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ORIGINAL ARTICLE

Intelligent decision support system for risk assessment and dairy price of dairy agroindustry supply chain

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ABSTRACT – Dairy and dairy processing industries are included in the group of food products and high-risk industries. Decision making in relation to risk management in dairy industry supply chain is significant. This study aimed at designing a Intelligent decision support system (DSS) for risk assessment of dairy agroindustry supply chain and the estimation of dairy price in the risk-based farmer level. The risk assessment is analyzed by fuzzy logic approach which is Fuzzy Inference System (FIS) and Fuzzy Assosiative Memories (FAMs). The basic knowledge of this system is obtained through the preparation of rule base of risk assessment and the relation of production cost and risks at the farm based on the expert arguments variables. There are six outputs yielded from RSDA, that is risk assessment in accordance with priority issue, risk assessment for delivery activity, risk source exploration, risk performance, risk management partially and the estimation of production cost and price with risks. The system provides several alternatives which will help decision making in preparing risk management in dairy agroindustry supply chain. Moreover, this system also provides several scenarios of dairy price estimation at the level of farmer who includes risk factor in the farmer. By this system, it is expected that the opportunity of risk and risk impact of dairy agroindustry supply chain can be minimized.

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INTRODUCTION

Dairy has product characteristic which is easily damaged [1]. Dairy contains three main components which are lactose, protein, fat milk and other substances such as water, mineral and vitamin [2] Dairy is media whose nutrient composition which is ideal for microorganism growth and development. Microbe activity can cause dairy chemical and physical natures [3]. Dairy damage and composition change particularly caused by the formation of lactic acid by bacteria activity forming acid [4].

This is consistent with FAO guideline for ASEAN countries in 2011/2022 concerning the categorization of industries and risk-based food. Dairy and dairy processing industries are included in high-risk food and industry category [5]. This risk emerges from a set of supply chain activity starting from activity in the farm, cooperative and Dairy Processing Industries (DPI) [6]. Moreover, the risk also emerges from dairy delivery activity from the farmer to Cooperative Service Site (CSS), CSS to cooperative and dairy delivery from cooperative to DPI [7]. The risk occurs in a network will affect other networks so that it will cause disadvantage affecting the supply chain performance thoroughly [8].

[9] defined risk management as the attempt to reduce the risk and minimize disadvantages as a result of risk uncertainty. [10] In his study mentioned that the implementation of supply chain risk management could enhance the amount and the quality of knowledge and could reduce the risk occurrence and risk impact. According [11] there was a strong implementation of supply chain risk management to the improvement of sustainable process in the supply chain. Meanwhile [12] in his study mentioned that to explore risk management in supply chain requires a comprehensive analysis.

Risks and risk management occurring in dairy agroindustry supply chain currently have not been performed systematically and measurable. The knowledge owned by the farmers concerning risks and the influence in supply chain performance is still low. Data documentation and information available in supply chain network have not been analyzed and utilized optimally as the knowledge source. This is consistent with the issue illustrated by [13]. Based on this issue, a system which can help relevant parties in decision making to resolve the problem in dairy agroindustry supply chin risk is necessary.

The application of risk management supported by the utilization of information technology performed by [14], [15], and [16]. [14] developed a comprehensive risk management tool through Intelligent Risk Mapping and Assessment System (IRMAS). [15] designed intelligent risk based on three principles which are focus on business, accountability and operational support. [16] Developed an information management of supply chain risk in make-to-order (MTO).

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Risk management is associated with various issues of decision making. Computer technology which can be used to support complex problem solving and decision making is decision support system [17]. Decision support system (DSS) is defined as a computer-based information system which is interactive, flexible and easy-to-adapt, is particularly developed to help smart decision support system as an interactive computer-based system using data, expert knowledge and model to support decision making in organization in resolving the complex and unstructured problems Intelligent Decision Support System (IDSS) is the combination between classic DSS (access to data, information and model of decision analysis) with knowledge-based system developed through intelligent system [18]. IDSS is used as virtual planning tool, intended for engineering and non-engineering. [19] developed DSS to enhance sustainable productivity on fishery agroindustry supply chain.

Risk management issue involves different decisions to do by relevant parties, such as cooperatives, Livestock Service, Combination of Indonesian Dairy Cooperatives, dairy cow breeding office, farmer association and dairy processing industry association. A system to help in identifying the main issue occurring in agroindustry supply chain is necessary. Furthermore, the improvement is explored by identifying and assessing risk systematically and measurable so that the plan of risk management can be prepared in accordance with the problem priority. Moreover, the risk also affects the production cost. [20] Prepared price model in corn supply chain based on balancing the fuzzy risk utility. [21] Designed fair price distribution for all palm oil supply chain stakeholders with agent based model approach.

