Soft System Methodology Framework for Fair and Balanced of Risk and Value-Added Distribution in Sugarcane Agroindustry Supply Chains

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Abstract*— Fair risk and value-added distribution within sugarcane agroindustry supply chain stakeholder is a complex and unstructured problem which had to be solved comprehensively. This research proposed a fair and balanced risk and value-added distribution model using Soft System Methodology (SSM) framework combined with negotiation system and Fuzzy Cognitive Maps (FCM) technique. SSM is a powerful approach to identify and solve a complex and unstructured problems then recommend effective solutions. Negotiation system was modelled to operate a fair and balanced risk and value-added distribution to achieve sugarcane supply chains goals. FCM was applied to validate the conceptual model and deliver system improvements. This research succeeded to describe and structure the sugarcane supply chains problems and deliver to conceptual and quantitative solution. Fair and balanced of risk and value-added distribution model with collaboration and negotiation mechanism had been formulated at fourth stage of SSM. This research also proposed a negotiation system with quantitative intelligent model to operate the supply chains collaboration. Framework for system validation and recommendation had been formulated through FCM at fifth and sixth stages of SSM. For further research, this framework required to be validated with more experienced expert then applied at real cases.

***Keywords*—** *Collaborative supply chain; Fuzzy cognitive maps; Soft system methodology; Sugarcane agroindustry; Negotiation*

1. Introduction

The main objective of supply chain is to fulfill consumer needs, gain benefit and develop a sustainable business. Sugarcane agroindustry supply chain is organized by multi-level stakeholders which have key activities and needs to collaborate for to achieve business goals [1]. Sugarcane agroindustry supply chain involve materials and cash flow, collaborative and coordinative relationship among stakeholders to produce high value product and fulfill consumer needs [2]. At this point, there are some obstacles which have to solved for producing a high quality products that can fulfill consumer needs and penetrate the market.

Sugarcane agroindustry faces inefficient production process and some complex problems which found at upstream and downstream of supply chain [3], [4]. At the upstream part, sugarcane supply chain should confront the climate changes, the uncertainty of cane production and quality also the low profit with high risk for farmers. At the processing part, sugarcane agroindustry meets inefficient production, low quality of raw material supplies and increasing in variable costs. At the downstream part, stakeholder have to maintain their marketing strategies decision since there is another cheaper and efficient processing product type which flooding the market at the milling/production period.

In a depth view, sugarcane agroindustry supply chain also meet an unfair risk and value added distribution which is also found at the other agricultural supply chain [5]–[7]. It means that the upstream stakeholder faces high uncertainty and risk with the lowest profit gain while downstream stakeholder gains higher profit/value-added with low uncertainty and risk. Eventually, this condition will interrupt the sustainability and good collaboration of business process, so that it should

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be comprehensively solved [8]. For these reasons, this paper proposes fair and balanced risk and value-added distributions among stakeholder with complex collaboration and coordination to achieve supply chains goal which operated in a negotiation system.

Moreover, the complexity of sugarcane agroindustry problems above have to be structured and solved with the best way then provide a compatible recommendation for the stakeholders. All this time, solving a complex problem in sugarcane supply chain focus on decentralized ways and lack of integrative and collaborative solution [9]. Batubara et al. [10], Hanafizadeh and Alieyaei [11] found that a complex problem which involve multi-stakeholder, human activity, social and cultural aspects had to be structured and solved through Soft System Methodology (SSM) framework. SSM framework is introduced by Checkland [12] as a system thinking framework for unstructured, ill-defined and complex problem. In addition, SSM framework enable to structure the agenda with systemic thinking framework to find an appropriate solution [13]. In this case, SSM framework correspond with sugarcane agroindustry supply chain which face 'soft' problem related to activities and goals of each supply chain stakeholders.

This research aims to formulate a framework for fair and balanced risk and value-added distribution for collaborative sugarcane supply chains which is structured in an SSM framework. This paper designs the operational model for distributing risk and value-added among stakeholder, maintain the supply chain collaboration and coordination model and validate the models to find appropriate solutions. We combine SSM framework with negotiation system and fuzzy cognitive maps as a framework to solve complex problem in sugarcane agroindustry supply chain.

2. Literature Review

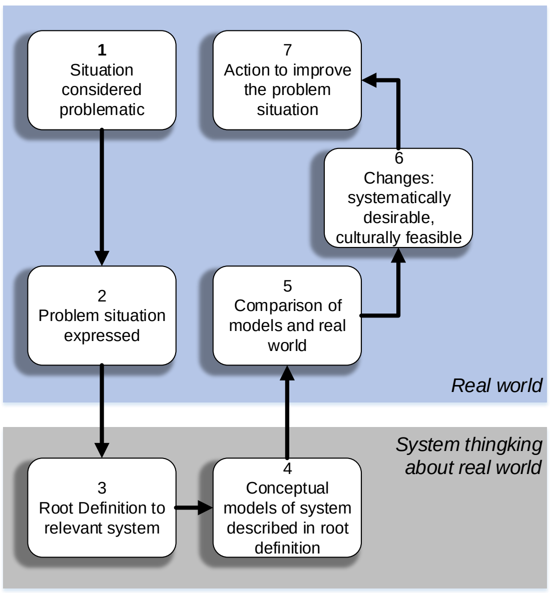
2.1. Soft system methodology

Soft System Methodology (SSM) is a system-based methodology to explain the problem and recommend ideal and appropriate solutions. The working principle of SSM is doing continuous and cyclic improvement as long as it is needed to develop effective system [14]. SSM had applied at many disciplines of practical and theoretical, because of its ability in solving a complex, unstructured and divergent problem well. SSM recommend the solution based on the real world situations and it is practical to applied at the real world [11].

The main idea of the SSM framework is assuming an organization as a system which has a series of activities and these do many changes over the time and affect the system relation to the environment [15]. These activities and relation will develop a transformation but it is intended to improve the performance and remove the undesirable transformation. Therefore, the analysis and improvement through SSM should perform continuously based on an assumption that the transformation will affect the system over the time.

To solving the complex, unstructured and ill-defined problem, Checkland and Scholes [16] proposed 7 steps to find compatible solution through SSM which is depicted at Figure 1.

SSM is powerful for solving complex problems that have occurred in the sugarcane agroindustry supply chain. In that case, SSM enable to structure the problem with not only accepting the current situation but also entering the problem, performing the analysis and recommendations and these are important for system improvement [17]. In addition, SSM enable to explain the problems through two perspectives, namely system thinking and real-world point of view, so that it has been widely applied by practitioners and academics. In practical issue, SSM framework enable to illustrate problem on real world and conceptual system, recognize unstructured issues to provide recommended actions for real-world improvement.



Adopted from Checkland & Scholes [16] and Wilson [18]

Figure 1. SSM framework

2.2. Supply chain management in sugarcane agroindustry

Sugarcane agroindustry supply chain has distinct characteristics with other supply chain management. Some characteristics of this supply chain are perishable and seasonal raw materials supply, complex transportation system which needs appropriate time and place, complex production process and the product should be standardized with the food standard. Chiadamrong and Kawtummachai [19] defined 3 aspects on sugarcane agroindustry supply chains with affect the complexity, (1) they relate to the climates and uncertainty of biological and physical variable which correspond the quality and capacity of the production, (2) involving multi-stakeholder decision makers which have different goals and risks, and it has variative scale and sector (farming, processing, transportation, distribution, marketing) that face different risk and costs, (3) it also meets some obstacles at the supply chain input and output as problem in fertilizer, transportation and marketing.

