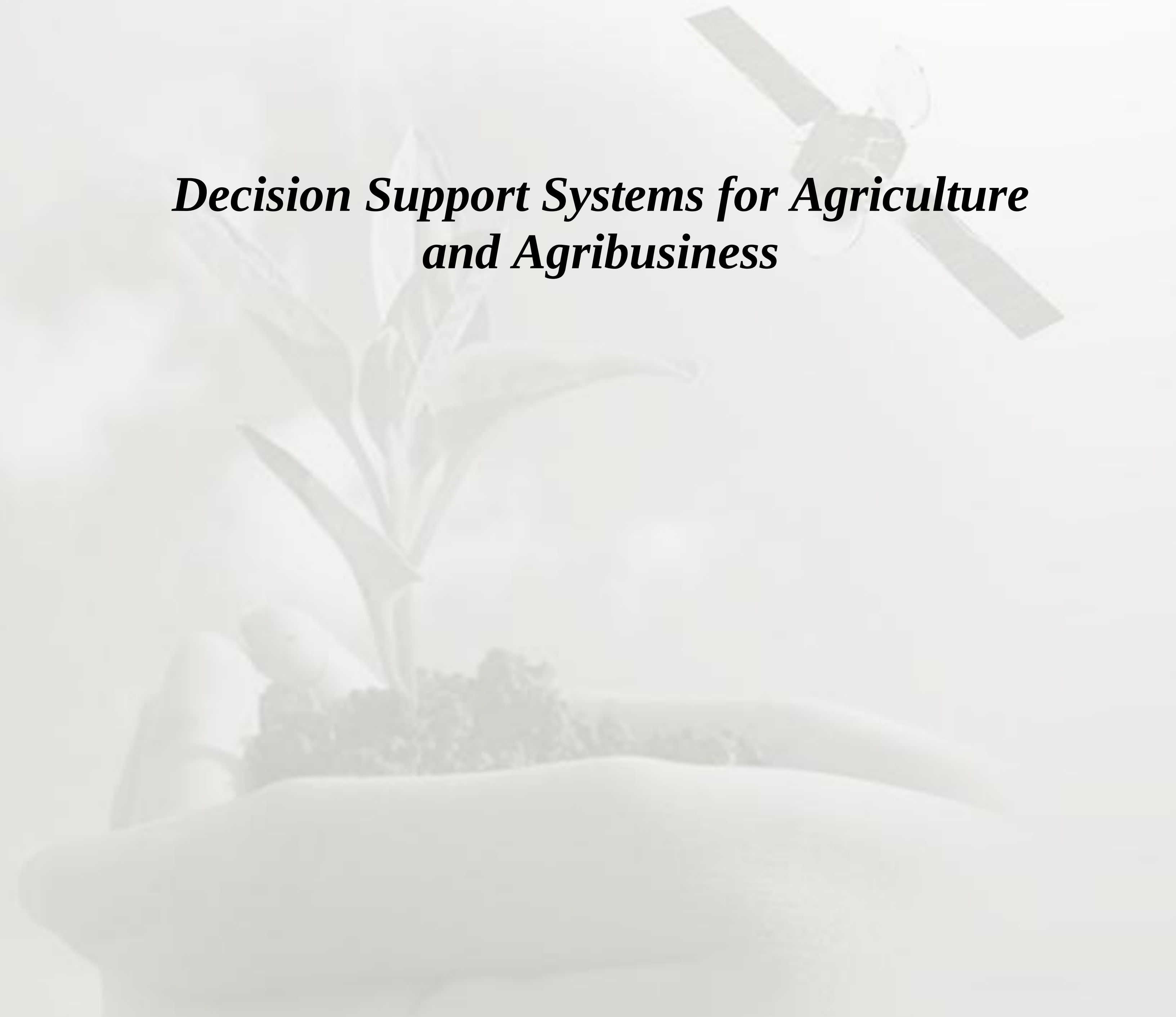
Decision Support Systems for Agriculture and Agribusiness



A Framework of Intelligent Decision Support Systems for Agro-Industrial and Agribusiness Supply Chain Management

