

# An Agri-food Supply Chain Model for Cultivating the Capabilities of Farmers Accessing Market Using Corporate Social Responsibility Program

W. Sutopo, M. Hisjam, and Yuniaristanto

**Abstract**—In general, small-scale vegetables farmers experience problems in improving the safety and quality of vegetables supplied to high-class consumers in modern retailers. They also lack of information to access market. The farmers group and/or cooperative (FGC) should be able to assist its members by providing training in handling and packing vegetables and enhancing marketing capabilities to sell commodities to the modern retailers. This study proposes an agri-food supply chain (ASC) model that involves the corporate social responsibility (CSR) activities to cultivate the capabilities of farmers to access market. Multi period ASC model is formulated as Weighted Goal Programming (WGP) to analyze the impacts of CSR programs to empower the FGCs in managing the small-scale vegetables farmers. The results show that the proposed model can be used to determine the priority of programs in order to maximize the four goals to be achieved in the CSR programs.

**Keywords**—agri-food supply chain, corporate social responsibility, small-scale vegetables farmers, weighted goal programming.

## I. INTRODUCTION

CONSUMERS in modern retailers need the high quality and safety of vegetables [1], [2]. They are willing to buy the commodities at a higher price to modern retailers. If the small-scale vegetables farmers could fulfill the requirements of the high-class consumers, they could sell directly to modern retailers and increase the revenues on agribusiness [3]-[5]. Unfortunately, the small-scale vegetables farmers in Indonesia have to deal with lower skills in improving the safety and quality of vegetables supplied to the high-class consumers [4], [6], [7]. The farmers group and/or cooperative (FGC) should be able to assist its members by providing training in handling and packing vegetables and enhancing the capabilities in marketing the vegetables to the modern retail. The modern retailers have several provisions for all suppliers on product specifications, delivery terms, and internal business requirements [2], [8], [9].

An agri-food supply chain (ASC) is a network of collaborative organizations and each of them has different functionality and activities. For instance, farmers establish vegetables cultivation; FGC distributes vegetables to modern

retailers; and modern retailers sell the vegetables to end consumer, in order to deliver products and services to the market, with the purpose of satisfying customers' demands [4], [9], [10]. The case described in the previous paragraph can be seen as the integration of key business processes from the integrated system in ASC that consists of three main components namely farmers, the FGCs, and the modern retailers, and also the customers as end users. As corporations, the modern retailers must take into account the environmental and social responsibility practices [11]-[13]. As a consequence, one of corporate responsibility is to cultivate the capabilities of its supplier. Thus, implementing the Corporate Social Responsibility (CSR) programs in the integrated system of ASC could be used to empower the FGCs in managing the small-scale vegetables farmers.

Several researchers have attempted to improve the coordination of buyer-supplier [14], to make business contracts [7], [15], and to understand the effect ASC improvements [8], [16], [17]. More recently, many researchers have tried to develop the implementation of CSR programs in supply chains. Using CSR programs, corporate enhanced its relationship with suppliers [18]-[20], reduced business risks and promoted brand [21], [22], and guided the CSR implementation in supply chain responsibility [23]-[25]. However, they didn't incorporate some factors which can be considered as particular weaknesses of the small-scale farmers, such as accessing market, adopting new technology, and upgrading skills in managing business. This study proposes an ASC model that involves the CSR activities to cultivate the capabilities of farmers or the FGCs by providing training in handling and packing vegetables and enhancing the capabilities in marketing the commodities to the modern retail.

This paper is organized as follows. In Section I, we describe the background of our research and describe the real problem. In Section II, we construct the modeling framework. In Section III, we provide the mathematical model formulation. In Section IV, we design the solution method and analysis. In Section V, we deliver the conclusion and future research.

## II. MODELING FRAMEWORK

The ASC model can be formulated considering several goals to be achieved in the CSR programs. The notations for this model are given in Table 1.