Many factors to consider in estimating production cost of milk and dairy price in at farmer level. According to [22], [21], the risk in relation to the price is a significant thing in risk management. The risk in relation to income, price and cost can be isolated, identified, measured and analyzed and managed theoretically. The magnitude of income is directly affected by selling price and production cost. Production cost consists of fixed cost and variable cost [23]. The cost is affected by the possible risk in the activity performed by the farmers [22]. Based on the analysis, a system to help decision making in determining dairy selling price considering risk value is necessary.

This study aims at designing a intelligent decision support system for risk assessment of dairy agroindustry supply chain and the estimation of dairy price at the level of risk-based farmer. The system is given name as Risk System for Dairy Agroindustry (RSDA). The system is established on three main components which are data-based management, model-based management and knowledge-based management. Database is established from the risks and risk factors on the supply chain network. The model employed to design this system consists of 3 main models which are risk identification, risk assessment model and dairy price estimation model at the level of farmer. Risk assessment is performed based on four consequences of the main issue in dairy agroindustry supply chain which are the decline of production amount, quality degradation, financial loss due to negligence and falsification and dairy delivery delay. By this system, it is expected that the opportunity of risks and risk factors in dairy agroindustry supply chain can be minimized.

RESEARCH METHOD

Framework model

Dairy agroindustry system is divided into three sub systems which are farming sub system producing fresh milk, dairy cooperative sub system receiving the farmer fresh milk to be used as raw material for milk, dairy processing industry (DPI) sub system processing the milk into processed product [7]. In this study, the system will be designed based on risks and risk factor in the three sub systems. The category of supply chain risk will refer to [24], whereas the risk of delivery refers to the category of transportation risk [25].

The system is established based on three main models which are risk identification model, risk assessment model and the model of dairy price estimation at the level of risk-based farmer. The models of risk assessment are divided into sub models which are risk measurement model, chain model of risk relations and risk performance model. Risk assessment is analyzed by using fuzzy logic approach which is Fuzzy Inference System (FIS) and Fuzzy Associative Memories (FAMs). Meanwhile, the models of dairy price estimation are divided in four sub models which are risk compliance factor estimation, the model of production cost estimation with risk compliance factor, Break Event Point (BEP) estimation model of price and BEP of Production and BEP model of sale and income. Thought framework of the system designed can be seen in Figure 1.

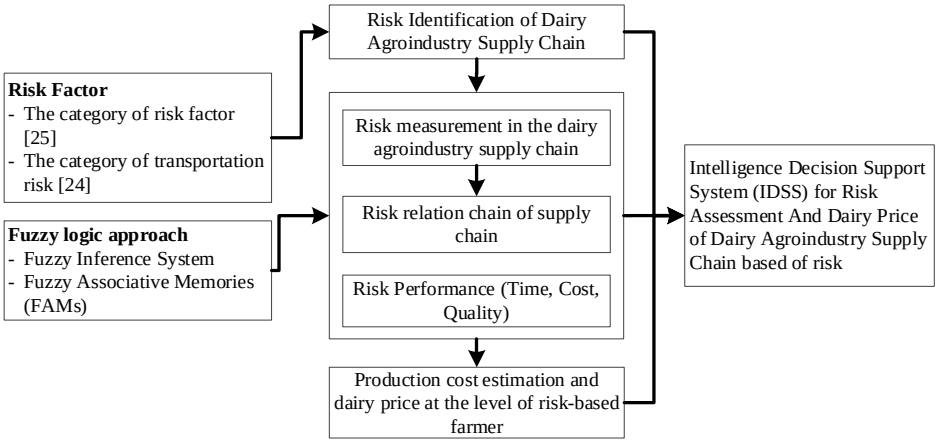

Figure 1. Framework model of RSDA.

Data Collection and Analysis

Data used consists of primary and secondary data. Primary data is obtained from the result of direct observation to the research location, questionnaire distribution and interview with experts. Survey activity to the field is undertaken in West Java area, with several main research locations which are KPBS Pangalengan, KSPBU Lembang, Kunak Bogor, KUD Bayongbong, Farmer Group of Sugih Mukti Lembang. The questionnaires are used to obtain initial data of risks and risk factors in the farmer, cooperative, dairy processing industry and delivery activity. Secondary data is derived from textbook and scientific journal, data documentation in cooperative and pasteurization dairy processing and dairy production data from Association of Dairy Cooperatives of West Java. Secondary data period employed starts from 2011 to 2015.

Modelling System

This research is written in several stages, which are (1) Planning, including stakeholder need identification, research problems, system designing objectives; (2) system analysis, including stakeholder analysis involved in the system, data flow illustration in the process using Data Flow Diagram (DFD) (2) Planning (4) System prototype testing consisting of conceptual model validation, model verification and operational validation and (5) implementation and system demonstration.