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Abstract **-The implementation of supply chain management in Agribusiness and agro-industry has a significant difference in terms of stochastic and dynamic behavior as a result of some factors such as (1) perishable characteristics (2) seasonal for cultivation, growth and harvesting (3) various shape and size on final yield (4) voluminous. These factors should be considered in designing a comprehensive, effective, efficient, responsive and sustainable agro-industrial supply chain management.**

As a consequence, the decision making is becoming more complex than common manufacturing application which are pragmatic, deterministic and static. In order to handle this problem we develop an Intelligent decision support system for Agricultural business and industry supply chain management (iDSS Agri-SCM) as a framework to improve decision making in supply chain. The framework proposes a more effective and efficient supply chain system that supports a fair distributed benefit and value added among stake holders from down stream to up stream equally. This system is supported with a database of Agricultural commodity and its knowledge based system. Hard System Methodology (HSM) and Soft System Methodology (SSM) is deployed in the model with supporting of soft computing such as fuzzy set, genetic algorithms and neural network which give adaptive and intelligent decision.

The implementation of this framework is designed with supporting for object oriented design by using UML (Unified Modeling Language). This design handles a wider application in terms of packaging, transportation routing, and distribution of Agricultural products. This framework also provides a mechanism for the supplier selection, pricing negotiation and evaluation which eventually lead to a comprehensive view of the system.

Keywords: Intelligent decision, supply chain management, hard and soft system methodology

I. INTRODUCTION

Supply chain managements in business and agro-industry represent the whole production process from processing, distribution, marketing up until the proposed product in customer's hand. They are different from conventional manufacturing systems in cases of (1) tend to be perishable, (2) cultivation, growth and harvesting are depend on the season, (3) varied form and size in the end products , (4) more over generally voluminous which lead to hard handling [1][2]. These factors must be considered well in designing SCM to assure for effective, efficient and responsive systems in the SCM implementation.

Being more complex, this problem is also stochastic and dynamic in conventional views. More over most of the problems were solved in a pragmatic approach, static and deterministic. Thus, it is urgent to setup a solution for the problems in agro-industry and business. In this paper, we proposed a framework to describe dynamic relationship of this complexity in the domain with a novel approach which comprehends as a system approach. Basically this approach used to build a comprehensive concept to describe and investigate visible solution and arrange decision and acts to drive for a better situation with consideration to all possible occurred risks.

Risks in SCM may derive from a company or relationship inter-organization and the environment that can result to a loss within the chain financially and halt the business activity entirely. Therefore it is necessary to manage and control supply chain risk [3].

Significant changes on customer demand for ready to use of various products have been occurred in few last decades with more quality requirements. They enforced enterprise to not only focus on organization improvement for competition but also have to seriously consider supply chain network as a whole from downstream to upstream [4].

The implementation of a SCM further faces harder step with uncertainty in managing complex relationship among stakeholders' sourced risks. Decision in SCM such as supply chain design, risk optimization and value added, including supplier and distribution selection and other related agents, production lot and scheduling, transportation engineering and other resource planning which directly related to supply chain. These all components contain critical probabilistic risk. Therefore rapid decision must be taken to handle uncertainty and business mechanism variability in supply chain efficiently and effectively [5].

Soft System Methodology (SSM) is defined as method to solve complex problem where stochastic and dynamic characteristics requires intelligent systems and soft computing techniques such as fuzzy logic, genetic algorithm and artificial neural network. Furthermore Decision support system framework might answer such problem as supply chain in agro-industrial and business, that make decision for supply chain network optimalization, managing distribution and transportation network, surveillance and risk controlling on each stake holder, proportional added values and an effective, efficient and sustainable supply chain institution arrangement.

The framework of intelligent decision support system for Agricultural business and industry supply chain management (iDSS Agri-SCM) was proposed in this paper. This framework consists of three main sub systems, price negotiation model, route and transportation optimization and the last one is optimization of multimode transporation. We claimed intelligence domain in the iDSS-Agri-SCM which has the capability as: (a) it contains various types of knowledge that describe selected aspects of the decision-maker's world; (b) it has an ability to acquire and maintain descriptive knowledge such as record keeping and other types of knowledge as well; (c) it can produce and present knowledge in various ways; (d) it can select knowledge to present or derive new knowledge; (e) it can interact directly [intelligently] with the decision maker.

