (Apriantono, 2005).

Several problems that caused the weakening of food endurance at this time were the conversion of the agricultural land, the decline in the productivity of agriculture, means and the infrastructure of agriculture that did not satisfy, the institutional weakness (the regulation and the infrastructure), as well as the marketing system and the supply chain that were not controlled. Especially in the last problem, the existence of the information gap between consumer and producer caused the occurrence of distortion in the aspect of distribution and accessibility of food endurance. This distortion showed several problems that were not fluent in foodstuff supplies, unproportional distribution of the risk, added value and the profit between the perpetrators, the low level of the quality and the security of the food product, inefficient cost along the supply chain as well as the jump of the price for food product. The farmer, as the provider of raw material was the main perpetrators who suffered the loss in this distortion that are bearing the portion of bigger risk and accepting the portion of profit and smaller added value (Arifin, 2001).

Risks in supply chain could be derived from a firm in supply chain or relations between organizations within the supply network or between supply network and their environment, which could cause major financial losses or even businesses discontinuities. There is a need to manage supply chain risk in order to avoid ripple effects that could take place in any point of the supply network (Karningsih, 2007).

There are considerable number of research on supply chain risk evaluation models (Hallikas, et al., 2002, Christopher & Peck, 2004; Nagurney et al., 2005; Wu et al., 2006; Balan et al., 2006, Goh et al., 2007; Schoenherr et al., 2008; Kull & Closs, 2008; Wu & Olson, 2008; Lee, 2008). However, there are fewer studies that discuss supply risk evaluation model in agricultural product supply chain management.

Supply chain management of agricultural product was different from supply chain management of manufacture product, because: (1) the agricultural product was easy broken, (2) the process of planting, the growth and the harvesting depended on the climate and the season, (3) the yield had the form and the varying size, (4) the agricultural product was bulky so as the agricultural product was difficult to be handled (Austin, 1992, Brown, 1994). Therefore, the risk of agriculture product supply chain was higher and more uncertainty than supply chain of manufacture product. Supply chain risk management of agricultural product needs to consider these characteristics to obtain optimal performance in supply chain continuity and product quality.

The purpose of this study is to develop an evaluation model of supply chain risk management for agriculture product in each chain level of the network. The result of this risk measurement can be applied by stakeholder of each chain level of agriculture product to make an optimal action which will be done by considering the level of risk to be faced.

2. THEORETICAL BACKGROUND

2.1. Supply Chain Risk Management

Customer demand has changed significantly over the past decades. They are asking on more product variety and faster time to market, while competitive price and good quality become basic requirement in order to be qualified in the market competition. This trend force companies to respond with product that has increasingly lower cost, better quality and shorter development time. In order to win on this tough competition, a company can not only focus on improving their internal organization process but should also managing their whole network, from their suppliers to their end customers (Pujawan, 2005).

Increasing level of interdependency and complexity of today's supply network makes the whole supply chain is now becoming more vulnerable to disruptions. Any disturbance happen in one of supply chain player could affect the whole supply network as it could interrupt the flow of information and resources from upper to lower stream of the supply chain resulting in inequality between supply and demand. Therefore, risk in supply chain could be defined as flow of information and resources impediments in the supply network due to uncertain variation or interruption (Juttner et al., 2003).

Supply Chain Risk Management is defined by Chapman et al. (2002) as "the identification and management of risk within the supply chain and risks external to it through a coordinate approach amongst supply chain members to reduce supply chain vulnerability as a whole". Supply Chain Risk Management (SCRM) focuses on how to understand and to avoid ripple effects whether major or minor accident could take place in one point of the supply network. In addition, the most important thing is to make sure that when a disruption occurs, the company has ability to go back to their normal and continue their business, which is termed by Christopher & Peck (2004) as supply chain resilience.

Several studies (Centre for Logistics and Supply Chain Management - Cranfield School of Management, 2003; Harland et al., 2003; Hauser, 2003; Juttner et al, 2003; Sinha et al., 2004 Hallikas et al., 2002; Deleris & Erhun, 2005; Kleindorfer & Saad, 2005; Kiser & Cantrell, 2006) suggest similar basic phase in managing risks in supply chain, which are: risk identification (identify what could happen, where, when and how), risk analysis (quantify/measure the impact of the risk), risk evaluation (put prioritization on identified risk) and risk treatment (develop and implement risk mitigation strategy to control the risk).

2.2. Supply chain risk evaluation

Risk evaluation is the next sophisticated step after risk recognition and identification. Commonly, risk assessment and evaluation are based on calculating a risky event occurrence probability with corresponding possible disruption values. There are 3 possible modes of probability evaluation: empirical, theoretical and subjective evaluation (Condamin *et al.* 2006).

