CHAPTER 6

Optimal Solution for Revenue Sharing in GCSC

This research defines the performances of the GCSC of Arabica coffee in the highland in three aspects including the operational optimization indicating the minimized cost of the operation resulted from the horizontal collaboration of the farmers, the appropriate revenue sharing contracts showing the maximized profit of the supply chain associated with the vertical coordination among the farmers, the assemblers, and the RPF, and the simulations of the competitiveness of the farmers attending the GCSC. The models obtained from Chapter 5, the case of no cluster in the supply chain that is each farmer sells his products independently (the non-GCSC model) and the presence of farmer cluster in each area (the GCSC model), are implemented. Moreover, the comparative analyses between both models in the perspectives of the operational optimization, the revenue sharing and the competitiveness, are used to investigate the appropriate model for promoting the farmers in the highland.

6.1 Assumptions for GCSC simulation

The assumptions for simulating the GCSC are necessary to control the unexpected variables affecting the studied situations and enable one to set the same patterns of the models used in the research.

1) There are 29 farmers in Pamiang area and 27 farmers in Pang Ma-O area, one assembler in Pamiang area (Pamiang RPDC), one assembler in Pang Ma-O area (Pang Ma-O RPEC), and one processor (RPF).

2) The assemblers and the processor separately operate their activities. This assumption is set for the ability to obtain self-reliant and effective operations.

3) The product of the farmers and assemblers is in the form of parchment coffee, whereas the products of the processor are in the form of parchment coffee for use as production input and green coffee beans for beverage consumption.

4) The total products of the farmers in Pamiang and Pang Ma-O areas are sold to Pamiang RPDC and Pang Ma-O RPEC, respectively; the total products of Pamiang RPDC and Pang Ma-O RPEC are sold to the RPF only.

6.2 Optimal operation in the GCSC

The results in Chapter 5 mentioned that the decision making of the farmers, the assemblers and the RPF are ambiguous because the adoption varies with individual criterion. This situation brings about the uncertainty in the cost involving the change from the traditional supply chain to green supply chain. The fuzzy variables used in the analysis models are shown in Table 6.1 consisting of the fuzzy costs of production of the farmers $(PRC_{fs}^{green}, PRC_{gs})$, the fuzzy costs of waste management of the farmers (DC_{fs}, DC_{gs}), the fuzzy of the transportation costs of the farmers (TRC_{fas}, TRC_{gas}), the transportation costs of the assemblers (TRC_{aps}), the waste management cost of the processor (DC_p), the fuzzy inventory capacity of the processor (TRC_{aps}), and the fuzzy consumer demand (D_m). The fuzzy mixed-integer linear programming (FMILP) is selected to analyze the GCSC optimization because the nature of the data is complex with raw data and integer data that has been chosen between 1 and 0.

Moreover, the linguistic terms of research have established the triangular fuzzy numbers, which are the three possible values, so the analysis of the model with fuzzy data has to transform the fuzzy numbers into crisp numbers. This research applies the method of Jiménez et al. (2007) and Peidro et al. (2010) to convert the data. The approach of transformation is as follows:

Let the linear programming problem with fuzzy parameters in this research be expressed as in Equation (6.1).

Table 6.1 Fuzzy variables considered in the models

Node	Fuzzy variable	Symbol	Used in
Farmers	Production cost	PRC_{fs}^{green}	Model A1
		PRC_{gs}	Model A2
	Waste management cost	DC_{fs}	Model A1
		DC_{gs}	Model A2
	Transportation cost	TRC_{fas}	Model A1
		TRC_{gas}	Model A2
Assemblers	Transportation cost	TRC_{aps}	Model A1, A2
Processor	Inventory capacity	$\tilde{I}_{p}^{capacity}$	Model A1, A2
	Waste management cost	DC_{p}	Model A1, A2
	Consumer demand	D_{m}	Model A1, A2

Source: Author's analysis.

Note: Model A1 and Model A2 represent the non-GCSC and GCSC models, respectively, that are mentioned in Chapter 3.

$$\begin{aligned} &Min\ \mathrm{Z} = \tilde{C}'X \\ &s.t.\ \ X \in N(a,\tilde{b}) \\ &\quad\ aX \geq \tilde{b} \\ &\quad\ X \geq 0 \end{aligned} \tag{6.1}$$

where $\tilde{C} = (\tilde{C}_1, \tilde{C}_2, ..., \tilde{C}_n)$ and $\tilde{b} = (\tilde{b}_1, \tilde{b}_2, ..., \tilde{b}_n)^t$ are the fuzzy parameters concerning the objective function and constraints, respectively, $a = \left[a_{ij} \right]_{m \times n}$ is the non-fuzzy parameter and $X = (X_1, X_2, ..., X_n)$ is the crisp decision vector.