Designing is divided into 4 which are database system designing, model base system, knowledge base system and user interface. System configuration established can be seen in Figure 2.

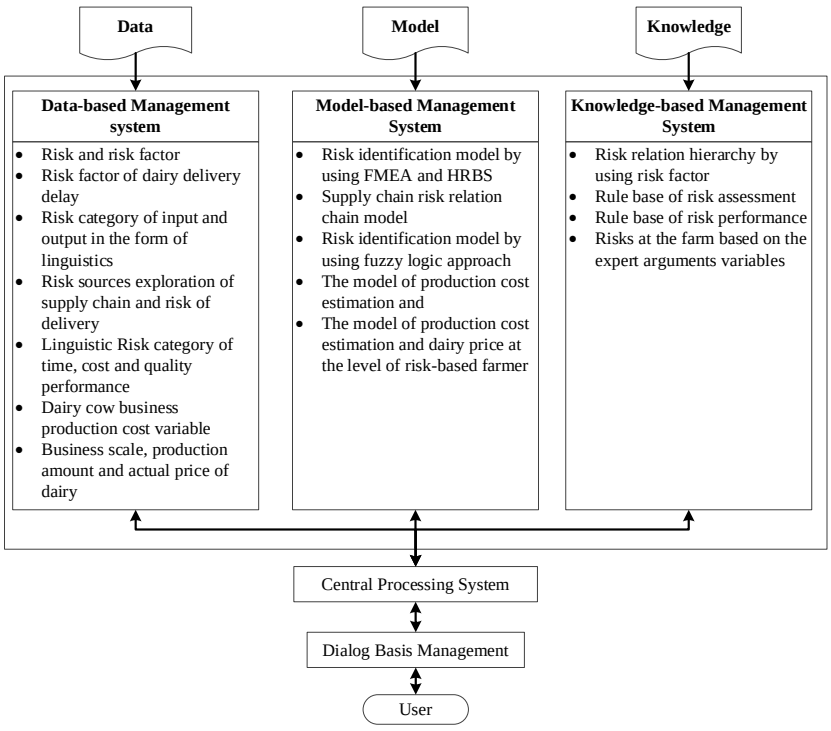

Figure 2. Risk System Dairy Agroindustry (RSDA) Configuration.

RESULTS AND DISCUSSION

Dairy Agroindustry System

Dairy agroindustry system includes three sub systems which are dairy cow farming business producing fresh milk, dairy cooperatives receiving fresh milk from farmer to be used as raw material for dairy and Dairy Processing Industry (DPI) processing milk into processed products [26]. Dairy delivery activities are divided into three stages of delivery, which are dairy delivery from farmer to Cooperative Service Site (CSS), CSS to cooperatives and dairy delivery from cooperatives to dairy processing industries. Cooperative Service Site (CSS) is a place for cooperative service to receive milk from the farmers. The structure of dairy supply chain network in West Java and influential factors in each network of supply chain can be seen in Figure 3.

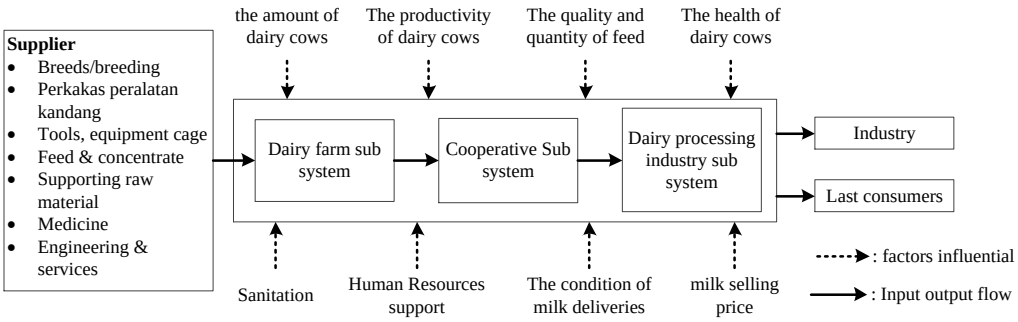

Figure 3. Dairy agroindustry supply chain and the influential factors

Risk System Dairy Agroindustry (RSDA) Main Program

The system is established in three main components which are database management, model base management and knowledge base management [27]. This system is named Risk Dairy Agroindustry (RSDA). Data base system consists of risks and risk factors in the farm, cooperatives, dairy processing industries and delivery activity. Meanwhile, data base for dairy price model consists of variable cost, fixed cost, business scale, production amount and actual price from cooperative.