Two main methods to evaluate supply chain risk are evaluation method of risk based on expert opinion and evaluation method of risk statistically (Klimov & Merkuryev, 2008). According To Argawal (2005), since long time ago a company has defined, prioritized, mitigated and audited risk with help of expert using subjectively measurement approach. Evaluation of risk statistically usually based on at average value, level of deviation, level of probability, risk coefficient and risk scale, such that it has been defined a measurement of Value at Risk (Var) in financial risk, Inventory at Risk (IaR) in warehouse, and Demand at Risk (DaR) as similar approach (Klimov & Merkuryev, 2008).

For previously defined concept of supply chains, risk evaluation might be based on varied mathematical methods. For instance, to evaluate characteristics of system transition between different conditional states, Markov process mathematics can be adopted; system stability for certain conditional states can be described by reliability theory. However, necessary mathematics becomes too labour intensive in large and volatile systems, such as supply chains. At the same time, some researchers state that risk quantification builds on knowledge elicitation rather than on data collection. Data must only be considered as part of the available knowledge, the main source being human expertise (Condamin *et al.* 2006). Thus, the use of simulation is advised as an effective tool for developing a supply chain model, which not only simplifies risk evaluation task within complicated systems, but also complies with expert opinion for input data realization.

2.3. Supply risk evaluation model

According to Neureuther & Kenyon (2008), in order to understand the risk associated with the supply chain failing to deliver the promised good/service, the supply chain structure itself along with sub-products and sub-services within the structure needs to be examined. This risk, which we will call the risk consequence (α), can be calculated as follows:

$$\alpha = \frac{\delta_{replace}}{\delta_{collapse}} \qquad (1)$$

where:

$\delta_{replace}$ = the time required for a supply chain to fully replace a given sub-product or sub-service, or resolve the disturbance to the product flow, and resume a normal product delivery schedule at the same quality level.

$\delta_{collapse}$ = the time a given sub-product or sub-service can fail to be delivered before the supply chain suffers the loss of a critical mass of its market share.

Note that $\delta_{replace}$ is limited in magnitude to that of $\delta_{collapse}$ because, at that point, the supply chain will cease to exist. Therefore the range of the consequence score (α) is from 0 to 1, where 1 implies the collapse of the supply chain should a failure occur and 0 implies there is no effect (or consequence) of the risk.

For the sake of the study, consequence scores were classified as vital, necessary, or desired. A 'vital consequence' score is assigned for sub-products or sub-services if there are no substitutes for this item and, should it not be present, there would not be a product or service for the supply chain to deliver. A 'necessary consequence' score is assigned for sub-products or sub-services in which substitutes do exist, but their usage, with respect to the sub-product or sub-service, would significantly reduce the functionality or quality in the product or service being produced by the supply chain. The usage of a substitute product or service could require a redesign in the supply chain's product or service. A 'desired consequence' score is assigned for sub-products or sub-services in which there are substitutes for the item and usage would not require any redesigns or significantly reduce the functionality or quality of the supply chain's product or service.

Table 1. The consequence score of risk

Clasification	Group	α
Vital	Not Replaceable	1.0
Necessary	Not Easily Replaced	0.6
Necessary	Easily Replaced	0.3
Desired	Easily Replaced	0.1

The purposed model to evaluate risk in each level of the supply chain network can be formulated as follow:

$$RI_x = \alpha_x \beta_x \left(1 - \prod_{i=1}^{n} \left(1 - P(\hat{s}_{xi})\right) \right) \qquad (2)$$

Where:

RI_x = risk index for x^{th}.level of the chain network

α_x = the consequence for x^{th}.level of supply chain fail supplying products.

β_x = the percentage of value added of x^{th}.level to supply chain

$P(\hat{s}_{xi})$ = the probability that the i^{th} firm of x^{th}.level fail

The value of the risk index was in the value between zero and one. The risk index was worth zero if the perpetrators of the supply chain did not have the risk completely, whereas the value of the risk was the same as one meaning that the perpetrators of the supply chain really played a role in the smoothness of the supply chain network, or if the problem in this stage happening then the supply chain on the whole will be disrupted.