For applying the Jiménez et al. (2007) and Peidro et al. (2010) approaches, the Equation (6.1) is transformed into the crisp equivalent parametric linear programming shown in Equation (6.2) where α is the feasibility degree of a decision *X*.

$$\begin{aligned} &Min\ E\left(\tilde{C}\right)X \\ &s.t.\ \ aX \geq \alpha E_2(b) + (1-\alpha)E_1(b) \\ &\quad\ X \geq 0 \\ &\quad\ \alpha \in \{0,1\} \end{aligned} \tag{6.2}$$

where $E(\bullet)$ represents the expected value of the fuzzy number that is the half point of expected interval assessed by:

$$E(\bullet) \;=\; \frac{E_1(\bullet)+E_2(\bullet)}{2} \tag{6.3}$$

and if the fuzzy costs in this research, $\tilde{C}$, is the triangular fuzzy numbers (mentioned in Chapter 5), the expected value is calculated as follows:

$$E(\tilde{C}) \;=\; \frac{C_1+C_2+C_3}{3} \tag{6.4}$$

Considering the fuzzy constraint, it could be transformed into the equivalent crisp constraint as follows:

$$aX \;\le\; (1-\alpha)\left(\frac{b_3+b_2}{2}\right)+\alpha\left(\frac{b_2+b_1}{2}\right) \tag{6.5}$$

6.2.1 Operational optimization in the non-GCSC model

In the case of non-GCSC model, conventional model, each farmer has independently produced and sold his coffee products, the objective equation of the model shown in Equation (3.11) in Chapter 3 contains the fuzzy cost data. The transformation of the fuzzy numbers into the crisp numbers by applying the methods of Jiménez et al. (2007) and Peidro et al. (2010) is shown in Equation (6.6).

$$\begin{aligned}
\min\ TC \;=\; & \sum_f \sum_s \left[\frac{(PRC_{fs1}^{green}+PRC_{fs2}^{green}+PRC_{fs3}^{green})}{3} + \frac{DC_{fs1}^{green}+DC_{fs2}^{green}+DC_{fs3}^{green}}{3} \right] \cdot Q_{fs} \\
& + \sum_f \sum_a \sum_s \left[\frac{(TRC_{fas1}^{green}+TRC_{fas2}^{green}+TRC_{fas3}^{green})}{3} \right] \cdot TR_{fas} \cdot \gamma_s + \sum_a \sum_s IC_{as} \cdot I_{as} \\
& + \sum_a \sum_p \sum_s \left[\frac{(TRC_{aps1}^{green}+TRC_{aps2}^{green}+TRC_{aps3}^{green})}{3} \right] \cdot TR_{aps} + IC_p \cdot I_p \\
& + \left[PRC_p + \frac{DC_{p1}^{green}+DC_{p2}^{green}+DC_{p3}^{green}}{3} \right] \cdot Q_p
\end{aligned} \tag{6.6}$$

For the restricted equations, there are the fuzzy data in equations (3.16) and (3.20); so when they are translated from fuzzy numbers into crisp numbers, the new forms are as shown in equations (6.7) and (6.8).

$$\sum_{a}\sum_{p}\sum_{s} TR_{aps} \;\leq\; (1-\alpha)\frac{I_{p2}^{capacity}+I_{p3}^{capacity}}{2}+(\alpha)\frac{I_{p2}^{capacity}+I_{p1}^{capacity}}{2} \qquad (6.7)$$

$$Q_{p} \;\geq\; (1-\alpha)\frac{D_{m2}+D_{m3}}{2}+(\alpha)\frac{D_{m1}+D_{m2}}{2} \qquad (6.8)$$

This research determines the value of the restricted equation used for analyzing the non-GCSC model (model A1) as shown in Table 6.2. The ability of individual farmer to produce parchment coffee for delivering to the RPF ($Q_{fs}^{capacity1}$) and overall parchment coffee ($Q_{fs}^{capacity2}$) are shown in Appendix E. The ability to store the parchment coffee inventory of the Pamiang RPDC ($I_{a1}^{capacity}$) and the Pang Ma-O RPEC ($I_{a2}^{capacity}$) are around 15,000 kilograms. Meanwhile, the fuzzy restricted variables consisting of the ability of the RPF to store the inventory ($\tilde{I}_{p}^{capacity}$) and the demand of consumers for green coffee beans ($\tilde{D}_{m}$) are equal to (25,000, 30,000, 35,000) kilograms of parchment coffee and (12,000, 15,000, 20,000) kilograms of green coffee beans, respectively.