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TABLE I  
DEFINITION OF NOTATION SETS

Notation	Definition of notations
$t \in T$	period set
$i \in I$	farmer set
$j \in J$	cooperative group set
$k \in K$	modern retailers set
$m \in M$	consumer market set
$v \in V$	vegetable set
$q_t^{v(ij)}$	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 $t$
$\omega^{(ij)}$	initial skill level of farmer $i$ in cooperative group $j$ at period $t$
$\phi$	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 $t$

TABLE II  
THE DESIGN OF A TAILOR-MADE THE ASC TRAINING

Level	The Outline of training contents	
1	Basic skill	Basic product knowledge and packing system Basic cost accounting and grading quality system
2	Intermediate	Procurement and ordering system Basic marketing & sales aspects Financial Management and Credit System
3	Advance	IT support for procurement and ordering system Vegetables storage system and Technology Distribution requirement planning
4	Excellence	Contract and Negotiation Business Process Reengineering Strategic Management

In order to improve farmers' welfare, the modern retailers cooperate with the FGC to implement CSR programs. The CSR activities are organized by Human Resource Development (HRD) of the modern retailers in collaboration with the FGC. The CSR activities are as follows: modern retailers devote some quantity of money allocated to CSR activities for farmers. The budget is split in two categories, CSR grant for the quality improvement of the vegetables and CSR grant for the skill enhancement of the farmers. Both grants are dedicated to farmers.

The first budget serves as a grant to improve the quality of the vegetables produced by the farmers. However due to budget limitation, not all farmers receive the CSR grant. Thus, modern retailers collaborates with cooperative groups must determine which farmers should receive the grant.

The second CSR budget is to enhance business skill of the farmers. Consider CSR budget for enhancing business skill of the farmers by organizing management training. First, business skill of each farmer is identified and classified. Then, modern retailers can decide what kind of training level is suitable for each farmer. For example, business skill of farmer 1, 2, and 3 are identified in the level 2, 3, and 1 respectively. Thus farmer 1 requires training level 2, farmer 2 requires training level 1, and farmer 3 requires training level 3. The maximum skill is determined by modern retailers, maximum skill level 4 is taken as an example. Table 2 lists the outline of training contents that needed to improve the skill of farmer.

By employing CSR activities, farmers can increase the quantity of vegetable sold to the modern retailers. Both the modern retailers and farmers will receive additional vegetable supply and additional revenue respectively. Moreover, the modern retailers can increase its revenue by selling additional vegetable to consumer. Hence, CSR activities will bring benefit not only to farmers in the FGC but also to modern retailers as well. Table 3 lists the decision variables that should be determined using a proposed ASC model.

Fig. 1 illustrates the ASC network. The FGC consists of several farmers who live nearby it. Each farmer plants several types of vegetables. For each vegetable type, each farmer in a FGC produces some quantity of vegetable and delivers it to the FGC warehouses. The FGC then sells the corresponding vegetable to modern retailers. However due to restrictive quality specification imposed by modern retailers, the FGC must conduct strict quality inspection to the vegetable before it can be sold to modern retailers. Therefore, only several percentages of the vegetable produced by each farmer can be sold to modern retailers. The remaining is sold to consumer which offers lower price than modern retailers does. As a result, farmer receives revenue from vegetable sales lower than it supposed to be.

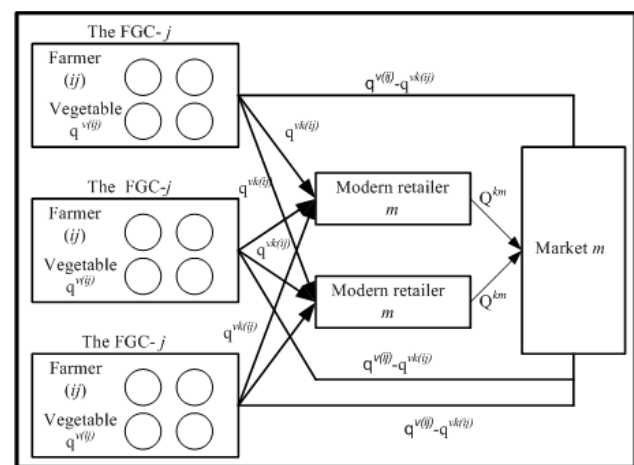


Fig. 1 The ASC network

TABLE III  
THE DECISION VARIABLE OF AN ASC MODEL

Notation	Definition of decision variables
$q_t^{vk(ij)}$	the quantity of the vegetables transacted by retailers $k$ from farmer $i$ in cooperative group $j$ at period $t$ .
$F_t^{v(ij)}$	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 $t$