The calculation result of this model combined with the the result of value at risk calculation, then was used to consider the financial risk that happened in each level of supply chain and was made as input the optimization profit model with consideration of the risk. The optimization profit model with considering risk minization in each chain stage of supply chain that was used refered to Nagurney's (2005) model as follows:

$$\text{Max } Z = \sum_{i=1}^{n} Q_i P - F_x - \sum_{i=1}^{n} C_i Q_i - R_x(Q) \quad (3)$$

Subject to:

$$Q_i \geq 0,\ 1 \leq i \leq n$$

$$\sum_{x=1}^{m} F_x \leq F \quad (4)$$

$$\sum_{i=1}^{n} C_i Q_i \leq C \quad (5)$$

Where:
Q_i = The number of production units
P_i = The selling price of the product
F_x = Investment for each project activity
C_i = The handling cost of each product unit
$R_x(Q)$ = The estimation of the risk cost
F = The total investment that was provided
C = The operational cost that was budgeted for

3. RESEARCH METHOD

This study conducted by survey and study of literature to find business process of food crops commodity, especially corn. Firstly, A diagram of supply chains mapping and constraints of each actor in the implementation of the fulfillment of consumer demand was made from this survey result Then an ideal supply chain design was created by considering the constraints and risks that may occur in every action. Risk analysis was performed on activities that have a high risk and will cause financial losses. Finnaly, risk evaluation model was created to obtained the risk level value of each supply chain actors.

Then, risk level value was used to measure the level of losses that will be received by applying the value at Risk model. Then, This value was used as input model to optimize the benefits that will be received by each supply chain actors. The Optimization model that will be used in this study is a modified version model that was developed by Nagurney (2005). Then the model was tested with the help of Excel-Solver software to optimize the expected value, with input data obtained from literature review and field surveys. The stages of this study can be seen on Figure 1 as follow:

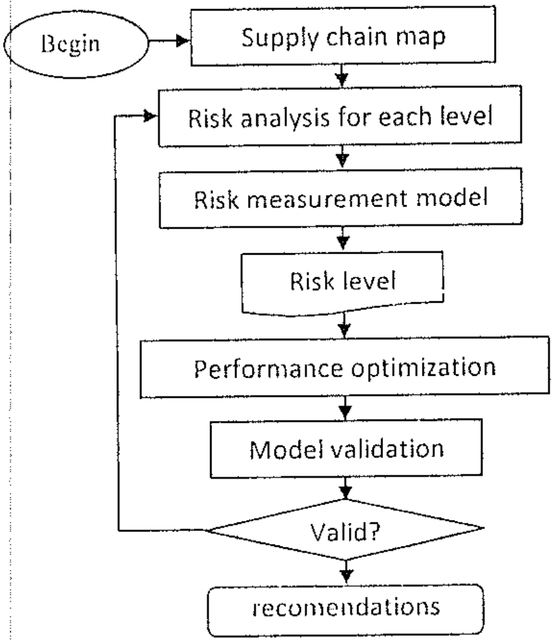

Figure 1. Stages of risk evaluation model

4. RESULT AND DISCUSSION

4.1. Food crop Supply chain map

Based on literature studies and the circumstances that often occur in the field and based on the study of Sarasutha et al. (2007), the corn commodity supply chain can be modeled with Figure 2 as follow:

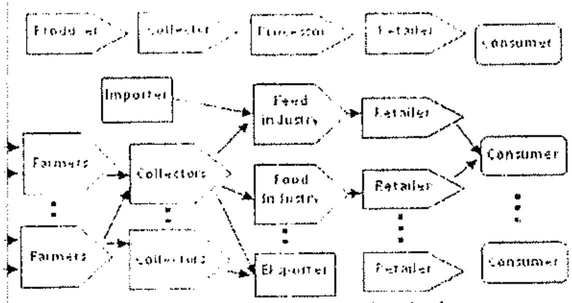

Figure 2. Food corp supply chain map

In that supply chain model risks that often faced by corn farmers is the use of maize varieties that are still using local varieties that have low productivity levels, post-harvest handling of the less well resulting in lower quality and planting schedule that are not exactly so at harvest time corn prices fell sharply (Kasryno, 2006).

While the risks frequently encountered by collectors trader is the decreasing quality because most of the corn maize harvested in the rainy season so that the drying process is not perfect and causes growth of the fungus. Besides the risks faced is the additional cost of additional storage and drying to obtain an appropriate quality standard (Kusumaningrum, 2008).

The main risks faced by the processor in this study is the risk of low quality due to different corn suppliers, the availability of supplies that are not fixed because of the seasonal corn products and price fluctuations that would complicate the estimation production.