Supply chain configuration and mechanism for sugarcane agroindustry involving primary and secondary stakeholders. Primary stakeholder to ensure the material, information and cash flow while secondary stakeholder coordinates and helps the primary stakeholder to do business process. According to Asrol [8] and Neves et al. [20] the primary stakeholder of sugarcane agroindustry supply chain stakeholders are sugarcane farmer, sugarcane milling and distributor.

2.3. Fair and balanced risk and value-added distribution in supply chain

Supply chains always have problem in distributing profit among stakeholders, that upstream suffer with the risk and downstream gain more profit [5], [21]. Fair and balanced risk and value-added distribution concept is an effective solution to solve this problem. It means that, this concept tries to distribute the profit among stakeholder based on their performance and achieve win-win solutions [22], [23].

Balanced risk and value-added distribution is an appropriate approach to increase the supply chains effectivity and efficiency with collaborative solutions [24]. Besides that, this concept also plays important role to developing good relation through coordination among stakeholder. The goals are to achieve a fair profit distribution, information and knowledge sharing and optimize the supply chain cost [25].

Modelling a fair and balanced risk and value-added distribution needs a supporting information in supply chain value-added and risk mitigation. Supply chain value-added identification is necessary to give quantitative information and define value-added enhancement strategies [26], [27]. Risk mitigation is a way to minimize the most high priority risk that interrupt the supply chain [28], [29]. Quantitative risk and value-added identification will be an input for the fair and balanced risk and value-added distribution model to reach an efficient and sustain supply chain. Furthermore, this model needs a mechanism to well operate the model through negotiation scheme and system.

3. Research Method

3.1. Research framework

This research applied Soft System Methodology combined with negotiation system for fair and balanced risk and value added and Fuzzy Cognitive Maps (FCM) to validate the models. The combination of SSM and other methodology is noteworthy to considered since problem descriptions from multiple points of view needs to solve in detail by appropriate methods in effective ways by many perspectives and methods [30]. Munro and Mingers [31] stated that SSM is a predominant framework to combine with other method in solving complex problem and enable to formulate appropriate solutions for the real world. The combination of SSM and other methods to solve complex problem had been formulated by Presley et al. [32] whose combines SSM and Quality Function Deployment, Rodriguez-Ulloa and Paucar-Caceres [14] combine SSM with system dynamic, Hanafizadeh & Aliehyaei [11] combine SSM with FCM, Batubara et al. [10] and Sriwana et al. [33] combine SSM with Interpretative Structural Modelling (ISM).

SSM framework is applied to accommodate perspectives and point of view for complex problem in sugarcane agroindustry supply chain and provide comprehensive recommendations for the real world. SSM framework has 2 points of view, real world view and system thinking view in all 7 steps for searching appropriate solutions. Fair and balanced of risk distribution model is developed in fourth step of SSM through negotiation system enrich with coordination concept. In detail, we also provide a coordination model to operate the negotiation system, maintain good collaboration and coordination to increase supply chain performance. Validation framework through FCM is applied the fifth and sixth step of SSM. At the last step, we formulate recommendations to improve the system to maintain an efficient sugarcane agroindustry supply chain. The research framework is showed in Figure 2 and the detailing stages of the research through SSM framework is described in Table 1.

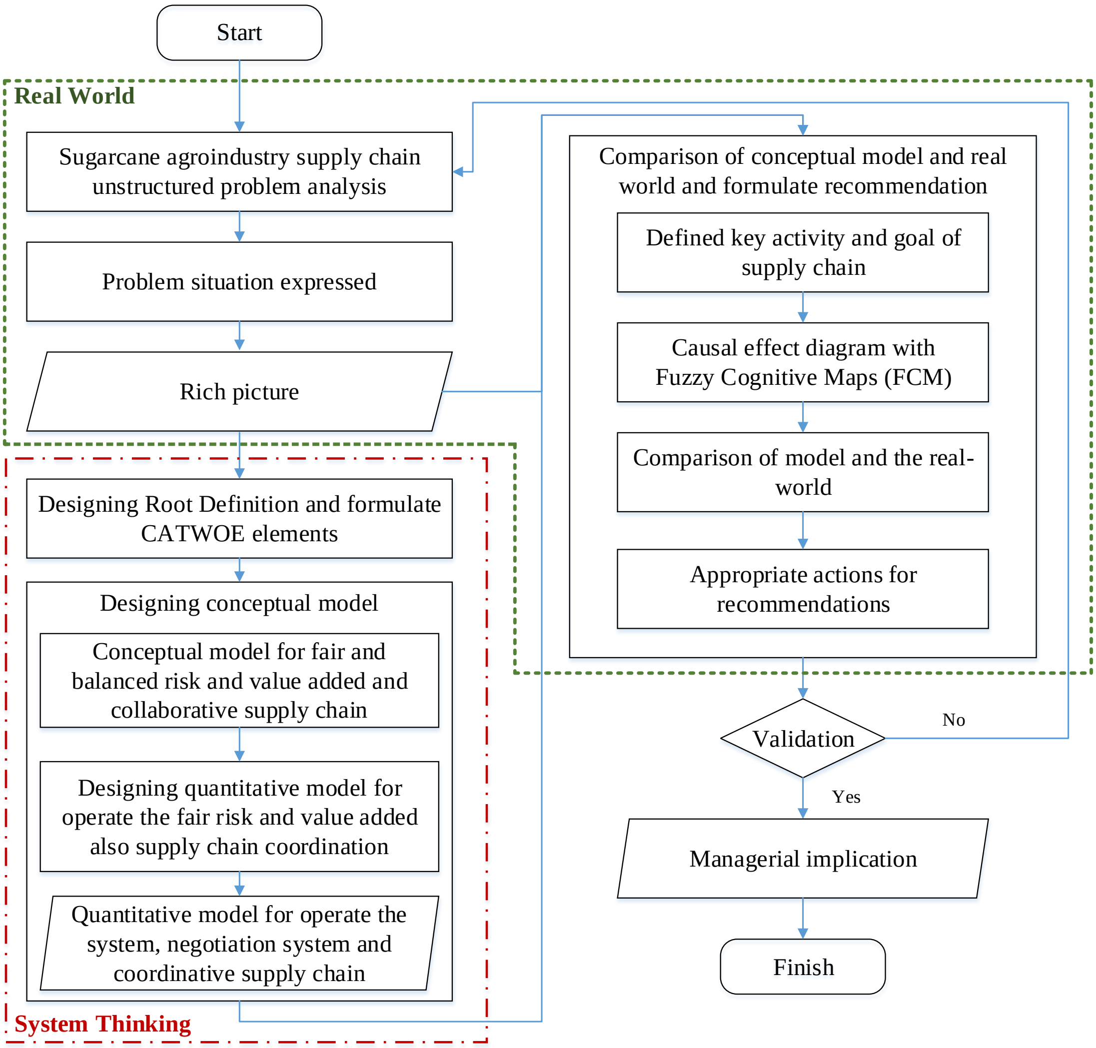


Figure 2. Research framework

Table 1. Research stages

SSM Stage	Description	Solution by this research
1. Problem situation unstructured 2. Problem situation expressed	Identify and define the problems at the research object's and describe in a structured way	Field observation and expert interviews enrich with the literature review then describe in a rich picture.
3. Root definition of relevant system	Define elements and problems which describe at the previous step and formulate transformation step to do and acceptable	Describe the sugarcane agroindustry supply chains stakeholder, configurations and main complex problem and determine transformation and worldview statements according to Root Definition which is decomposed to CATWOE elements.
4. Conceptual model	Developing conceptual relevant models to solving the problems according to root definition	Formulate conceptual model and decompose to be quantitative solution through fair and balanced risk and value-added distribution models, negotiation system, collaboration and coordination scheme to achieve supply chain goals.