In this paper we provide a framework of iDSS design in two main subsets, namely a support component for conducting price negotiation and the second one to assure the optimization of the system by deploying intelligent algorithm of Ant-colony in the route of our Agri-SCM which is developed using UML. The structure of this paper is as follows, in the next part we discuss related works that underlied our work, and then in the third part we elaborate the modeling of our iDSS-Agri-SCM. In the fourth part we discussed the result with an example to price negotiation as our verification; we close our paper with concluding remarks of our result in part five.

II. RELATED WORKS

Basically intelligent Decision support system (iDSS) is designed to interactively support all phases of a user's decision-making process. There are various notions about all aspects of this definition. There can be individual, group, and other users. Support can be direct or indirect. The decision-making process can be viewed in various ways. 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 [7]. An online negotiations have been proposed by [8] who used a reservation price reporting mechanism to reduce the number of negotiation rounds before reaching an agreement. Chen and Kang [9] has developed an integrated inventory model which enables delay in payment and price negotiation under collaboration of two-level trade credit policy. Cheng, Chan, and Lin [10] 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 Agricultural Product-Supply Chain Management (Agri-SCM).

Intelligent Decision Support System (iDSS) can be implemented, because iDSS has been researched by many researched in many business fields. Kwon [11] used context-aware computing technology to support his research in iDSS. On the other research, Xu [12] implemented iDSS in business innovation self assessment. Loebbeck [13] developed model-based netsourcing decision support system using a five-staged methodology.

One of methodologies model used in iDSS developing is an ant colony algorithm. The ant colony algorithm has been used in many researches in many fields. This algorithm was used as single method or combined to other methods. As a single method, ant colony algorithm was used in: production and maintenance scheduling optimization [14], routing design [15], determining project critical paths [16], simultaneous pickup and delivery [17], and transportation problem solving [18]. Many researchers have combined ant colony algorithm and other algorithm in their researches. The ant colony algorithm and genetic algorithm combination was used in searching research field [19]. In the other research, Vieira et al. [20]combined ant colony algorithm and fuzzy model to classify data and to select feature. In the same year, combination of ant colony algorithm and support vector machine was used for power load forecasting [21], or in optimization for flexible job shop scheduling problem research that used combination of ant colony algorithm and knowledge based management [22]. In production system field, there are many researches that used ant colony algorithm too, such as: structured optimization in parallel production system [23] and preventive maintenance optimization in production process system [24].

III. FRAMEWORK OF iDSS Agri-SCM

A framework that conceptualizes an intelligent DSS is illustrated in Fig. 1. We provide the main core of i-DSS to solve four main problems in Agri-SCM (perishable, seasonal, voluminous and varied) by structuring an intelligent system modelling with initialization of requirement analysis.

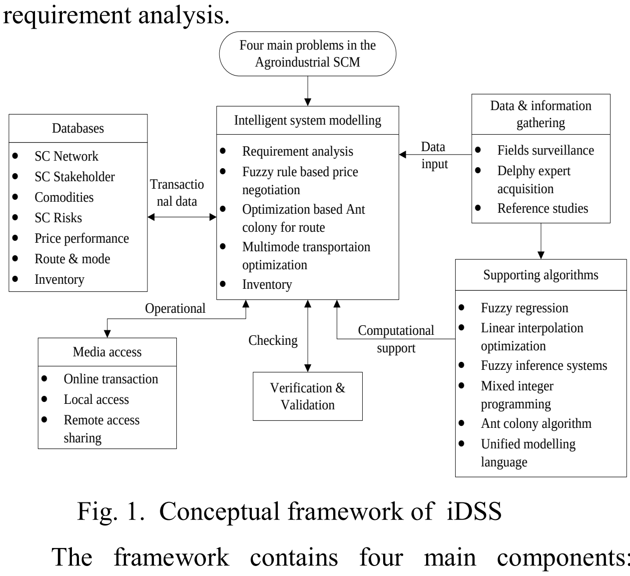

Fig. 1. Conceptual framework of iDSS

The framework contains four main components: databases, intelligent system model, supporting algorithms and media access. Databases component uses to store and manage data that include supply chain network structure and stakeholder, commodities price and risk, route and mode of transportation, capacity of inventory. Intelligent system model contains some sub-models that are price negotiation modeling using fuzzy regression, Route optimization model using ant colony analysis, and multimode optimization model for perishable product transportation. Supporting algorithms that used in this model were fuzzy regression, fuzzy inference system, linear interpolation, mixed integer programming, and Ant colony algorithms. Media accesses of this system are onlince transaction, remote access sharing and local access. In addition, to check the performance of the model, this framework containts was facilitating components, namely verification and validation component and data & information gathering system.