Model base system consists of three main models which are risk identification model, risk assessment model, risk-based dairy price estimation model. Risk identification models are divided into two sub models which are risk identification model of supply chain by using Fuzzy Failure Mode and Effect Analysis (FMEA) and risk identification model of delivery by using Hierarchy Risk Breakdown Structure (HRBS) method. Risk assessment models consist of three sub models which are risk measurement model, supply chain risk relation chain model and risk performance model. Meanwhile, dairy price models are divided into 4 sub models which are risk compliance factor estimation model in the farm, production cost estimation sub model with risk complicance factor, BEP estimation sub model of price and BEP of production and income estimation sub model and BEP sub model of sale and farmer income.

Knowledge base is intelligence source in the system. Knowledge source derives from the experts, literatures, and journals. Interaction with experts is undertaken by interview. The technique employed is problem description, discussion and intuition. The representation of expert knowledge is by using rule base. The knowledge base for this system consists of (1) risk relation hierarchy, risk factors and risk consequences; (2) risk source, risk causes and risk impacts in the dairy agroindustry supply chain; (3) risk relations in the farm with dairy cow business production cost variable.

The outcomes of RSDA comprise:

1. Risk assessment in accordance with the priority issue
   Priority issues comprise the decline of dairy production amount, dairy quality degradation, financial loss due to falsification and fraud, delay of dairy delivery to DPI)
2. Delivery risk assessment, divided into dairy delivery to CSS to Cooperatives and dairy delivery from cooperative to DPI.
3. Risk exploration, including: risk sources, risk causes, risk impacts and partial risk management.
4. Risk performance in accordance with the final result of risk magnitude in the measure of time, cost and quality linguistically.
5. Production cost estimation and dairy price at the level of risk-based farmer

Dialog basis management system is a facility connecting central processing system with the users in performing identification and risk assessment taking place in the network of dairy agroindustry supply chain. The example of risk assessment in the issue of the decline of dairy production amount can be seen in Figure 4.

Interface for the price estimation consists of three main displays. The main interface provides a facility for risk rating factor (RRF) estimation for all risks in the farmer affecting the cost variable, dairy cow business production cost estimation with RRF and the simulation of price BEP and farmer income variables. Prior to the main system, RSDA provides three alternatives of dairy cow business scale, which can be selected by the system users. Interface for production cost estimation system input can be seen in Figure 5.

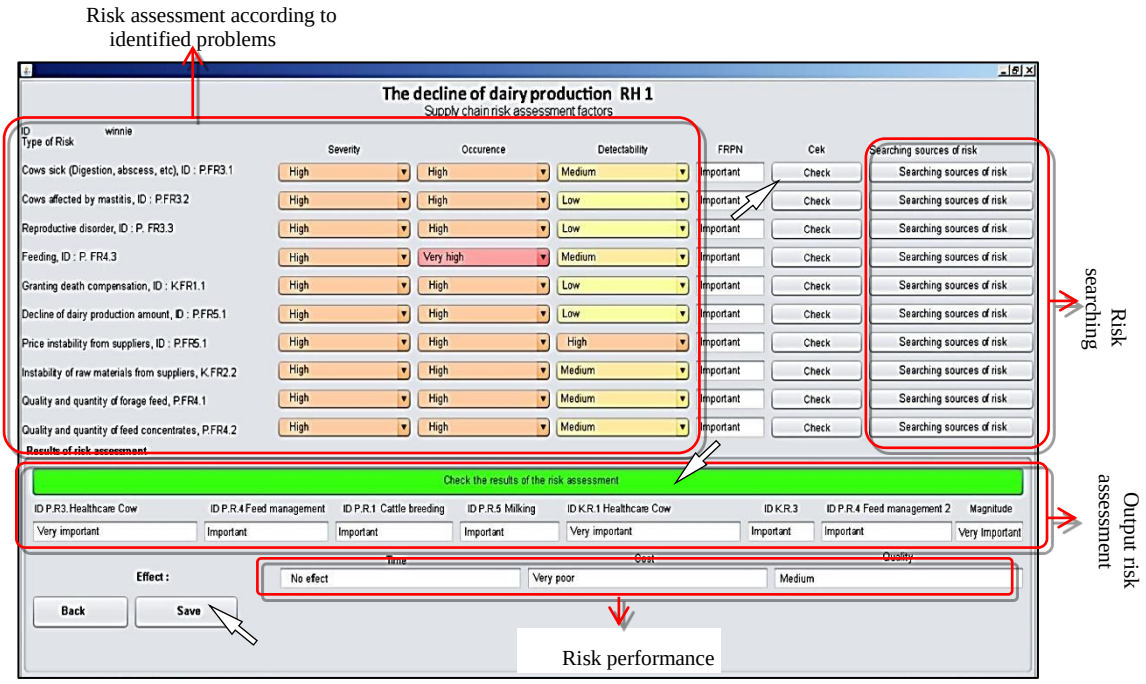

Figure 4. Interface of risk asessment on the issue of the decline of dairy production amount