Table 6.2 Information of the constraint variables in the non-GCSC model

Variables	Symbols	Value
The ability of the farmers to produce parchment coffee for delivering to the RPF	$Q_{fs}^{capacity1}$	Shown in Appendix E
The ability of the farmers to produce overall parchment coffee	$Q_{fs}^{capacity2}$	Shown in Appendix E
The ability of the assemblers to store the inventory	$I_{a1}^{capacity}$	15,000 kg parchment coffee
	$I_{a2}^{capacity}$	15,000 kg parchment coffee
The ability of the RPF to store the inventory	$\tilde{I}_{p}^{capacity}$	(25,000, 30,000, 35,000) kg parchment coffee
Demand of the consumer to coffee bean	$\tilde{D}_{m}$	(12,000, 15,000, 20,000) kg green coffee beans

Source: Analyzing.

Results are analyzed by using the fuzzy mixed integer linear programming (FMILP) to determine the proper operation in the supply chain. The objective function in the Equation (6.6) subject to the restrictions in Equations (3.12) - (3.15), (3.17) - (3.19), (3.21) - (3.22), and (6.7) - (6.8) are implemented and the defined feasible degree (α) in the range from 0 to 1, are shown in Table 6.3.

Table 6.3 The optimal operation under the non-GCSC model

Feasible degree (α)	Area	Decision variable (kg product)						Total cost (Baht)
		$\sum Q_{f1}$, $\sum Q_{f2}$	$\sum TR_{fa1}$, $\sum TR_{fa2}$	I_{a1}, I_{a2}	TR_{ap1}, TR_{ap2}	I_p	Q_p	
0.0	Pamiang	13,325	13,325	-	13,325	2,000	17,500	1,668,854
	Pang Ma-O	10,550	10,550	-	10,550			
0.1	Pamiang	12,825	12,825	-	12,825	2,000	17,100	1,640,892
	Pang Ma-O	10,550	10,550	-	10,550			
0.2	Pamiang	12,325	12,325	-	12,325	2,000	16,700	1,613,635
	Pang Ma-O	10,550	10,550	-	10,550			
0.3	Pamiang	11,825	11,825	-	11,825	2,000	16,300	1,588,355
	Pang Ma-O	10,550	10,550	-	10,550			
0.4	Pamiang	11,325	11,325	-	11,325	2,000	15,900	1,563,711
	Pang Ma-O	10,550	10,550	-	10,550			
0.5	**Pamiang**	**10,923**	**10,923**	-	**10,923**	**2,000**	**15,500**	**1,545,254**
	Pang Ma-O	**10,550**	**10,550**	**98**	**10,452**			
0.6	Pamiang	10,923	10,923	-	10,923	2,000	15,100	1,547,634
	Pang Ma-O	10,550	10,550	598	9,952			
0.7	Pamiang	10,923	10,923	-	10,923	2,000	14,700	1,550,014
	Pang Ma-O	10,550	10,550	1,098	9,452			
0.8	Pamiang	10,923	10,923	-	10,923	2,000	14,300	1,552,394
	Pang Ma-O	10,550	10,550	1,598	8,952			
0.9	Pamiang	10,923	10,923	-	10,923	2,000	13,900	1,554,774
	Pang Ma-O	10,550	10,550	2,098	8,452			
1.0	Pamiang	10,923	10,923	-	10,923	2,000	13,500	1,557,154
	Pang Ma-O	10,550	10,550	2,598	7,952			

Source: Calculated.

The form of the optimal operation of the Arabica coffee under the non-GCSC model (model A1) brings about the cost minimization at the feasible degree (α) of 0.5. Considering the details, the demand for green coffee beans about 15,500 kilograms at the RPF level has to use the parchment coffee as raw materials from Pamiang and Pang Ma-O areas around 10,923 and 10,550 kilograms, respectively. The farmers in both areas would delivery their parchment coffee to the assemblers, the Pamiang RPDC and the Pang Ma-O RPEC. The Pamiang RPDC would not store the parchment coffee whereas the Pang Ma-O RPEC would transport 10,452 kilograms of parchment coffee to the RPF and store the rest. In terms of the RPF, the minimum storage level of parchment coffee is set around 2,000 kilograms for preventing the stock run-out problem and the rest is transformed into green coffee bean products for delivery to the consumers. The operations of the farmers, the assemblers and the RPF result in the cost minimization of supply chain approximately 1,545,254 baht.