[1] Sub model of optimization iDSS SCM

The main structure of iDSS syatem can be showed in Fig. 2. This model have three methods to optimize measurement: fuzzy rule that was implemented in class fuzzyRuler, fuzzy regression that was designed in class fuzzyRegressor, and the third one is ant colony algorithm that was design in class antColony. The class fuzzyRuler and fuzzyRegression measured plant schedule and risk balancing of supply chain. Therefore, class antColony searched the best path of supply chain based on distance, moda, financial performance and SCOR performance, included plant schedule and risk balancing.

The main model of ant colony algorithm based supply chain path searching can be showed in Fig. 2. Both class ant and antColony associated with class antGraph. Class antGraph related to class supplyChainPerformance that consisted of class riskBalancing, financialPerformance, plant Schedule, and SCORPerformance. In this work, the assumptions based on [25] as follow:

1. The problem is represented by a graph G = (N, A) where N is the set of nodes and A is the set of arcs which connect the nodes;
2. Cooperation between ants is made by using an indirect form of communication mediated by pheromones they deposit on the arcs of the graph representing the problem. In this case, the problem is graph of supply chain network;
3. The functions cost measure δ (r, s) and desirability measure τ (r, s), where r, s ∈ N, are defined on the graph;
4. The rules defining the behavior of the ants and the whole colony are the same as those proposed in the mentioned paper:
    a. A State Transition Rule which brings the concrete ant from a node to another across an arc;
    b. A Local Updating Rule which updates the pheromones deposited by the ant on the arc it walked in;
    c. A Global Updating Rule which updates the pheromones deposited on the arcs when an ant ends its trip.

Supply chain performance consisted of four parts: risk balancing, plant schedule, financial performance and SCOR performance. Class fuzzyRegressor of this model was used to measure riskBalancing variable of class riskBalancing. PlantSchedule variable of class plantSchedule was measured by class fuzzyRuler as its' measuring model. The other classes: financialPerformance and SCORPerformance were used tobe included in ant colony modeling. On the hand, Class distance and moda was part of class antGraph. Moda variable of class Moda was defined by class multiModaChooser.

