Developing an Agri-food Supply Chain Application for Determining the Priority of CSR Program to Empower Farmers as a Qualified Supplier of Modern Retailer

Wahyudi Sutopo, Muh. Hisjam, and Yuniaristanto

Abstract— **We proposed an application of Agrifood Supply Chain (ASC) model for determining the priority of programs to empower the farmers as qualified supplier of modern retailer (MR). We have proposed two mathematical models that involve corporate social responsibility (CSR) activities to enhance the business skills and to improve capabilities of the farmers accessing market. By using the ASC application, MR does not need to solve the Weighted Goal Programming (WGP) to simulate its policy despite they want to change index values or parameters repeatedly. The ASC application is Decision Support System (DSS) based that incorporates database, model base, analysis tool, and Graphical User Interface (GUI). The test results of case examples provided also give good results, where the application is capable for processing data based on proposed mathematical model. The ASC application is capable to choose the priority of CSR program for quality improvement of the vegetables and for skill enhancement of the farmers. The result can be a consideration for Human Resources Department (HRD) of modern retailers to make decision in CSR programs.**

Index Terms—**agri-food supply chain application, corporate social responsibility, decision support system, supplier of modern retailer.**

I. INTRODUCTION

In this paper, we discuss the issue of vegetables farmers in Indonesia that deal with marketing and low selling price problems although they produce good quality of vegetables [1]-[3]. Since the farmers group and/or cooperation (FGC) could fulfill the requirements of the high-class consumers, they could sell directly to modern retailers and increase the revenues on agribusiness [4], [5]. The farmers and/or FCG should fulfill some criterion related to product specifications, delivery terms, and internal business requirements to become a qualified supplier of modern retailer [5-7].

The case described in the previous paragraph can be seen as the integration of key business processes from the integrated system in agri-food supply chain (ASC) that consists of three main entities namely farmers, the FGC, and the modern retailer (MR), and also the customers as end users [3]. Several model had been developed by previous researchers to improve the coordination of buyer-supplier [8], to make business contracts [9], [10], and to understand the effect ASC improvements [6], [11], [12]. We also investigated previous results related to the implementation of CSR programs in supply chains i.e. corporate enhanced its relationship with suppliers [13]-[15], reduced business risks and promoted brand [16], [17], and guided the CSR implementation in supply chain responsibility [18]-[20].

Therefore, there are no models that incorporate some factors which can be considered as particular weaknesses of the small-scale farmers and CSR programs. In previous works, we proposed an ASC model that involves the CSR activities to improve capabilities of the farmers or the FGCs and to enhance the capabilities in marketing the commodities to the modern retail [3]. Unfortunately, the ASC model involves a complicated mathematical formulation namely Weighted Goal Programming (WGP). An application is intended to simulate its policy if they want to change index values or parameters repeatedly based on the model that has been proposed by Sutopo *et al*. [3]. A decision support system (DSS) is a system to utilize models with internal and external databases, emphasize flexibility, effectiveness, and adaptability [21], [22]. An application based on DSS can be developed in any environments that support data storage, data analysis, solution methods, and graphical user interface.

This paper is organized as follows. In Section 1, we describe the background of our research and describe the problems in the real system. In Section 2, we construct the WGP for farmers-modern retailer relationship. In Section 3, we provide the development of an agri-food supply chain application. Discussion and analysis is provided in Section 4. In Section 5, we deliver the conclusion and future research.

II. THE WEIGHTED GOAL PROGRAMMING (WGP) FOR FARMERS-MODERN RETAILER RELATIONSHIP

We extend our previous work in [3] by developing a user interface to ease the process of numerical input and output for simulating policy. In previous work, Multi period ASC model is formulated as WGP) to analyze the impacts of CSR programs to empower the FGCs in managing the small-scale vegetables farmers. MR proposes two CSR programs conducted by the division of HRD. The quality improvement (QI) of the vegetables and the skill

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enhancement of the farmers are designed in limited budget of CSR programs. The WGP formulation is not only to maximize the profit of farmers, but also to maximize CSR benefits for the modern retailers. The model should capable to determine the amount and timing of supply, level of farmers training skills, quality improvement target, and the CSR total cost.

Fig. 1 describes an ASC network of the relevant system. The ASC model for improving the capabilities of farmers can be formulated by the mixed integer linear programming (MILP). The following notations are used to develop the proposed model.