SSM Stage	Description	Solution by this research
5. Comparison of conceptual model and real world	Compare the models in system thinking to the real world according to elements which has transformed	Define key activities and supply chain main goals based on rich picture and conceptual model then compare to the real-world view.
6. Recommendation and managerial implication	Formulate recommendation based on conceptual model and comparison model at the previous steps.	Formulate cause-effect diagram of key activities to the supply chain goals through FCM and define appropriate recommendation according to comparison between system thinking and the real world

3.2. Research stages

3.2.1. Problem situation unstructured

This is an early and important stage to take for gaining information and assumptions regarding problems at the sugarcane agroindustry supply chains. Information, perception and assumptions are collected from multiple point of views. These technique agree with Wang et al. [17] that to achieve a robust and appropriate solution should consider many perspectives about the system.

3.2.2. Problem situation expressed

Information and assumptions that have collected at the previous stage are described in this stage. Problem situation expressed is a transition stage to describe the complexity of the problem to be easily understood based on real world view. The problem description is described in a rich picture which has unique symbols to tell the problems consistently.

3.2.3. Root definition (RD) of relevant system

Root definition about the problem is necessary to formulate clearly to create strategy for solving the problems in the sugarcane agroindustry supply chains. Root definition is formulated through rich picture as a basic idea and describe in a strong statement based on system thinking view [11]. Root definition has an important role to mark off real world and system thinking which is indicated through transformation activities. According to Wilson [18] below are conditions to define root definitions.

a. Every root definition has ‘transformation’ statement.
b. Root definition should be one sentence to express transformation.
c. Root definition is evaluated by a consistent CATWOE (Customer, Actor, Transformation, World-view, Owner, Environment). CATWOE elements is define in Table 2.
d. Transformation (T) and Weltanschauung/world view (W) must be well identified and root definition just have one transformation statement.
e. Additional statements may be added to enrich root definition, even if not shown in CATWOE.

3.2.4. Conceptual model

Conceptual model is a core finding in SSM which develop according to root definition statement in a detail description [34]. Conceptual model contributes to applied transformation statement for the real world which has defined in previous stage. In this research, we define conceptual model to operational definition through negotiation system, collaborative and coordinative supply chain models to achieve supply chain goals.

3.2.5. Comparison of conceptual model and real world also provide appropriate recommendations

To complete this stage, we applied Fuzzy Cognitive Maps (FCM) which was developed by Kosko [35]. Firstly, we decompose rich picture and conceptual model to define systems key activities and goal also provide a causal-effect diagram. The system recommendation is formulated through define the benefit and impact of key activities for gaining supply chain goals.

The assessment of benefit and impact of the key activities to the supply chain goals is describe in indirect causal effect (I_r) and total causal effect *(T)* based on formulations by Hanafizadeh and Aliehyaei [11] and Kosko [35] as stated at Equation 1 and 2.

$$I_r(A_k, A_o) = \{min\,(A_p, A_{p+1}) : (p, p+1) \in (i, k_n, \ldots, k_{n+1}, j)\} \quad (1)$$

$$T(A_k, A_o) = max\, I_r(A_k, A_o) \quad (2)$$

Table 2. CATWOE elements and definitions

Element	Definition
Customer (C)	The recipient of the transformations output, the victims or gain benefits or both
Actors (A)	Whose do the activity in conceptual model if implemented in the real world
Transformation (T)	Basic and key activity and its relation which is necessary to convert input to output
Weltanschauung (W)	A world view statement to understand the transformation process comprehensively also describe root definition statement clearly
Owner (O)	A system's decision maker who have full authority and concern to the systems performance
Environment (E)	External features of the system which may be obstacles for the system

Adopted from Wilson [18] and Checkland and Scholes [16]

Indirect causal effect relation I_r *(*A_k*,* A_o*)* is known through minimum value of all causal-effect relation between key activities *(*A_k*)* and goal activity *(*A_o*)* for all activities *(i,* k_n*,...,* k_{n+1}*, j).* The relation and causal effect of key activity and goal activity is determined by experienced expert judgment in a fuzzy scale [36] which is described at the Figure 3.

There are 9 levels of fuzzy scale to determine relation of key activity to gain supply chain goals, they are Negative Very Strong, Negative Strong, Negative Moderate, Negative Weak, None, Positive Weak, Positive Moderate, Positive Strong and Positive Very Strong. Mathematically, the level of causal effect relation between key activity and goal are stated at Equation 3, 4, 5, 6, 7, 8, 9, 10 and 11.

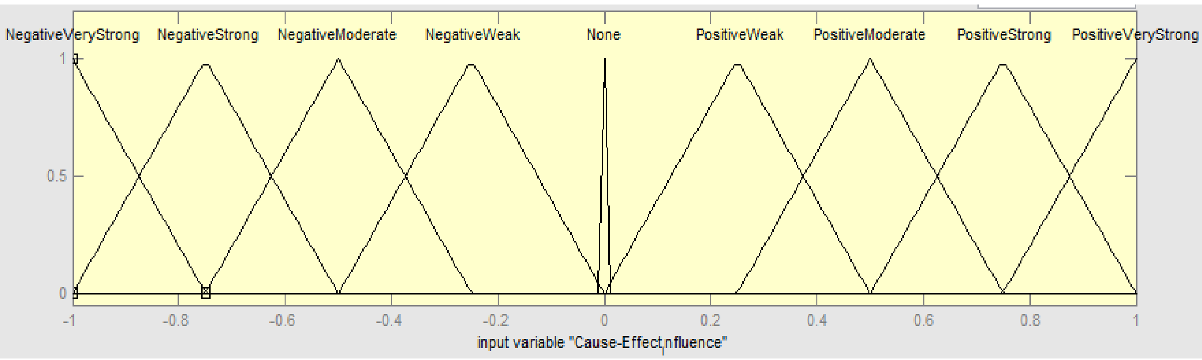


Figure 3. Fuzzy scale to determine relation of key activity and supply chain goal activity

$$\mu_{NegativeVeryStrong}[X] = \begin{cases} (-0.75 - x)/(-0.75 - (-1)); & -1 \le a \le -0.75 \\ 0 & x \ge -0.75 \end{cases} \tag{3}$$

$$\mu_{NegativeStrong}[X] = \begin{cases} 0; & x \le -1 \; or \; x \ge -0.5 \\ (x - (-1))/(-0.75 - (-1)); & -1 \le x \le -0.75 \\ (-0.75 - x)/(-1 - (-0.75)) & -0.75 \le x \le -0.5 \end{cases} \tag{4}$$

$$\mu_{NegativeModerate}[X] = \begin{cases} 0; & x \le -0.75 \; or \; x \ge -0.25 \\ (x - (-0.75))/(-0.5 - (-0.75)); & -0.75 \le x \le -0.5 \\ (-0.5 - x)/(-0.25 - (-0.5)) & -0.5 \le x \le -0.25 \end{cases} \tag{5}$$