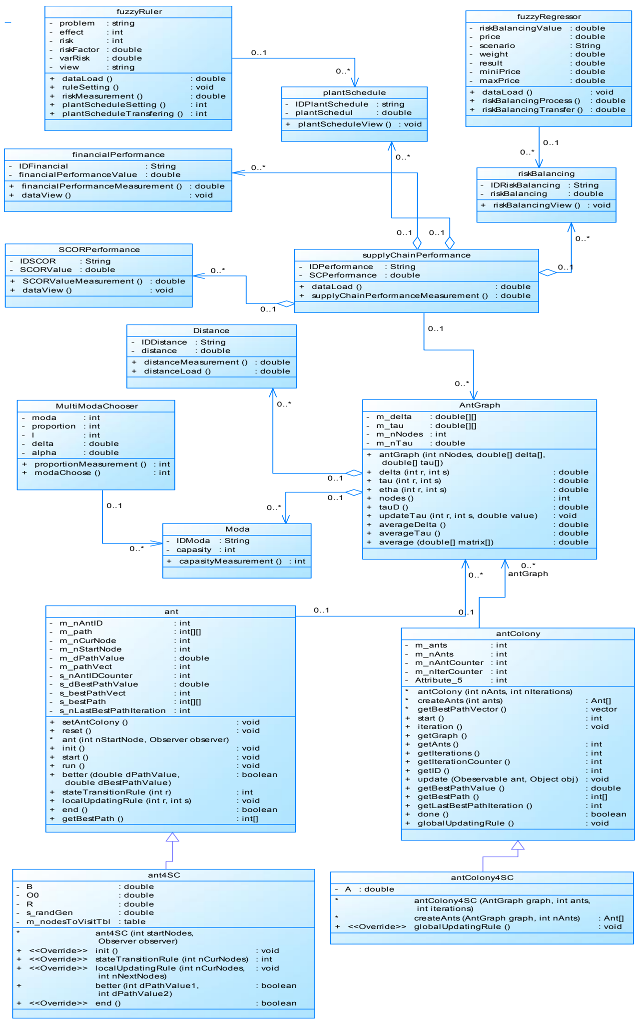

Fig. 2. Structure of iDSS main class

Price negotiation model

Conflict resolution to make decisions together or group has been widely described by several papers. But the resolution of conflict in decision-making of supply chain risk management has not been done yet. This paper describes a mechanism for pricing of Agricultural commodities using a stakeholder dialogue approach to achieve the resolution of conflicts of interest based on balancing the risk of Agri-SCM using fuzzy utility risk optimization. Fuzzy logic approach is used to measure and evaluate risk at every stages of supply chain with the input preferences or utility function of every supply chain actors in dealing with the risk of certain price changes [26]. Fuzzy non linear regression is used to estimate the value of risk utility of supply chain for each participant in dealing the price changes. With this mechanism all levels of the supply chain will be modelled by using an exponential fuzzy utility function with price as independent variable and the level of risk utility as dependent variable. Conflict resolution is done by making conjoint function between farmers' level of fuzzy utility functions with other levels of the utility function of the supply chain. Fuzzy utility function of each level of the supply chain will be approximated by using fuzzy linear regression [27]. The results of conjoint function will be searched to find a solution for settlement price of the deal. The solution of conjoint functions performed by linear interpolation with a range of values between the highest price and lowest price obtained from price quotes in the stakeholder dialogue of supply chain actors. The flowchart of price negotiation based on risk balancing in Agri-SCM can be shown on Fig. 3.

The method used in the risk balancing of Agri-SCM is stakeholder dialogue among the parties concerned in the supply chain risk management in order to obtain the consensus value in the balancing of risk because of conflicts of interests in the determination of prices at farmer level. Consensus is done by assessing the value of risk utility for each level of supply chain based on corn price exchange at the farmer level. This process will be modeled using fuzzy nonlinear regression for risk utility function of each level of supply chain with the price exchange at the farm level as independent variables.

Fuzzy regression function was used in this model, because the utility value of risk as the dependent variable and the value of price exchanges as the independent variable are fuzzy number. The utility value of each risk factor was assessed by risk posibility and risk impact in fuzzy number.

The risk balancing of supply chain is done by determining the risk utility function of each level of using fuzzy price exchange scenarios. it will be got a risk utility function for each level in the supply chain as follow:

$$U_k(x) = \alpha e^{\beta(x)} \quad (1)$$

Where $U_k(x)$ is the risk utility function at k level of a AP-SC network and x is the price of corn at the farmer level. This process is done by creating a conjoint function of each utility function of risk in order to obtain the following equation:

$$H(x) = U_p(x) - \sum_{k=1}^{n} Q_k U_k(x) \quad (2)$$

$$\sum_{i=1}^{n} Q_i = 1 \quad (3)$$

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. 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 α and β.