Index

$t \in T$	period set
$i \in I$	farmer set
$j \in J$	cooperative group set
$k \in K$	modern retailer set
$m \in M$	consumer market set
$v \in V$	vegetable set

Parameters and Variables

$q_t^{v(ij)}$	quantity of vegetable *v* produced by farmer *i* in cooperative group *j* at period *t*
p_t^{vmk}	price of vegetable *v* from retailers *k* to market *m* at period *t*
$p_t^{vm(ij)}$	price of vegetable *v* transacted by market *m* from farmer *i* in cooperative group *j* at period *t*
$p_t^{vk(ij)}$	price of vegetable *v* transacted by retailers *k* from farmer *i* in cooperative group *j* at period *t*
$c_t^{v(ij)}$	vegetable *v* production cost of farmer *i* in cooperative group *j* at period *t*
$d_t^{v(ij)}$	distribution cost of farmer *i* in cooperative group *j* at period *t*
$g_t^{v(ij)}$	quality improvement cost of vegetable *v* of farmer *i* in cooperative group *j* at period *t*
$h_t^{(ij)}$	training cost of farmer *i* in cooperative group *j* at period *t*
$\varpi^{(ij)}$	initial skill level of farmer *i* in cooperative group *j* at period *t*
ϕ	maximum skill level determined by modern retailers
Q_t^{km}	the quantity of the vegetables transacted between retailers *k* and each demand market *m* at time *t*

Decision Variables

$q_t^{vk(ij)}$	the quantity of the vegetables transacted by retailers *k* from farmer *i* in cooperative group *j* at period *t*.
$F_t^{(ij)}$	training level taken by farmer *i* at cooperative groups *j* in period *t*
$\psi_t^{v(ij)}$	quality improvement percentage of vegetable *v*, farmer *i* at cooperative group *j* in period *t*

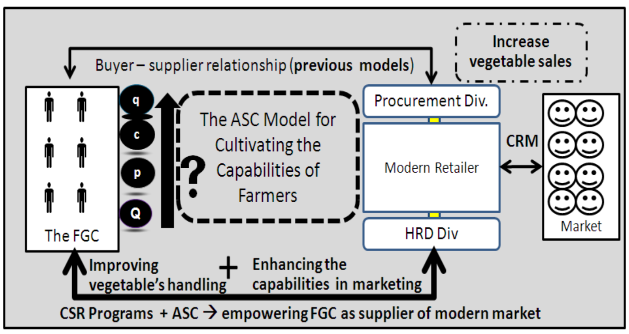

Fig. 1. ASC network of relevant system.

The four goals (G) will cover all aspects from for farmers-modern retailer relationship [3]. G1 denotes the profit maximization of modern retailer, G2 denotes the profit maximization of farmers, G3 denotes the total of CSR cost, and G4 denotes the level of training that must be taken by the farmers. The multi period ASC model then can be formulated as WGP below:

$$\text{Min}\left(\sum_{q\in Q}\omega_q\left(n_q+p_q\right)\right) \tag{1}$$

subject to

$$\sum_{t\in T}\sum_{v\in V}\sum_{k\in K}\sum_{m\in M}p_t^{vmk}Q_t^{km}-\sum_{t\in T}\sum_{v\in V}\sum_{k\in K}\sum_{j\in J}\sum_{i\in I}p_t^{vk(ij)}q_t^{vk(ij)}+n_1-p_1=b_1 \tag{2}$$

$$\begin{aligned}&\sum_{t\in T}\sum_{v\in V}\sum_{k\in K}\sum_{j\in J}\sum_{i\in I}p_t^{vk(ij)}q_t^{vk(ij)}\text{-}\sum_{t\in T}\sum_{v\in V}\sum_{j\in J}\sum_{i\in I}\left(c_t^{v(ij)}+d_t^{(ij)}\right)q_t^{v(ij)}\\&+\sum_{t\in T}\sum_{v\in V}\sum_{m\in M}\sum_{j\in J}\sum_{i\in I}p_t^{vm(ij)}\left(q_t^{v(ij)}-q_t^{vk(ij)}\right)+n_2-p_2=b_2\end{aligned} \tag{3}$$

$$\sum_{t\in T}\sum_{v\in V}\sum_{j\in J}\sum_{i\in I}\psi_t^{v(ij)}g_t^{v(ij)}+\sum_{t\in T}\sum_{j\in J}\sum_{i\in I}F_t^{(ij)}h_t^{(ij)}+n_3-p_3=b_3 \tag{4}$$

$$\sum_{t\in T}\sum_{j\in J}\sum_{i\in I}\varpi^{(ij)}+F_t^{(ij)}+n_4-p_4=b_4 \tag{5}$$