$$\mu_{NegativeWeak}[X] = \begin{cases} 0; & x \le -0.5 \; or \; x \ge 0 \\ (x - (-0.5))/(-0.25 - (-0.5)); & -0.5 \le x \le -0.25 \\ (-0.25 - x)/(0 - (-0.25)) & -0.25 \le x \le 0 \end{cases} \tag{6}$$

$$\mu_{None}[X] = 1 \qquad = 0 \tag{7}$$

$$\mu_{PositiveWeak}[X] = \begin{cases} 0; & x \le 0 \; or \; x \ge 0.5 \\ (x - 0)/(0.25 - 0); & 0 \le x \le 0.25 \\ (0.25 - x)/(0.5 - 0) & 0.25 \le x \le 0.5 \end{cases} \tag{8}$$

$$\mu_{PositiveModerate}[X] = \begin{cases} 0; & x \le 0.25 \; or \; x \ge 0.75 \\ (x - 0.25)/(0.5 - 0.25); & 0.25 \le x \le 0.5 \\ (0.5 - x)/(0.75 - 0.5) & 0.5 \le x \le 0.75 \end{cases} \tag{9}$$

$$\mu_{PositiveStrong}[X] = \begin{cases} 0; & x \le 0.5 \; or \; x \ge 1 \\ (x - 0.5)/(0.75 - 0.5); & 0.5 \le x \le 0.75 \\ (0.75 - x)/(1 - 0.75) & 0.75 \le x \le 1 \end{cases} \tag{10}$$

$$\mu_{PositiveVeryStrong}[X] = \begin{cases} 0; & x \le 0.75 \\ (x - 0.75)/(1 - 0.75); & 0.75 \le x \le 1 \\ 1 & x \ge 1 \end{cases} \tag{11}$$

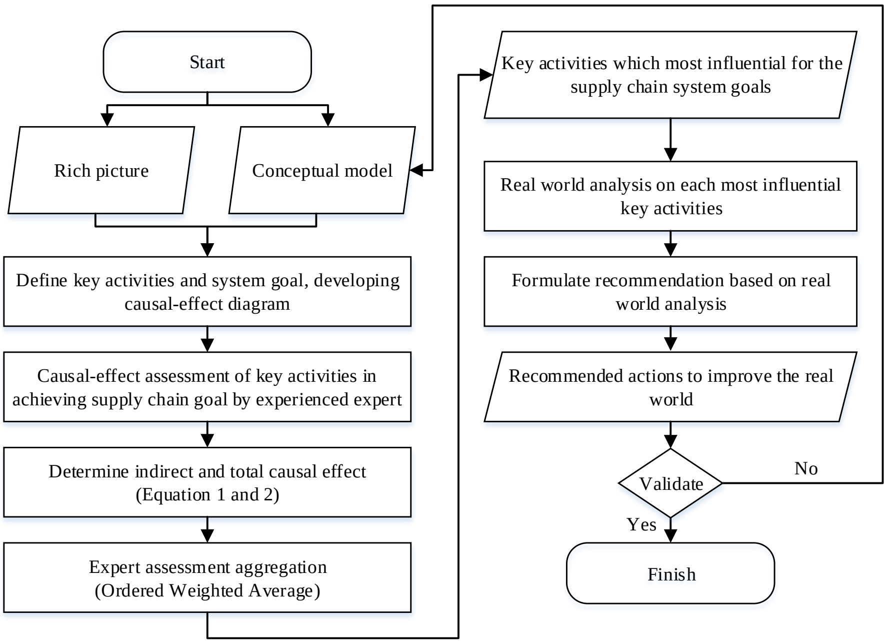


Figure 4. Stages for model validation and generating recommendation for system improvement

Expert judgments are aggregated through Ordered Weighted Average (OWA) [37], which is described at Equation 12 and 13. *P* is aggregation value, *Qj* is the assessment weight, and *bj* is the order of greatest expert assessment for criterion. The number of rating scales in is represented by the *q;* and the number of experts is represented by *r*.

$$P = MAX[Q_j \wedge b_j] \tag{12}$$

$$Q_j = Int[1 + j \times \frac{q-1}{r}] \tag{13}$$

At the last stage, the most influential key activities to the goal activity based on expert judgement are synthesized and compared with the real-world condition. This stage produces the appropriate and acceptable recommendation to the real world to achieve supply chain goals and improving the most influential key activities. The detail process to generate the recommendation for improving the system is depicted at Figure 4.

4. Result and Findings

4.1. Unstructured problem and rich picture

At the early stage, various problems that pose threats to the achievement of the system objectives are expressed from various perspectives and are structured in a rich picture [16]. The identification of sugarcane agroindustry supply chain issues from various perspective are derived by in-depth interview and literatures review. Generally, sugarcane agroindustry supply chain is affected by social, economic, environment, culture, institution and policies. Table 3 shows various issues and problems of sugarcane supply chain agroindustry which are obtained from previous research enriched with experts and practitioners' in-depth interview and also supporting by information from field observation at the sugarcane agroindustry in Indonesia.

In the upstream supply chain, sugarcane agroindustry faces low sugarcane productivity and yield issues, insufficient sugarcane production to fulfilling mills capacity and consumer needs also climate anomaly that impact the efficiency of sugarcane production. Besides that, it also faces seasonal sugarcane harvesting characteristic, poor and inefficient harvesting techniques and still relies on the burnt sugarcane for quick supply to the mills. These issues are also consistent with the previous research by Antony et al. [38], Tcereni [39], Kadwa [40], Fahrizal [41], and Ardana et al. [42].

In its production, constraints and problems faced by sugarcane agroindustry is low initiative to carry out revitalization which is not supported by integrative legislation yet [43]. In addition, we found low performance overall recovery and efficiency of whole sugar mills [44], [45]. Operationally, sugar mills must face the risk of raw material supply and quality that impact in producing low sugar quality. We also found inefficient at sugarcane handling and transportation executions.

In the downstream supply chain, main problem faced by sugarcane agroindustry is excess supply of the world's sugar which trigger the high possibility of risk on domestic sales lost [46]. In all supply chain mechanism, the main problems found is the imbalance of benefits gained by primary stakeholder of supply chain. Previous research also found that upstream supply chain stakeholders bear the highest risk with the lowest profit level, while downstream supply chain stakeholders savor high profits and lower risks [8], [47]. In addition, Bezuidenhout et al. [48] stated that the sugar cane agroindustry supply chain also faces institutional and inefficient payment system problems which rising distrust between stakeholders and threatening supply chains sustainability. Furthermore, unstructured problems delivered above are described in a structured and consistent rich picture depicted in Figure 5.

Wang et al. [17] state that in order to solve soft problems, all stakeholders in the system must be involved for the solution model. Furthermore, Asrol et al. [2] identifies that the stakeholders involved in the sugar cane agroindustry supply chain are farmers, sugar mills, distributors, cooperatives and associations also sugar marketing management that summarized at rich picture.