4.2. Risk of farmers

Risks that often faced by corn farmers are not many who use superior seed varieties like hybrid maize so that decrease their productivity levels. According to Sarasutha et al, (2007), the probability of the use of hybrid maize is 22%, therefore the possibility of farmers still use seed corn with inferior type is 78%. Besides the risk of damage to corn caused by the milling done on the water content of maize by 30% reaching 15% -20%. Meanwhile, corn prices at harvest season, the average falls by 25% resulting in less profitable for farmers. Of these things can be obtained probability risks suffered by farmers for each category of risk can be explained as follows:

Table 2. Risk type of corn farmer

Farmer risk types	P(x)
The low productivity because of not using the prime seed	78%
Damage resulting from post-harvest in rainy season	20%
Anachronistic planted so as the price descended when harvest	25%

The Value of consequences (α) for the farmers is necessary (0.6), because the use of corn for feed or food are not easily replaced and, if replaced will affect the functionality of the feed or food products. While value-added corn for food products is 50% because of the supply chain required for corn feed products are not less than 50%. Of these values is by using the formula (2) risk index values obtained at the level of farmers in the supply chain network is 0.26 or 26%.

Further will be explained calculating the optimal planting period for farmers to consider the level of risk which led to harvest corn prices down. Some component values required to optimize the benefits with the appropriate harvest schedules are: capital to be allocated to each investment, operating costs used in each cycle of planting, the estimated income of farmers and the risk index for each planting cycle.

By using the excel-solver software can be obtained that for optimum benefit, harvest schedules should be done is in May, and between September and December. So the estimated time of planting corn for 3 months then the optimal planting period should be done in February and June.

4.3. Risk of collectors

As mentioned upfront risks which will be used to measure the risk index for collectors are the risk of storage, the risk of additional drying for harvest usually occurs in the rainy season and the risk of lower quality from some farmers who do not use the prime seeds. Probability value of each risk event can be explained by the following table:

Table 3. Risk types of collector level

Risk types	P(x)
The risk of the quality because of the aflatoxin fungus	35%
The quality of corn that not the uniform	25%
The additional drying	15%

The consequences value (α) of the collectors is 0.3 because in addition to collecting the farmers can make direct sales to distributors without reducing the quality of activities and supply chain functionality to be able to supply food or feed industry. Meanwhile, value added (β) of collecting the maize supply chain are 50% due to the need of feed corn in the production of no less than 50%. From these values, then by using the formula (2) obtained supply chain risk index to collectors is 0.0878 or 8.78%

By using the excel-solver software and model on formula (3) ca be explained actions that should be carried out by collectors in selecting supplier of corn by farmers and how many units of corn are taken from each farmer partners to optimize the benefits of the restriction that belongs to the warehouse capacity of middlemen, the ability of partners to provide corn by farmers and business capital and operational costs allocated.

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4.4. Risk of processors

To analyze the risks faced by the processor, it is necessary to identify the main types of risk arising on the processor. Some of the major risk types most frequently encountered are related to the risk of transportation delays in transportation and price fluctuations of raw materials. Besides the distribution of risk is also noteworthy because the limited transport capacity and the selection of transportation routes that are less optimal. Storage risks also noteworthy because the distribution need enough storage to maintain product quality. Probability value of each risk should be borne by the processor are as follows:

Tabel 4. Risk type of processor level

Risk types	P(x)
Transportation jump and delay	30%
Wrong rute selection	15%
Price fluctuation of raw materials	25%

Value consequences (α) to the processor level is 0.3 because this level can be replaced easily either by the collectors or farmers who sell directly to consumers of animal feed mill or food industry. Meanwhile the value added (β) at processor level of the feed and food products nearly equal to the other party in the amount of 50% for industrial use of corn in the no less than this value. Then by using the formula (2) can be calculated a risk index value for the processor is 0.0831 or 8.31%.

The same thing with the optimization of profits at the collector level, profit optimization at the processor level is to optimize the benefits with an initial investment of capital constraints for the purchase of the collector and the total cost of operating constraints that are used for transporting products from the collector to the consumer and storage costs, with capacity constraints supply of each collector in the supplying of corn to the processor in selecting the optimal supplier

From these values can be seen that this optimization model can choose the appropriate allocation to each supplier with a consideration of risk and cost of supplies

5. CONCLUSION

Based on the results of this study could be concluded as follows.

- From the results of analysis of supply chain risk index of agricultural products, farmers have the highest risk index values of 26% followed by collectors of 8.78% and 8.31% of the processor.
- To reduce the risk at the level of farmers has been simulated profit optimization models in determining the optimal schedule of planting corn in February and June.
- Profit optimization model for each level of the supply chain can be used to optimize supplier selection decisions with consideration of risk and operating costs, both at the processor level and the level of collector.

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