$$\sum_{i\in I}q_t^{v(ij)}\geq\sum_{k\in K}\left(1+\psi_t^{v(ij)}+\alpha F_t^{(ij)}\right)q_t^{vk(ij)},\forall t,j,v \tag{6}$$

$$\sum_{m\in M}Q_t^{vmk}\leq\sum_{k\in K}q_t^{vk(ij)},\forall t,j,v \tag{7}$$

$$\sum_{t\in T}\sum_{j\in J}\sum_{i\in I}F_t^{(ij)}\leq\phi \tag{8}$$

$$F_t^{(ij)}\in\mathbb{Z}_+,\psi_t^{v(ij)},q_t^{vk(ij)}\geq 0,\forall i,j,t \tag{9}$$

where ω_q, n_q, and p_q are defined as preferential weights, negative deviational variables, and positive deviationals ~~of~~ from the $q-$th goal, b_1, b_2, b_3, and b_4 denote the target level for each goal respectively. In this paper, we four goals q. The achievement function must be minimized to ensure that the solution is closely as possible to the desired goals (1). The first goal, profit maximization of the modern retailers is expressed in (2). Equation (3) states the second goal; profit maximization of farmer is expressed.

Equation (4) and (5) define the CSR goals, which seek CSR cost minimization and training level maximization. Vvegetables quality improvement and farmers skill enhancement can increase the quantity of vegetable sold to modern retailers is expressed in (6). Equation (7) states that the vegetable flow transacted by consumer market must not exceed quantity bought by modern retailer form framers. In (8), modern retailer determines maximum skill level of each farmer required to become MR supplier. Finally, the last equation is utilized to enforce non-negativity for all decision variables.

III. Developing The Agri-food Supply Chain Application

The application was developed using Java programming language and Object Relational Mapping (ORM). Database Server was developed using web server Localhost and MySQL. The algorithm used to solve the WGP formulation was branch and bound method. We used NetBeans IDE 7.0, JDK 1.6, XAMPP 1.7.7, Library Hibernate JPA, JCommon 1.0.15, JFreeChart 1.10.12, BettaGlasess 1.0 to develop application and to solve the WGP formulation. The ASC application for determining the priority of CSR programs was developed consists of five major components: database, model base, analysis tool, Graphical User Interface (GUI) and user.

Initially, the user only interacts with the home page of the ASC application to fill in values of model parameters. The user can input data such as all the parameters and set the parameters of the farmers and modern retailer. Display data input can be seen in the Fig. 2 and Fig. 3.

Fig. 2. Homepage of the ASC Application for Farmers.

Fig. 3. Home page of the ASC Application for Modern Retailer.

The supply chain comprises 3 the FGC j, j = 1, 2, 3; 1 modern retailers k, k = 1; 1 vegetable v, v = 1; 1 consumer market m, m = 1; and 2 periods t, t = 1, 2. The numbers of farmers associated with the FCG are 3, 2, and 4 respectively, labeled by capital letter. Data input of the application is adopted from [3], in period 1 farmer produces 285 kg of vegetable, but only 69 % worthy to be sold to modern retailers. Table 1 illustrates the farmers' data. Table 2 demonstrates the target's scenario.

TABLE 1.
THE FARMERS DATA

Period	Farmer	The FCGs	Vegetable Prod. (kg)	Vegetable Worth (%)	Production cost (Rp)	Trans. cost (Rp)	Price to MR (Rp)	Price to TM (Rp)
1	A	1	288	69	2,437.00	1,818.00	6,819.00	6,578.00
1	B	1	337	66	2,447.00	1,254.00	6,595.00	6,541.00
1	C	1	259	65	2,251.00	1,453.00	6,659.00	6,573.00
1	D	2	128	66	2,081.00	1,580.00	6,963.00	6,526.00
1	E	2	292	68	2,470.00	1,627.00	6,946.00	6,560.00
1	F	3	434	70	2,208.00	1,846.00	6,549.00	6,588.00
1	G	3	356	69	2,326.00	1,588.00	6,940.00	6,520.00
1	H	3	328	70	2,157.00	1,385.00	6,896.00	6,551.00
1	I	3	477	70	2,018.00	1,358.00	6,967.00	6,500.00
2	A	1	398	68	2,680.70	2,090.70	6,580.00	6,518.00
2	B	1	449	68	2,691.70	1,442.10	6,972.00	6,581.00
2	C	1	488	67	2,476.10	1,670.95	6,570.00	6,575.00
2	D	2	384	70	2,289.10	1,817.00	6,771.00	6,551.00
2	E	2	327	65	2,717.00	1,871.05	7,000.00	6,530.00
2	F	3	335	67	2,428.80	2,122.90	6,735.00	6,503.00
2	G	3	487	65	2,558.60	1,826.20	6,850.00	6,511.00
2	H	3	274	69	2,372.70	1,592.75	6,928.00	6,548.00
2	I	3	298	67	2,219.80	1,561.70	6,885.00	6,536.00