Table 1. Various sugarcane supply chain problems from previous research

Sources	Problem definition
[8]	✓ Imbalance of profits and risks obtained by sugarcane agroindustry supply chain actors. ✓ Farmers earn small profits while charge most risk among supply chain stakeholders. ✓ In-transparent of information on sugar prices at all supply chain stakeholder. ✓ The weakness role of research institution to improve sugarcane agroindustry performance, inaccessible of business capital for the farmers, weakness of role of cooperative and association in fighting for prosperity of farmer and other stakeholder, low integration in regulation to support performance improvement. ✓ Low value-added ratio generated by local farmers compared with international sugarcane farmers and it is possible to improve and increased.
[44]	Low farmers trust for the mills related to the determination of farmers cane quality and yield which is affected the farmers income, Low productivity and yield of Indonesian sugarcane variety, Low performance of mills overall recovery.
[49]	Low utilization and recycling of mills by-products then low value-added gained.
[41]	Sixth level ratoon cane as cultural farmers activities which decrease the sugarcane quality and productivity which caused unfulfilling sugar mills capacity and demands.
[39] [42]	Insignificant rise of sugarcane wide area which is unreliable to fulfil sugarcane mills capacity and failure to meet consumer needs.
[43]	The revitalization policy of sugar mills has not gone well and has not been supported by integrative regulation.
[50]	Performance and efficiency improvement efforts dominantly focus on trading strategies and policies which is not solve problems and issues comprehensively
[40]	Inconsistent quality of sugar and sugarcane caused by seasonal variability, poor harvesting techniques, poor resources allocation, numerous sugarcane varieties, burnt sugar cane and transport delay.
[51]	✓ Mills focuses on fulfilling factories raw materials capacity and excluding sugarcane or raw material quality ✓ An old production machinery ✓ The high auction price difference with the import price causes the domestic sugar is not strong enough to compete in the market
[46]	Worlds sugar excess supply causing a difference in domestic and international sugar prices up to 31.7% which affect high market competition for domestic sugar
[52]	The main problem of sugarcane agroindustry supply chains are problems in farming technique and productivity, inefficient production process and sugar trading inconsistency
[38]	Uncertain climate and season greatly affect the sugarcane harvesting decision and productivity

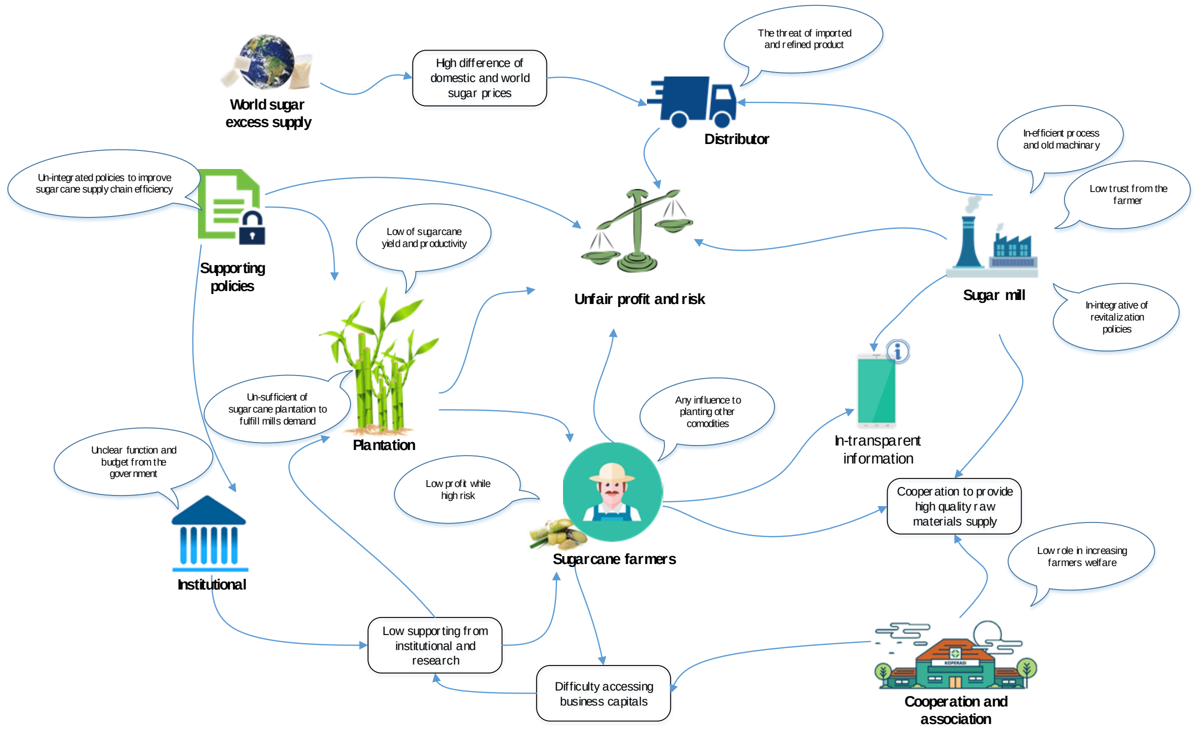


Figure 5. Rich picture

Table 4. CATWOE elements

Elements	Definition
Customer	Farmers, sugar mills, distributor and government
Actor	Farmers, sugar mills, distributor, government, research institution, university, cooperation and association
Transformation	Establish a fair supply chain management for sugarcane agroindustry involving all stakeholders
Weltanschauung (World-view)	Improving the performance of supply chain collaboration and sharing a fair benefits and risks to all supply chain stakeholders which can help to achieve supply chain goals
Owner	Farmers, sugar mills and distributor
Environment	Government regulation, world sugar supply and prices

4.2. Root definition and CATWOE elements

Based on the unstructured problems and rich picture above, we define root definition in a system thinking. The root definition statements insight in this research is *"system owned by farmers, sugar mills, distributors, government and other stakeholders to establish a fair and strong sugarcane agroindustry supply chain by distributing risk and value-added to each primary stakeholder and improving supply chain collaboration and coordination that share equitable and fair benefits for all stakeholders with effective risk mitigation efforts and achieve a better supply chain performance improvement and robust to against multiple threats"*.

To describe how the root definition developing the system and solve problems, we analyses CATWOE elements which is described at Table 4.

4.3. Conceptual model

The conceptual model is built to provide ideal sugarcane agroindustry supply chain model which was born from the researcher idea within in a system thinking scope to be implemented in real world. The analysis and synthesis result in the previous stages illustrate that to create and transform an efficient sugarcane agroindustry supply chain needs to be supported by a fair and collaborative supply chain management system. The collaborative approach is particularly appropriate to solve complex problems in the sugarcane agroindustry supply chain. This approach can deliver to solve disintegrative problems that threaten supply chain sustainability [53], [54].

The conceptual model for a fair and collaborative sugarcane agroindustry supply chain is organized of two important aspects of supply chain performance, namely value-added and supply chain risk. Based on Frumkin and Keating [24] to improve supply chain efficiency and effectiveness, it is necessary to consider the risk and value added aspects of all supply chain stakeholders. Furthermore, a fair and collaborative sugarcane agroindustry supply chain is achieved by balancing risk and value-added distribution to improve coordination among stakeholders, winning market competition, improve supply chain performance and sustainability [55]–[57].

Arsenyan et al. [58] stated that a collaborative approach to solving complex problems requires a negotiation model, so that each supply chain stakeholder savor ideal benefits and achieves a win-win situation. In this research, a win-win situation means equitably distributing risk and value added for all supply chain stakeholders while improving supply chain performance. The negotiation system is considered as an operating model for balancing risk and value-added as two conflicting aspects in supply chain. Negotiations in the supply chain are also important to develop since it enhance collaboration, facilitate resolution of conflicting variables, maintain coordination and facilitate stakeholder efficient agreement with different strengths and levels [29], [59].