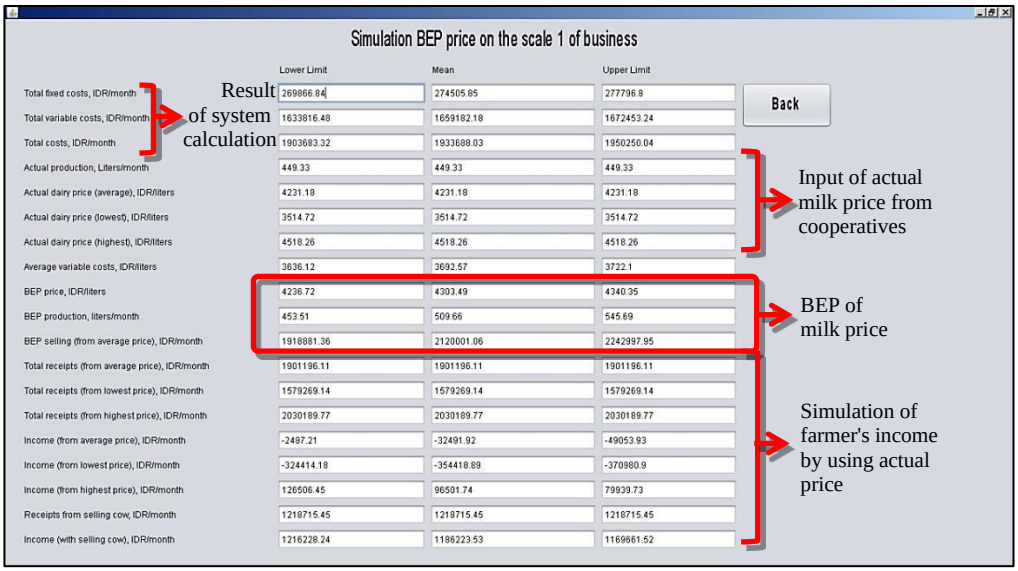

Figure 5. System interface for production cost estimation input

Supply Chain Risk Identification Model

Risks and risk factors are identified from the three sub systems which are farmers, cooperatives and dairy processing industries [26]. Moreover, the risks are also identified from dairy delivery activity. Each risk and risk factor is given code to ease the system designing. The code for activity in supply chain is prepared as followed:

R : Risk **FR** : Risk Factor
P : Farmer **K** : Cooperative
I : Dairy Processing Industry
P : Delivery, divided into three delivery activities :
PA : Dairy delivery from Farmer to CSS
PB : Dairy delivery from CSS to Cooperative
PC : Dairy delivery from Cooperative to DPI

The example of making risk catalog can be seen in Figure 6.

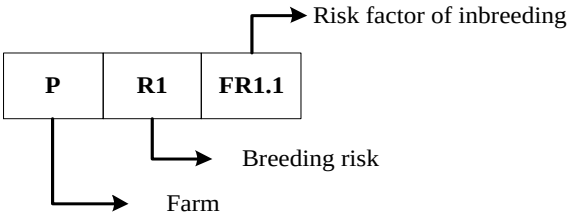

Figure 6. Example of making risk catalog in farmer

P.R1 : Breeding risk in the farm
P.FR1.1 : Risk factor of inbreeding in livestock breeding risk in the farm

Risk Assessment Model of Supply Chain

These models are divided into three sub models which are risk measurement, the model of risk relation chain and risk performance model.

a. Risk measurement model

Risk assessment is performed in three risk input dimensions which are severity (S), occurrence (O) and detectability (D) (Perez&Rodriguez,2012). Meanwhile, the output variable is Fuzzy Risk Priority Number or known as risk magnitude.
Generally, there are four basic elements namely Fuzzification, fuzzy rule base, fuzzy inference system (FIS) and defuzzification.

- Fuzzification

  Representation of graphic from the membership function of fuzzy input and output variables can be seen in Figure 7.

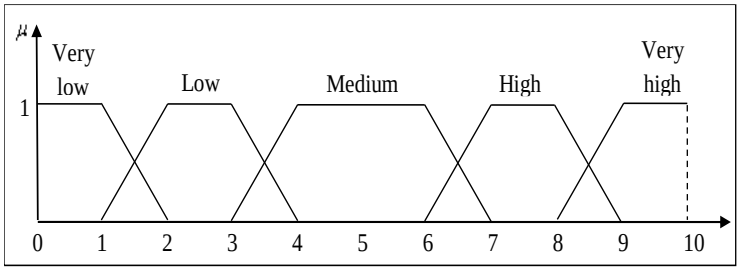

Figure 7. Representation of the graphic of membership function of fuzzy for linguistic variable of severity, occurrence, and detectability.