Source: (Sutopo et al. [3])

TABLE 2.
SCENARIO DATA

Scenario	Goal	Target Level	Weight
A	G1	At least 20,000,000.00 (n_1)	0.25
	G2	At least 30,000,000.00 (n_2)	0.25
	G3	At most 10% of G1 (p_3)	0.25
	G4	At least 15 (n_4)	0.25
B	G1	At least 10,000,000.00 (n_1)	0.25
	G2	At least 15,000,000.00 (n_2)	0.25
	G3	At least 10% of G1 (n_3)	0.25
	G4	At most 15 (p_4)	0.25
C	G1	At least 15,000,000.00 (n_1)	0.25
	G2	At least 20,000,000.00 (n_2)	0.25
	G3	Exactly 10% of G1 ($n_3 + p_3$)	0.25
	G4	Exactly 15 ($n_4 + p_4$)	0.25

Source: (Sutopo et al. [3])

IV. DISCUSSION AND ANALYSIS

In this section, we analyze the impact of the changes in parameters in solving the WGP to simulate its policy. Outputs of the application are recommendations for the quantity of the vegetables transacted by retailer (Fig. 4), training level taken by farmers (Fig. 5), and quality improvement percentage of vegetables (Fig 6). Fig. 7 describes the sensitivity analysis to determine how the model responds to changes.

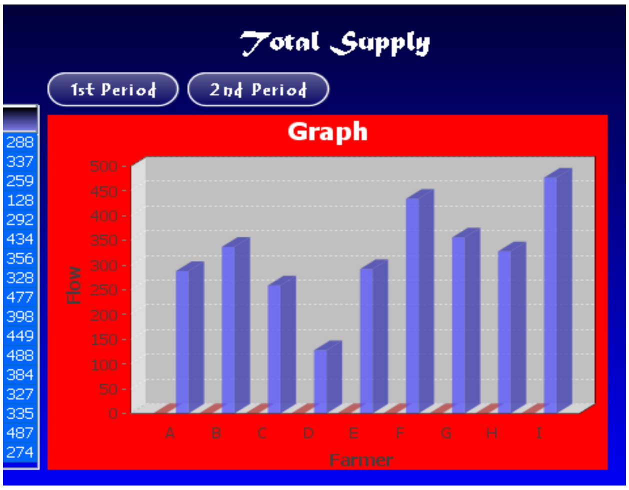

Fig. 4. The output of the vegetables transacted by retailer.

Fig. 5. The output of training level taken by farmer.

Fig. 6. Quality Improvement Percentage of Vegetable.

Fig. 7. The Sensitivity Analysis.

TABLE 3.
GOAL ACHIEVEMENT RESULTS

	Target Level	Achieved Value	Satisfied
G1	≥ 100,0000	1,000,000	Yes
G2	≥ 1,718,9861.39	17,201,406	Yes
G3	≤ 247,781,7.59	2,467,579	Yes
G4	≤ 9	8	Yes

The result of the best scenarios is shown in Table 3. The achievement function of the fourth scenario and the goals then can be stated as follows:

G1: Achieved maximum profit at least 1,000,000.00.
G2: Achieved maximum profit at least 17,201,406.
G3: CSR cost must not exceed 2,477,579.
G4: Training level must not exceed 8.

Recognized that effective application is intended for semi-structured problem, using a model with internal and external databases, and emphasize flexibility, effectiveness and adaptability. The test results of case examples provided also give good results, where the software is capable for processing data based on selected model. In a nutshell, ASC application succeeds to describe two CSR programs, the quality improvement of the vegetables and enhancement of the skill of the farmers.

V. CONCLUSION AND FUTURE RESEARCH

In this study, we investigated the ASC application to choose the priority of CSR program for the quality improvement of the vegetables and for the skill enhancement of the farmers. The HRD division of modern retailers can utilize the application to make decision in CSR programs. The test results of case examples also give good results, where the application is capable for processing data based on the ASC model for improving the capabilities of farmers.

Further research is needed to extend the ASC application which considers the integration with mobile supply chain. The proposed model should be extended by considering uncertainty factors such as price, demand, and supply.

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