III. MATHEMATICAL MODEL FORMULATION

In multi period ASC model, the modern retailers as the decision maker allocated budget as CSR commitment in order to improve quality of the vegetables produced by farmer and to enhance business skill of the farmers. The allocated budget however must be economically feasible for modern retailers to leverage its business objective. Furthermore CSR activities must be able to accommodate both modern retailers and farmers objectives. Therefore, there are many objectives involving modern retailers and farmers as the stakeholder in the multi period ASC.

Based on the above description, we develop four goals which can be categorized as two main objectives. We define the first main objective as economic objective which comprises two criteria: maximization of modern retailers and farmers' profit. The second main objective is defined as social objective which consists of two criteria: minimization of CSR costs and maximization of CSR activities. Notice that three goals belong to the modern retailers, and one belongs to farmers which is the profit maximization.

Goal Programming (GP) is a suitable tool for decision maker to analyze the achievement of the desired goals considering different and sometimes conflicting multiple objectives. The multi period ASC model then can be formulated as Weighted Goal Programming (WGP) below:

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

subject to

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

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

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

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

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

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

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

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

where  $\omega_q$ ,  $n_q$ , and  $p_q$  are defined as preferential weight, negative deviational variable, and positive deviational of the  $q$ -th goal,  $b_1$ ,  $b_2$ ,  $b_3$ , and  $b_4$  denote the target level for each goal respectively. In this paper the number of goals  $q$  is four. Some literatures defined (1) as the achievement function, which must be minimized to ensure that the solution is closely as possible to the desired goals. Equation (2) stated the first goal, profit maximization of the modern retailers. The second

goal, profit maximization of farmer was expressed in (3). Equation (4) and (5) defined the CSR goals, which seek CSR cost minimization and training level maximization. Equation (6) states that vegetables quality improvement and farmers skill enhancement can increase the quantity of vegetable sold to modern retailers. Equation (7) states that the vegetable flow transacted by consumer market must not exceed quantity bought by modern retailers from framers. In (8), modern retailers determine maximum skill level of each farmer required to become supplier.

IV. THE SOLUTION METHOD AND ANALYSIS

In this computational study, we analyze the impact of the changes in parameters in the multi period ASC supply chain model on optimum vegetables flow, training level taken by farmers, and quality improvement percentage considering several goals that must be achieved. The algorithm used to solve the WGP formulation was branch and bound method. We use IBM® ILOG® CPLEX Academic version solver to solve the WGP formulation [26].

Table IV illustrates the farmers' data. 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. Below vegetable column are vegetable production and vegetable quality. For example, in period 1 farmer produces 285 kg of vegetable, but only 69 % worthy to be sold to modern retailers. MR denotes modern retailers, and TM denotes traditional market.

The training cost per level and improvement quality cost budget is 100,000.00 and 190,000.00 respectively. All cost units are in rupiahs. The vegetable selling price in period 1 and period 2 faced by consumer from the modern retailers are set at 8,500.00. In order to analyze the goals achievement of modern retailers and farmers, three scenarios are presented to illustrate the impact of the different priorities to the goals achievement.

TABLE IV  
THE FARMERS DATA

Period	Farmer	The FCGs	Vegetable		Production cost (Rp)	Trans. cost (Rp)	Price to MR (Rp)	Price to TM (Rp)
			Prod. (kg)	Worth (%)				
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

TABLE V  
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

Table 5 lists the scenarios along with the associated values. G1 denotes the profit maximization of modern retailers as in (2), G2 denotes the profit maximization of farmers as in (3), G3 denotes the total of CSR cost as in (4), and G4 denotes the level training that must be taken by the farmers as in (5).