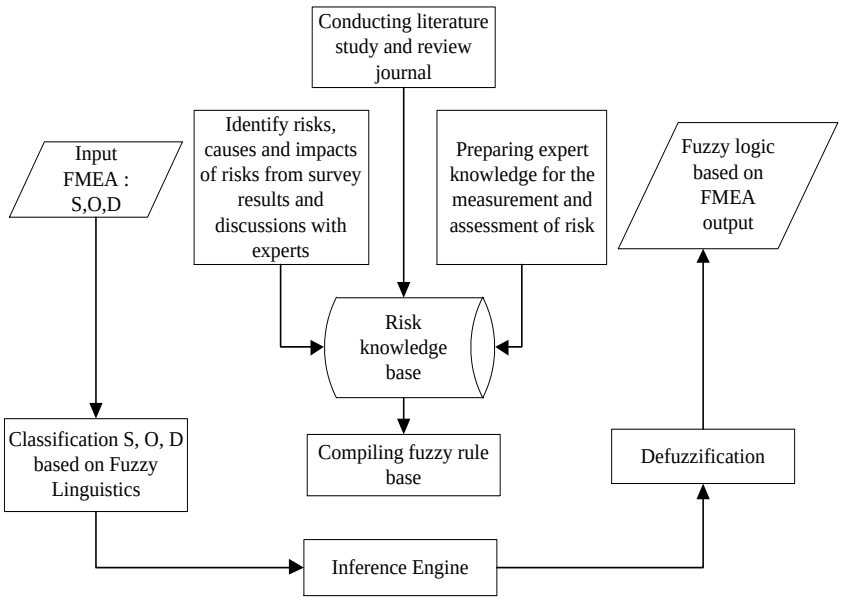

Figure 8. Architecture fuzzy linguistic model on risk assessment

Table 1. The domain of fuzzy assemblage for linguistic output variable

Variable Output Linguistics	*Domain Fuzzy Association*
Very not important (STP)	(0,0,175)
Not important (TP)	(75,250,425)
Medium (S)	(325,500,675)
Important (P)	(600,750,925)
Very important (SP)	(825,1000,0)

- Fuzzy rule base

  Rule is formulated in the form of linguistics and expressed in the form of IF-THEN. Proposition following IF is called as antecedent, whereas the proposition following THEN is called as consequence.

  R1 : IF x is Mi THEN y is Ni, i = 1,2,3,.....K (1)

  Where:
  X : input (occurrence, severity, detectability) variable
  M : linguistic constant variable
  Y : output (FRPN) variable
  N : linguistic constant consequence

- Fuzzy Inference System (FIS)

  The evaluation of risk level for each risk factor employs Fuzzy Inference System (FIS). The reasoning method fuzzy is used Mamdani fuzzy Method. In Mamdani method, both input (antecedent) and output (consequence) the system is in form of fuzzy assemblage.
  Fuzzy rule is expressed in a formula to represent fuzzy relation *R* : (*X* x *Y*) :

$$\mu R(X,Y) = |[\mu A(X), \mu B)y] \quad (2)$$

- Defuzzification

  Defuzzification is undertaken to obtain crips ranking from *fuzzy conclusion set*, which is used to express critical lecel of the risk so that the action of repair can be determined according to the priority [28]. Defuzzification method used is centroid method with formulation as follows:

$$z = \frac{\int_z^n z\mu(z)dz}{\int_z^n \mu(z)dz} \quad \text{or} \quad (3)$$

$$z = \frac{\sum_{j=1}^{n} z_j \mu(z_j)}{\sum_{j=1}^{n} \mu(z_j)} \quad (4)$$

  Where B' is *output fuzzy* set, and μ_B is *membership function*

b. Risk dependency chain of supply chain

The risks evaluated are then modeled regarding the relation using risk relation chain approach [29]. It is obtained four risk relation chain models of supply chain, showing four consequences of the risks and risk factors which are: The decline of dairy production amount (**RH1**) see Figure 9, dairy quality degradation (**RH2**), Financial loss due to negligence and falsification (**RH3**), Delay of dairy delivery to DPI (**RH4**).