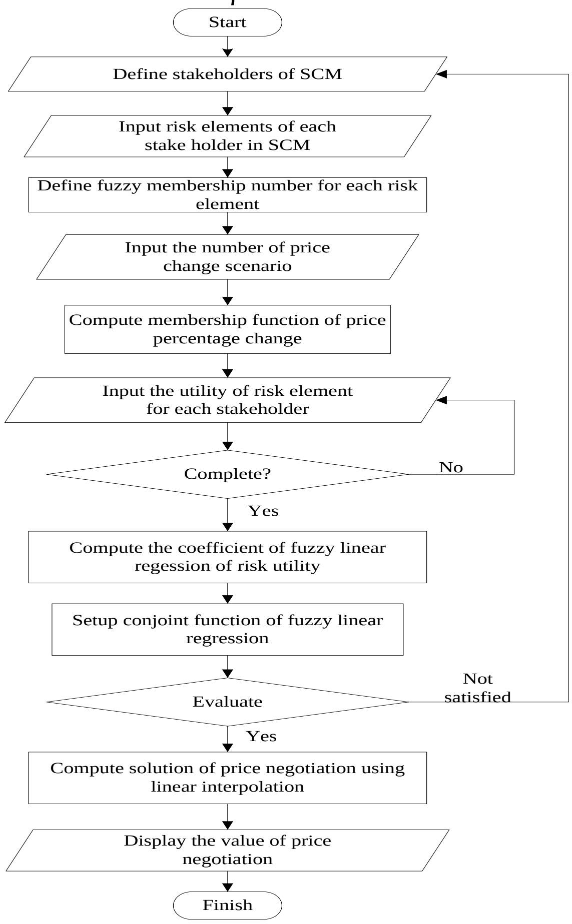

Fig. 3. Flowchart of price negotiation based risk balancing for Agri-SCM

IV. RESULT AND DISCUSSION

In the following passages, we give examples as verification of our model in negotiation. By using the utility values and all others formulation (1 to 3), we consider a real data acquisited of those risks and the input current price by IDR.3000/Kg of certain agricultural product. Fuzzy linear regression analysis can be obtained from the risk utility function of each level of supply chain.

The fuzzy risk utility function at farm level of Agri-SCM can be represented as follow:

$$U_F(x) = 18.23549 e^{-0.000383x} \quad (4)$$

By using the same procedure the fuzzy risk utility function at collector level of Agri-SCM can be represented as follow:

$$U_{Col}(x) = 0.940473e^{0.000545X} \quad (5)$$

The fuzzy risk utility function at processor level of Agri-SCM can be represented as follow:

$$U_P(x) = 1.192086e^{0.000489X} \quad (6)$$

The fuzzy risk utility function at distributor level of Agri-SCM can be represented as follow:

$$U_D(x) = 0.794616e^{0.000590X} \quad (7)$$

And the fuzzy risk utility function at consumer level of Agri-SCM can be represented as follow:

$$U_{Cus}(x) = 0.725807e^{0.000624X} \quad (8)$$

Price negotiation can be done bilaterally or multilaterally between each level of the supply chain of Agricultural products. As an example of a conjoint function of the risks utility function with equal weight to each level of the supply chain for multilateral negotiating prices can be represented by the following equation:

$$H(X) = 18.23549e^{-0.000383X} - (0.940473e^{0.000545X} + 1.192086e^{0.000489X} + 0.794616e^{0.000590X} + 0.725807e^{0.000624X})/4 \quad (9)$$

Therefore, by using linear interpolation with the initial input value x is the value of the highest bid price for IDR.3500/Kg and the lowest bid price of IDR.2700/Kg, it will get the negotiated price for IDR.3187/Kg (note: 1US $ = IDR.9200,-).

Conjoint function for price negotiates bilaterally between farmers and the processors can be represented as follows:

$$H(X) = 18.23549e^{-0.000383X} - 0.940473e^{0.000545X} \quad (10)$$

Therefore, by using linear interpolation with the highest bidding price of inputs for IDR.3500/Kg and the lowest offer price for IDR.2500/Kg will get the price agreement between the two sides of IDR.3128/Kg. This result shows that this price negotiation model can developed price appointment better than traditional price negotiation based on average bidding prices, that generates IDR.3000/Kg as price negotiation result.

The result of price negotiations with the consideration of the risk balancing of supply chain is greater than the initial price forecast, it means that this concept has shown a shift of risk from the farmer to the other parties in the supply chain in accordance with the balance of risk constraints.

V. CONCLUDING REMARKS

This paper has provided a framework of iDSS for SCM that use of fuzzy non linear regression as a tool to obtain constant values of the risk utility function of each stage of SCM in order to negotiate a price of corn at farmer stage of supply chain network based on the risks constraint of each stakeholder by using stakeholder dialogue approach to balance their risks. Pricing negotiation on this approach can determine a fair price negotiation using risks utility preference of each stakeholder in SCM.

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.

These supply chain risk balancing research can be continued to create a stakeholder dialogue negotiation model with multiple objectives such as improving the quality, profit sharing, fair pricing and value added distribution by using a multi attribute fuzzy regression as estimators of utility functions for each decision maker on SCM.

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