Besides negotiation system, a collaborative approach also needs coordination system and mechanism [58]. Coordination means all stakeholders in the supply chain that come from different organizations work together to achieve supply chain objectives and win the market competitions. The sugarcane agroindustry stakeholders need effective coordination scheme since it will increase profits, revenue sharing, risk mitigation, improve risk sensitivity, improve performance, minimize costs, optimize resource consumption, and improve supply chain sustainability [60]–[63]. According to Zhang and Hong [64] coordination system is required to be applied in supply chain management, especially to supply chain stakeholders who have different power and level, as we found in the sugarcane agroindustry supply chain management.

Based on above descriptions and introduction, it is known the main purpose of this system is to build a fair and collaborative sugarcane agroindustry supply chain system. To achieve this objective requires several key activities and subsystems including the supply chain value-added identification and enhancement, supply chain mitigation and risk mitigation, fair and balanced risk and value-added distribution, supply chain negotiation system, supply chain coordination mechanism and supply chain performance improvement. Comprehensive key activities are organized to achieve goals through organized in a complete conceptual model of the system, depicted in Figure 6.

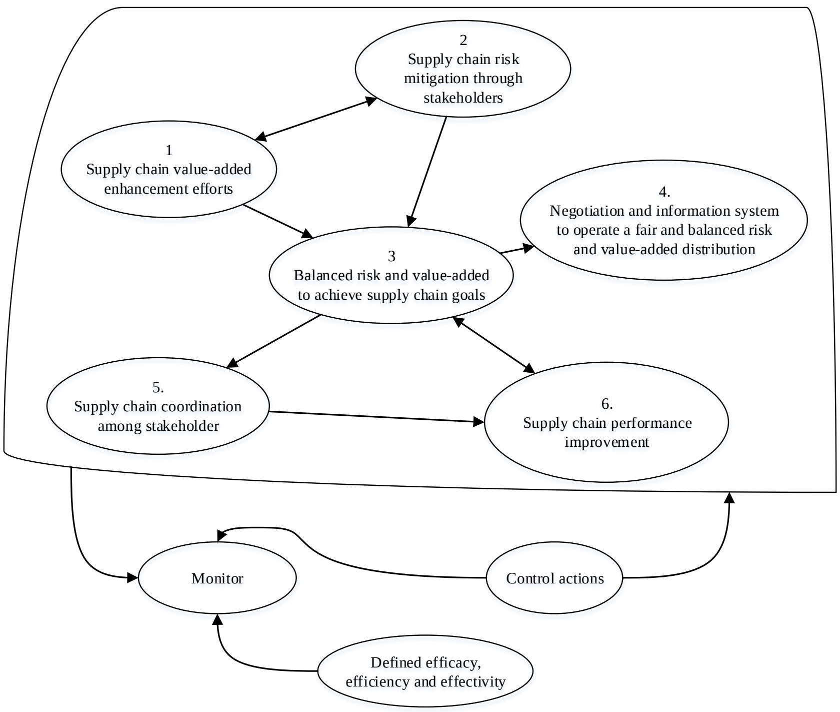


Figure 6. Conceptual model for sugarcane agroindustry supply chain

Based on Liu et al. [15], root definition and conceptual model are not actually happening in real-world but are the result of the researcher's thinking within the scope of the system. Hopefully root definition and conceptual model can be implemented to the real world for the improvement of existing systems. To implement a conceptual model in the real world, here are some operational definitions of the conceptual model.

4.3.1 Supply chain value-added identification

Supply chain value-added is an increase in the value of a commodity or raw material due to the addition of input and undergoing a continuous specifically process on each supply chain stakeholder. Operationally, we defined supply chain value-added through the amount of the value that would be paid by the consumer [65]–[67]. Supply chain value-adding determines the efficiency of the supply chain and needs to be well identified in order to reflect the true state of the supply chain. Supply chain value-adding identify and calculate through various methods such as Economic Value Added (EVA), Cash Value Added (CVA), Operating Cash Value Added (OCVA), Value Chain Analysis, Operating Cash Value Demand and Hayami method and modification.

In this research, we apply Hayami concept to calculate the value added as it is in accordance with the characteristics of business process in sugarcane agroindustry. Furthermore, Modified Hayami have been proposed by Hidayat and Marimin [6] and Asrol et al. [2] for seasonal plantation crops, and it is suitable with the characteristics of sugarcane agroindustry. We define value-adding as the benefits and profit to derived by stakeholders. We also define the value-added ratio as a way generalize the unit value of value-added. The value-added ratio defined as the percentage value between the acquisition of adding value and the resulting output value in a single work unit or in each stakeholder' business process. In a simple calculation of supply chain value-adding ratio describe in Equation 14.

$$Value - added\ ratio(\%) = \frac{value - added}{Product\ value} \times 100\% \quad (14)$$

4.3.2. Supply chain risk mitigation

Supply chain risk mitigation means efforts to minimize risks bad effect that occur throughout the supply chain. Before mitigating supply chain risks, firstly risks should be identified and assessed through its impact on business processes [68]. Various risk management methods have been developed, but in this study, we apply fuzzy-House of Risk as a comprehensive method in supply chain risk identification, assessment and mitigation.

Fuzzy House of Risk is an expansion of the framework of house of risk developed by Pujawan and Geraldin [69] with an assessment model by experts based on fuzzy scale. Fuzzy house of risk is powerful for supply chain risk assessment since it can detect risk events and agents and formulate risk mitigation strategies based on risk agents' priorities. The assessment of supply chain risk based on value of Aggregate Risk Potential (ARP) describes in Equation 15.

$$\widetilde{ARP_j} = \widetilde{O_j} \sum_i \widetilde{S_i} \widetilde{R_{ij}} \quad (15)$$

Risk assessment formula on Equation 15 describe Aggregate Risk Potential (ARP) to mitigate, based on assessing the level of risk event severity (*S*), the level of risk agent occurrence (*O*) and correlation (*R*) of risk event and agent.

4.3.3. Supply chain fair and balanced risk and value-added distribution

Supply chain fair and balanced risk and value-added distribution model is constructed on input of supply chain value-added and risk which are define in previous stage. The result of supply chain value-adding identification is the percentage of added value and profit obtained by each supply chain stakeholder. The result of supply chain risk identification is risks priority that must be considered in each supply chain stakeholder.

Risk priorities are derived from the higher Aggregate Risk Potential (ARP) value corresponding the threshold value which is set for each stakeholder. At each risk priority, we calculate the amount of costs which is earned to mitigate the risks. It is important to consider quantitative risk value since value of risk and value-added must be equated, to facilitate optimization and balancing risk and value-added throughout the supply chain. Based on the formula by Giannakis and Louis [60], the costs for risk mitigation at each stakeholder of the sugarcane agroindustry chain at the Equation 16.

$$Risk\ cost = r + P(r)L(r) \quad (16)$$

Where r is the amount of cost and investment that must be spent on to mitigate the risk, $P(r)$ is the risk occurrence probability obtained from the stakeholder risk identification and *L (r)* is the losses that may be incurred if the priority risk occurs.