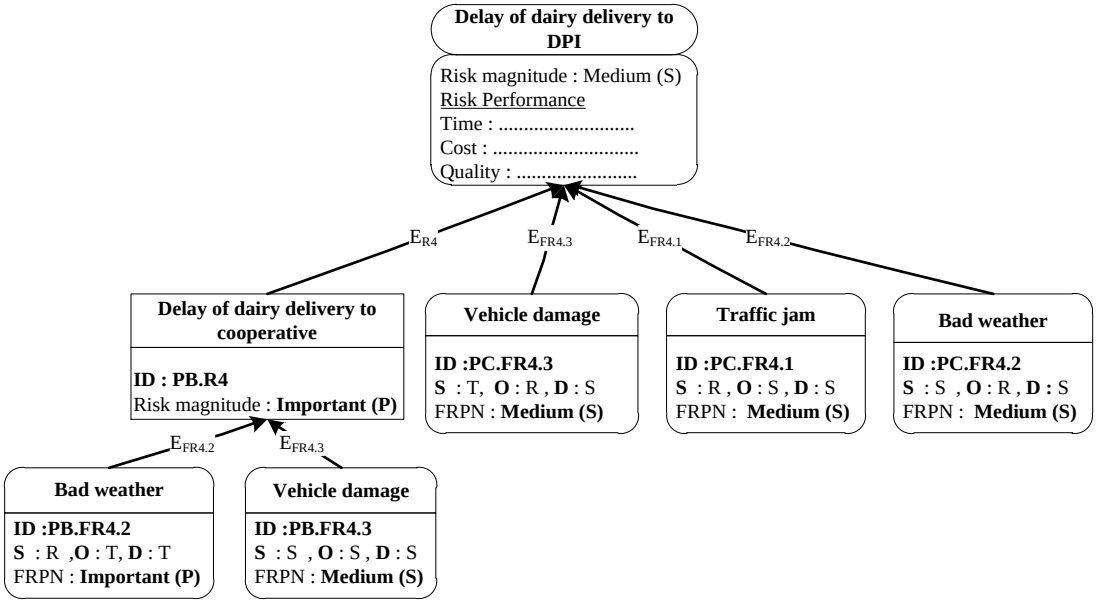

Figure 9. Risk relation chain – consequences on the delay of dairy delivery

Risk Performance Model of Dairy Agroindustry Supply Chain

Risk performance model of supply chain uses Fuzzy Associative Memories approach [30] measured in three forms of performance measure namely time, cost and quality. The relation of fuzzy magnitude assemblage membership of risk (A_i) and performance fuzzy assemblage (B_j) can be seen in Figure 10 and Table 2.

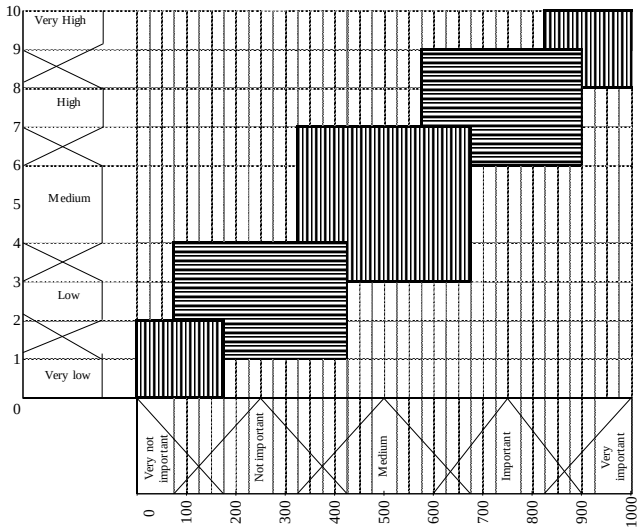

Figure 10. Mapping of fuzzy magnitude of risk (A_i) and performance fuzzy assemblage of risk (B_j)

Table 2. Risk Magnitude vs. risk performance of dairy agroindustry supply chain

Chain model of risk relations	*E*	Risk performance		
		T	C	Q
RH 1	SP	-	SR	S
RH 2	P	-	R	SR
RH 3	P	-	SR	R
RH 4	S	S	S	S

Caption :

SP	: Very important		SR	: Very poor
P	: Important		R	: Poor
S	: Medium		S	: Medium

Dairy Price Estimation Model at the Level of Risk-Based Farmer

The models are divided into 4 sub models namely estimation sub model of risk compliance factor in the farm, estimation sub model of production cost with risk compliance factor, BEP estimation sub model of price and BEP of production and income estimation sub model, BEP of sale and farmer income.

a. The estimation sub model of risk rating factor (RRF)
The risks affect the price, the higher the risk, the greater the influence on the price [22]. Therefore, in this model, dairy cow business production cost will be estimated by including risk compliance factor taking place in the farm. Risk values are divided into three, lower threshold risk value, middle threshold and upper threshold.

b. Estimation sub model of production cost with risk compliance factor (TCR)
Production cost is physical value of production factor usage measured by currency value [23]. Production cost consists of fixed cost and variable cost [31]. Fixed cost is relatively fixed cost and continuously incurred although the output obtained is substantial or a little. Variable cost is the cost which the magnitude is influenced by agriculture commodity production obtained. [22] will affect production cost. The higher the risk, the higher the cost. Therefore, the estimation of production cost by including risk factors is estimated by formulation as follows:

Fixed cost with risk:

$$FCR = FC \times (1 + RRF) \quad (5)$$

Variable cost with risk:

$$VCR = VC \times (1 + RRF) \quad (6)$$

Total production cost:

$$TCR = TVCR + TFCR \quad (7)$$

Where:
VCR : Variable Cost with Risk Factor
FCR : Fixed Cost with Risk Factor
RRF : Risk Rating Factor
TCR : Total Cost Risk Factor

c. BEP Estimation sub model of Price and BEP of Production
This sub model consists of BEP estimation of Price, average variable cost and BEP of Production. Each of them is estimated in the formulation of estimation as follows :

BEP of Price:

$$\text{BEP of Price (Rp/liter)} = TCR / Y \quad (8)$$

Average variable cost:

$$AVCR = TVCR / Y \quad (9)$$

BEP of production is estimated as follows:
BEP of Production (liter):

$$TFCR/ (P - AVCR) \quad (10)$$

Where:
AVCR : Average variable cost with risk, Rp/liter
Y : Dairy production amount, liter
P : Actual dairy price (average), Rp/liter
TR : Total income, Rp/liter

d. Income estimation sub model, BEP of sale and income:
The number of farmer income from dairy sale is estimated as follows:

$$TR (P) = Y \times P \quad (11)$$

BEP of Sale is estimated as follows :

$$\text{BEP of Sale} = TFCR /(1-TVCR/TR) \quad (12)$$

Farming business income is the difference obtained by the cost incurred. Therefore, the farmer income is based on the income of the dairy sale is estimated as follows:

$$\text{Income} = TR - TCR \quad (13)$$

Farmer income by adding the income of calf sale, male and female, is estimated as follows:

$$\text{Income} = (TR + \text{Income of cowsale}) - TCR \quad (14)$$

It is obtained nine price simulation as the combination of three business scales and three threshold of risk value. Meanwhile, for farmer income simulation, it is obtained 18 income simulation as the combination of three business scales, three threshold of risk value and 3 threshold of actual price received by the farmer from the cooperative.

Verification and Validation

Conceptual model validation is performed by using face validity method namely by asking directly to the experts who have knowledge and experiences in dairy agroindustry supply chain [32]. Model verification is undertaken by using black box testing method [33]. Operational validation is performed by operating the model and the result is compared to the real data. The test result of the system by comparing the system output to the result of expert assessment is obtained validity value of 99,33%. This shows that the result of system assessment is equal to the result of expert assessment.

Managerial Implication

RSDA is designed by system groove which is easy to understand by the users. The system is divided into two main sub systems namely risk assessment of dairy agroindustry supply chain and the estimation of dairy price at the level of risk-based farmer. RSDA can be used by cooperative management, cooperative combination, province farming office, farmer association and dairy processing industry association in performing evaluation in dairy agroindustry supply chain. The user of this system should have ability to (1) undertake initial identification in the main problem, (2) give evaluation in the linguistic form in three risk dimensions, (3) understand to use several dairy cow business production cost variable.

This system can help decision making in determining the risk management plan. Moreover, dairy processing industry can also use risk knowledge base available in this system, to help farmer and cooperative in increasing the amount of dairy production and dairy quality. In the estimation of dairy price, the system provides three dairy cow business scale alternatives, prepared based on the number of dairy cow ownership. Risk value is divided in three value thresholds which are lower threshold, middle threshold and upper threshold. The use of value threshold aims at making RSDA provide the facility of dairy cow business production cost without including risk value, the estimation of risk compliance and the estimation of dairy price with risk compliance factor and the simulation of farmer income based on the income from dairy sale reduced by total production cost.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study has produced the design of intelligent decision support system which can be used to assess risk taking place in dairy agroindustry supply chain. This system is named as Risk System Dairy Agroindustry (RSDA). RSDA consists of two main outputs namely risk assessment in dairy agroindustry supply chain and the estimation of dairy price at the level of risk-based farmer. This system provides several alternatives which can be used as evaluation material for relevant parties in determining the attempt of improvement of dairy agroindustry supply chain. Among them is cooperative management, cooperative combination, province farming office, farming association and dairy processing industry.

The result of system model testing shows that the system is consistent with the result of risk assessment performed by the experts. The percentage of system testing result is obtained result of 99,33%. This shows that the system has a good compliance with error value under 0,5%.

Recommendation

System further development with integrated risk management plan is necessary. This system can be developed in the form of web so that it can be easily accessed by academician, practician and bureaucracy having interest with the dairy supply chain risk management.

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