In addition, the results in Table 6.3 also suggest that if the feasible degree (α) increases, the demand for green coffee beans, which is the fuzzy number $(\tilde{D}_m)$ and the amount of green coffee bean production of the RPF to fulfill the consumer orders (Q_p) will decrease. This phenomena results in the increase of parchment coffee inventory in Pang Ma-O area, but no inventory is stored in Pamiang area. The main reason is the distance of transportation from the product gathering area to the RPF coffee processing plant. Because the road distance from Pang Ma-O area is farther than from Pamiang area, the transportation cost per kilogram of Pang Ma-O parchment coffee is higher than the case of Pamiang. Consequently, the optimization procedure for cost minimization would firstly select the Pamiang parchment coffee before the otherwise leading to the storing of parchment coffee inventory to be remained at the Pang Ma-O RPEC. However, the volume of transportation of the parchment coffee will increase if the demand for green coffee beans increases. The optimal operation can be summarized as in Figure 6.1.

The findings of the operational optimization in the non-GCSC model are compared with GCSC model in the next section.

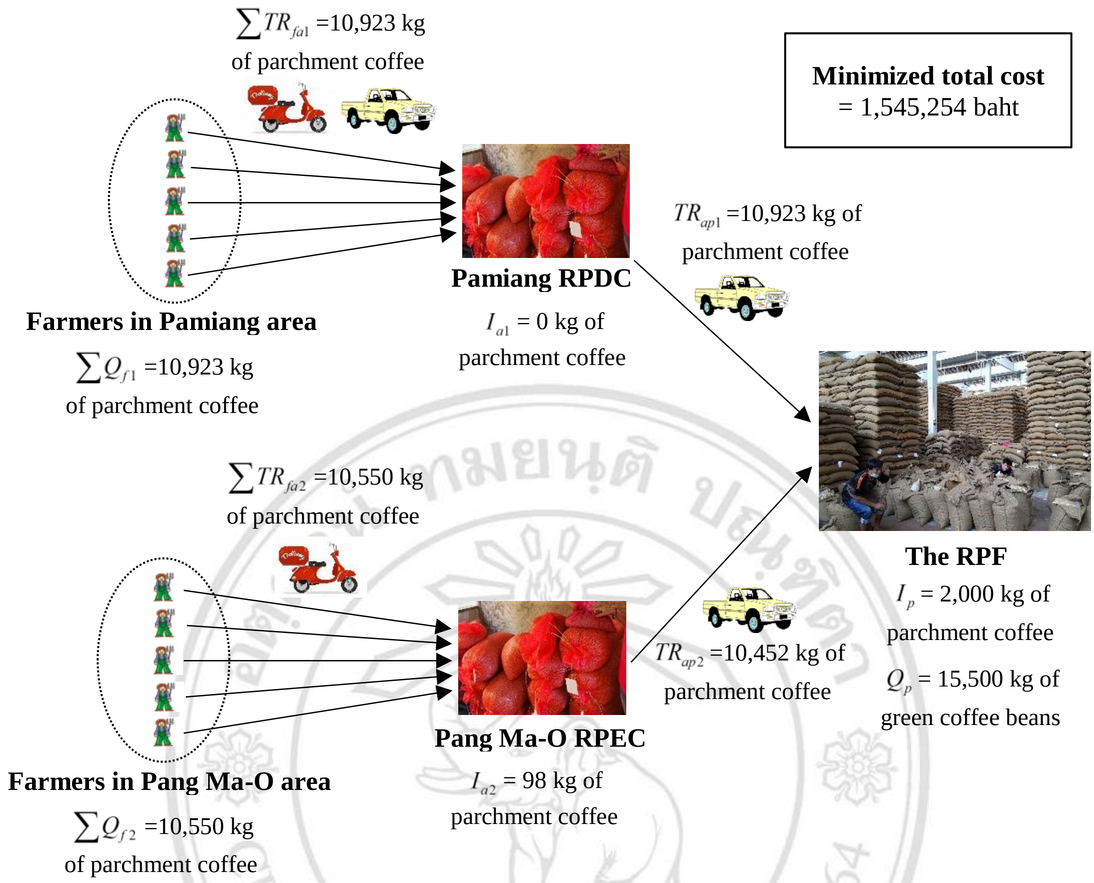


Figure 6.1 Operational optimization in the non-GCSC model

6.2.2 Optimal operation in the GCSC model

In the second case that is mentioned in Chapter 5, the farmers have horizontally collaborated in their areas and sold their products only in their own communities. This way is involved in closely working together among the farmers in planning and implementing to achieve the main goals and mutual benefits, such as information sharing, joint decision, resource sharing and joint transportation by establishing the group of the farmers. This research assumed that horizontal collaboration would lead to the reduction in the production; waste disposal costs around 20%, and the decrease in the transportation cost approximately 50%.