Target level for each goal is set to the desired value along with the corresponding deviational variables that must be minimized. For example the goal of scenario A which is the modern retailers objective, must achieve at least 20,000,000.00 and the corresponding deviational variables that must be minimized in achieved function is  $n_1$ . We set the weight for all goals in for all scenarios 0.25, which means all the goals have the same importance. We set scenario A to optimistic target level, scenario B to pessimistic target level, while scenario C to normal target level. Note that for all scenarios, the CSR cost was determined around 10% of the modern retailers' profit. The results of the computational study using data in Table 4 and Table 5 are given in the Table 6 and Table 7.

In the first scenario, all goals cannot satisfy the target level set by all objectives. We can conclude that the target levels for all objectives are too optimistic hence the target level must be lowered to satisfy all objectives. In the second scenario all goals, except the third goal which is the CSR cost, satisfy the target level. The profit maximization of modern retailers achieved the same value with the desired target level. The second goal is exceeded by 2,189,861.39. The results in the third scenario are the same with the results of the first scenario.

TABLE VI  
GOAL ACHIEVEMENT RESULTS FROM ALL SCENARIOS

Scenario	Goal	Target Level	Achieved Value	Satisfied
A	G1	$\geq 20,000,000.00$	10,685,875.76	No
	G2	$\geq 30,000,000.00$	17,324,336.81	No
	G3	$\leq 2,000,000.00$	2,412,530.00	No
	G4	$\geq 15$	0	No
B	G1	$\geq 10,000,000.00$	10,000,000.00	Yes
	G2	$\geq 15,000,000.00$	17,189,861.39	Yes
	G3	$\geq 1,000,000.00$	2,477,817.59	No
	G4	$\leq 15$	9	Yes
C	G1	$\geq 15,000,000.00$	10,685,875.76	No
	G2	$\geq 20,000,000.00$	17,324,336.81	No
	G3	$= 1,500,000.00$	2,412,530.07	No

G4 = 15 0 No

TABLE 7. GOAL ACHIEVEMENT RESULTS FROM SCENARIO D

	Target Level	Achieved Value	Satisfied
G1	$\geq 1000000$	1000000	Yes
G2	$\geq 17189861.39$	17201406	Yes
G3	$\leq 2477817.59$	2467579	Yes
G4	$\leq 9$	8	Yes
$n_1$	0	0	Yes
$n_2$	0	0	Yes
$p_3$	0	0	Yes
$p_4$	0	0	Yes

Consequently, we can develop the fourth scenario that can satisfy all the goals. Some changes must be made to the current goals. The first goal is set to achieve profit at least 10,000,000.00. The second goal is set to get the maximum profit at least 17,189,861.39. Note that the third goal in all scenarios never satisfies the target level. Its value takes around 2,477,817.59. Hence the third goal cannot be set as 10% of the first goal. The target level of the third goal is set as CSR cost must not exceed 2,477,817.59. The target level of the fourth goal also must be lowered to 9.

The achievement function of the fourth scenario and the goals then can be stated as follows

$$\text{Min } [\omega_1 n_1 + \omega_2 n_2 + \omega_3 p_3 + \omega_4 p_4] \tag{10}$$

G1: Achieved maximum profit at least 10,000,000.00.

G2: Achieved maximum profit at least 17,189,861.39.

G3: CSR cost must not exceed 2,477,817.59.

G4: Training level must not exceed 9.

The results of the fourth scenario are shown in Table IV. The scenario gives the achieved values that satisfy all the target level. The target level of goal 2 can be increased by 11545, which is the achieved value 17201406 minus the current target level in this scenario 17189861.39. The CSR cost satisfies the target level at 2467579. Hence the modern retailers must change the 10% profit policy for the CSR budget in order to satisfy the social objective. Goal 4 which is the total training level is 8, is satisfied within scenario 4.

## V. CONCLUSION AND FUTURE RESEARCH

In this paper, we propose multi period ASC considering CSR which empowering farmers in the RGC to become qualified supplier and improving vegetables quality. The CSR fund is given to farmers as grant term. The farmers can increase the quantity of vegetable sold to modern retailers. The WGP is used to formulate the four goals as the tradeoff between economic and social objectives. The results can be used for HRD division of modern retailers to make decision in CSR programs.

However, further research is needed to extend uncertainty factors such as market, demand, and supply effects. Fuzzy Goal Programming along with Pareto efficiency analysis might be suitable to overcome this paper's deficiencies.

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