Risks and value-added in the supply chain need to be balanced comprehensively for all supply chain stakeholders. The initial model of balancing risk and value added in the supply chain whose basic model referred to Melese et al. [70] formulated at Equation 17.

$$E(U) = -e^{-\left(\frac{\pi_i}{R_i}\right)} \quad (17)$$

In this study, π_i is the magnitude of value-added of supply chain stakeholder *i* and R_i is the magnitude of risk to supply chain stakeholder *i* calculated by Equation 16. The utility model in Equation 17 is then apply to determine the optimal sharing and selling price level for each supply chain stakeholder.

4.3.4. Supply chain negotiation model

Optimization and balanced of risk and value-added models are developed based on game theory model and combined with soft computing technique to support intelligent decision making which the basic formulation had been describe in Equation 17. The basic development goal is to achieve the win-win solution between all supply chain stakeholder. Furthermore, balancing risk and value-added framework is structured in stakeholder dialogue to facilitate a negotiation model involving all supply chain stakeholders as described at Figure 7.

As an initiation, we propose two side stakeholders to do negotiations, namely farmers and manufacturer or mill to find balanced risk and value-added distribution among them. In this system, we provide learning engine (Adaptive Neuro Fuzzy Inference System (ANFIS) / Case Based Reasoning (CBR) for all stakeholder then formulate strategies to achieve win-win solution in every negotiation process.

The negotiation mechanism model is expected to recommend an equitable sharing of benefits and risks throughout the supply chain. By this system recommendation, it is assumed that all stakeholder get appropriate information sharing through the system and increase the trust among them to support business process sustainability.

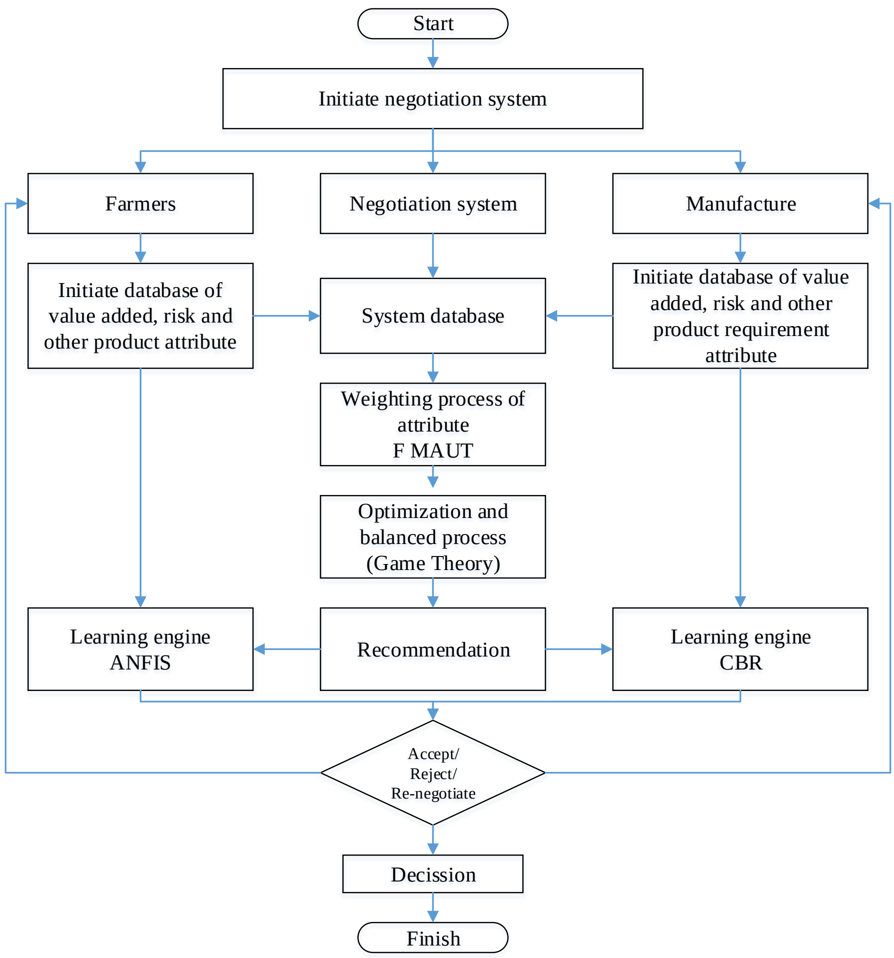


Figure 7. Negotiation scheme for fair and balanced risk and value-added in sugarcane agroindustry

Besides value-added and risk information which identify in early stage, each supply chain stakeholder also informs the product attributes to negotiate, such as farmers ratoon rate, sugarcane yield, cane brix and pol value, specified price, product quality, product safety or product requirement for buyer and seller side. These weights of product attribute will determine the acceptance or rejection of a negotiation. In this stage, we apply Fuzzy Multi-attribute Utility Theory (MAUT) approach to weighted each product attribute which basic equations referring to Xue et al. [71] and Wang and Singh [72].

At the evaluation of this attribute is done by *m*-negotiator with *n*-attribute so that it will yield the *X* decision matrix as seen in Equation 18. Then, determination of each negotiator weight is defined at Equation 19, 20 and 21.

$$X = (x_{ij})_{mxn} \tag{18}$$

$$\tilde{U}_i = \sum_{j=1}^{n} \tilde{w}_j \times \tilde{y}_{ij} \tag{19}$$

$$\tilde{w}_j = \frac{\sum_{j=1}^{n} \tilde{a}_{kj}}{\sum_{k=1}^{n} \sum_{j=1}^{n} \tilde{a}_{kj}} \tag{20}$$

$$\tilde{y}_{ij} = \frac{\tilde{x}_{ij}}{\sqrt{\sum_{i=1}^{m} \tilde{x}_{ij}^2}} \tag{21}$$

4.3.5. Supply chains stakeholder coordination and supply chain performance improvement

Coordination is a key factor for achieving successful supply chain collaboration. Coordination means different level of stakeholders in the supply chain do work together to achieve goals and all efforts to undertake must be coordinated [58]. Determining the direction of coordination in the supply chain is not only to achieve supply chain objectives, but deeply it is to avoid stakeholders in decentralized supply chain systems that produce low benefit gain [73].

Mitigate risk, increased value-added and balanced risk and value-added are some important aspects of coordination among supply chain stakeholders. In addition, the supply chain coordination to improve supply chain performance also requires information sharing to support the material and cash flow among stakeholders [74], [75]. Therefore, the goal of supply chain coordination is to improve the supply chain performance. Furthermore, we design conceptual coordination mechanism for sugarcane agroindustry supply chain as describe in Figure 8.

According to Xiao [76], when supply chains have coordinated, the gains will be obtained. To obtain the effectiveness implementation of coordination and collaboration systems in the supply chain, coordination evaluation is required to controlling the supply chain performance improvement efforts. According to Arshinder et al. [73], effectiveness evaluation for coordination mechanism in improving supply chain performance is determined through Supply Chain Coordination Index (SCII) which is described in Equation 22.

$$SCCI = f(P_i) \tag{22}$$

SCCI is determined by the successful implementation of coordination scheme and mechanism (P_i), in this case, it is defined as risk mitigation (P_1), value-added enhancement (P_2), fair and balance of risk and value added (P_3), and information sharing (P_1). To see the effectiveness of coordination implementation, each coordination performance (P_i) should be calculated relatively by compare it when supply chain performance is in coordination (SCP_c) and without coordination $(SCP_{w/c})$. In addition, each coordination performance $(P_{1,2,3,4})$ in the supply chain has a different level of importance (Wp_i), so that the level of importance can be determined relatively through weighting techniques. In more detail, the determination of the effectiveness of coordination to improve supply chain performance on sugarcane agroindustry describe in Equation 23 and 24.

$$SCCI = \sum_{i=1}^{n} P_i \tag{23}$$

$$SCCI = \sum_{i=1}^{n} \left((W_{pi}) \left(\frac{SCP_{ic} - SCP_{iw/c}}{SCP_{iw/c}} \right) \right); \tag{24}$$

SCP_{ic} and $SCP_{iw/c} \in P_i$

4.4. Comparison of conceptual model and real world and formulating recommendations

Based on the rich picture and conceptual model which has defined at the preliminary stage, it known that there are several activities required in achieving the supply chain objectives, namely collaborative supply chain for fair and balanced risk and value-added distribution. In addition, at this section we synthesize key activities that influences the achievement of supply chain goal, which is structured through a causal effect diagram based on the Fuzzy Cognitive Maps (FCM) assessment framework.

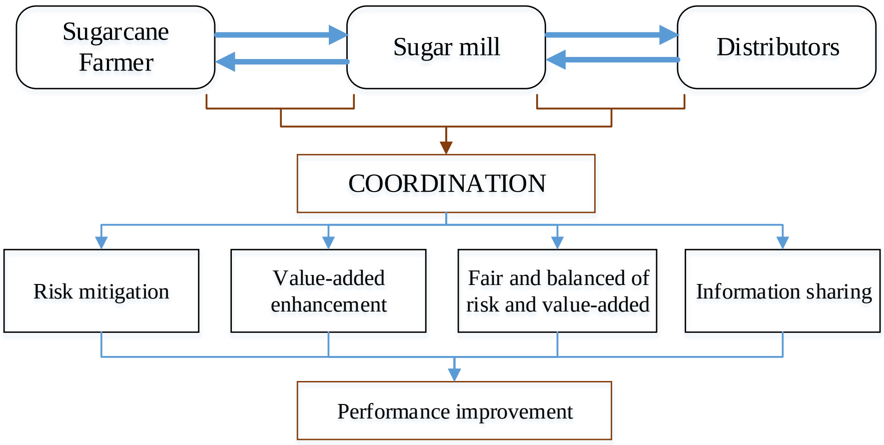
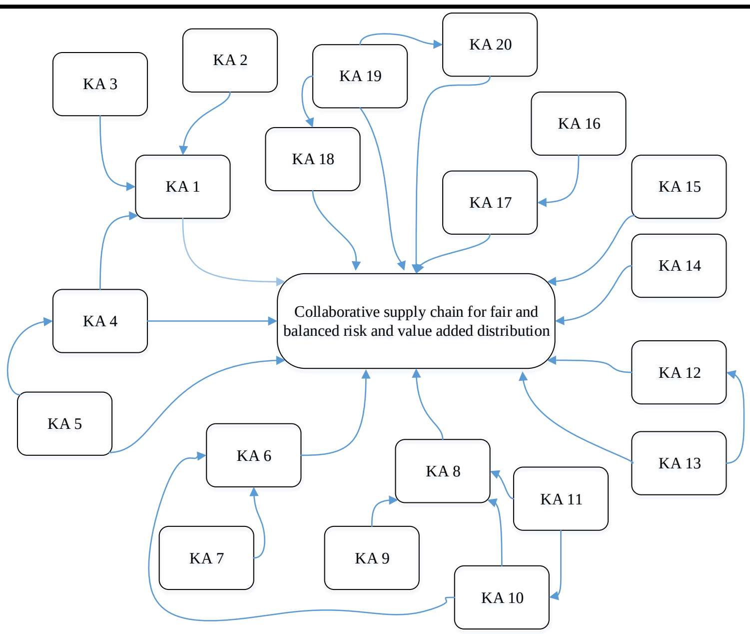


Figure 1 Sugarcane agroindustry supply chain coordination concepts and mechanism



KA1	:	Low profit for farmers	KA11	:	Old machinery facilities
KA2	:	Low access to business capital	KA12	:	Decentralized effort of supply chain performance improvement
KA3	:	Low subsidy for sugarcane input plantation	KA13	:	low coordination effort to improving performance and productivity
KA4	:	Information system for sugarcane price is not gone well	KA14	:	Value-adding effort is not sufficient
KA5	:	In-transparent information for sugarcane quality and prices	KA15	:	Downstream stakeholder gains high profit with lowest risk
KA6	:	In-effective function of related institutions	KA16	:	Impact of imported sugar
KA7	:	Diseconomies of scale condition of cooperative institution	KA17	:	Low government intervention to the market
KA8	:	Low production efficiency	KA18	:	Un-structured mitigation effort
KA9	:	Low quality of raw materials which is not support production process efficiency	KA19	:	Supply chain sustainability
KA10	:	In-effective executions of mills revitalization program	KA20	:	Gaining better income for supply chain stakeholder

Figure 9. Causal-effect diagram for key activities and goal of sugarcane supply chain

The causal effect diagram of the key activities for achieving the supply chain goal is decomposed from the rich picture and conceptual model of the system. Figure 9 shows the causal effect diagram for supply chain key activities. There are 20 key activities which influence the achievement of the supply chain objectives, each of which achievement is assessed for its effect on the achievement of the supply chain objectives in accordance with Equations 1 and 2 and Figure 3 through expert judgment and interview.

Recommendations to improve the system is analyzed through the most influential key activities to the systems goal. The most influential key activities which are assess through Fuzzy Cognitive Maps (FCM). After that, key activities are synthesized by looking at the current state and seeing its advantage and disadvantage. Furthermore, the recommendation focuses on improving key activities to achieve the goals, collaborative sugarcane agroindustry supply chain for fair and balanced risk and value-added distribution.

Finally, SSM framework combine with other quantitative methods indicates that solving complex problems occurring in the sugar cane agroindustry supply chain are completed in a structured and comprehensive way. Each stage of SSM is able to provide a complete description of the problem and can be properly resolved in accordance with the system thinking framework. The SSM Framework combined with quantitative methods, namely negotiation model for balancing risk and value-added and Fuzzy Cognitive Maps (FCM) are able to identify and solve problems to achieve system objectives and be able to provide effective recommendations in accordance with real-world circumstances.

5. Conclusion and Recommendation

Soft System Methodology framework combined with the negotiation system and the Fuzzy Cognitive Maps (FCM) technique has been able to provide an effective solution framework to developing collaborative supply chain for fair and balanced risk and value-added distribution in sugarcane agroindustry. The complexity of sugarcane agroindustry problems has been well described through the rich picture which the solutions have translated into the root definition and conceptual model. The negotiation system framework for the operation of balancing risk and value-added has been modelled quantitatively at the fourth stage of SSM. This paper provides supply chain collaborative and coordinative model to evaluate and improve supply chains performance. The validation framework through FCM compiled at fifth and sixth stages of SSM. This paper also enables to provide a framework to give appropriate recommendations for sugarcane agroindustry supply chains performance improvement based on problem definition. For further research, it necessary to synthesize the model validation through experienced expert judgement to provide appropriate recommendations. These frameworks require implementation on the real world and determine strategic steps for improving a fair sugarcane supply chain.

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