The conversion of the fuzzy to crisp numbers of objective Equation (3.23) is as shown in Equation (6.9).

$$
\begin{aligned}
\min\ TC \ =\ & \sum_{g}\sum_{s}\left[\frac{(PRC_{gs1}^{green}+PRC_{gs2}^{green}+PRC_{gs3}^{green})}{3}+\frac{DC_{gs1}^{green}+DC_{gs2}^{green}+DC_{gs3}^{green}}{3}\right]\cdot Q_{gs} \\
& +\sum_{g}\sum_{a}\sum_{s}\left[\frac{(TRC_{gas1}^{green}+TRC_{gas2}^{green}+TRC_{gas3}^{green})}{3}\right]\cdot TR_{gas}\cdot\gamma_{s}+\sum_{a}\sum_{s}IC_{as}\cdot I_{as} \\
& +\sum_{a}\sum_{p}\sum_{s}\left[\frac{(TRC_{aps1}^{green}+TRC_{aps2}^{green}+TRC_{aps3}^{green})}{3}\right]\cdot TR_{aps}+IC_{p}\cdot I_{p} \qquad (6.9) \\
& +\left[PRC_{p}+\frac{DC_{p1}^{green}+DC_{p2}^{green}+DC_{p3}^{green}}{3}\right]\cdot Q_{p}
\end{aligned}
$$

The information on the restriction variables for analyzing the optimized operation in the GCSC model (model A2) is shown in Table 6.4.

Table 6.4 Information on the constraint variables in the GCSC model

Variable	Symbol	Value
The ability of farmer cluster to produce parchment coffee	$Q_{g1}^{capacity}$	21,560 kg parchment coffee
	$Q_{g2}^{capacity}$	10,550 kg parchment coffee
The ability of assemblers to store the inventory	$I_{a1}^{capacity}$	15,000 kg parchment coffee
	$I_{a2}^{capacity}$	15,000 kg parchment coffee
The ability of RPF to store the inventory	$\tilde{I}_{p}^{capacity}$	(25,000, 30,000, 35,000) kg parchment coffee
Demand of consumer to green coffee beans	$\tilde{D}_{m}$	(12,000, 15,000, 20,000) kg green coffee beans

Source: Author analyzing.

Because of the horizontal collaboration among the farmers in each area as the cluster, the ability to produce parchment coffee of farmer clusters in Pamiang area $(Q_{g1}^{capacity})$ and Pang Ma-O area $(Q_{g2}^{capacity})$ are equal to 21,560 and 10,550 kilograms of parchment coffee, respectively. Meanwhile, the ability to store parchment coffee inventory of the Pamiang RPDC $(I_{a1}^{capacity})$ and the Pang Ma-O RPEC $(I_{a2}^{capacity})$, the ability of the RPF to store the inventory $(\tilde{I}_{p}^{capacity})$ and demand of consumers for green coffee beans $(\tilde{D}_{m})$ are the same as in the non-GCSC model.

The optimization analysis of the objective equation (6.9) by using FMILP method under the restrictions in equation (3-15), (3.17) - (3.19), (3.21), (3.24) - (3.27) and (6.7) - (6.8), and the defined feasible degree (α) between 0 and 1, are shown in Table 6.5.

Table 6.5 Optimal operation under the GCSC model

Feasible degree (α)	Area	Decision variable (kg product)						Total cost (Baht)
		Q_{g1}, Q_{g2}	TR_{ga1}, TR_{ga2}	I_{a1}, I_{a2}	TR_{ap1}, TR_{ap2}	I_p	Q_p	
0.0	Pamiang	13,325	13,325	-	13,325	2,000	17,500	1,381,278
	Pang Ma-O	10,550	10,550	-	10,550			
0.1	Pamiang	12,825	12,825	-	12,825	2,000	17,100	1,354,253
	Pang Ma-O	10,550	10,550	-	10,550			
0.2	Pamiang	12,325	12,325	-	12,325	2,000	16,700	1,327,228
	Pang Ma-O	10,550	10,550	-	10,550			
0.3	Pamiang	11,825	11,825	-	11,825	2,000	16,300	1,300,203
	Pang Ma-O	10,550	10,550	-	10,550			
0.4	Pamiang	11,325	11,325	-	11,325	2,000	15,900	1,273,178
	Pang Ma-O	10,550	10,550	-	10,550			
0.5	**Pamiang**	**10,923**	**10,923**	**-**	**10,923**	**2,000**	**15,500**	**1,251,858**
	Pang Ma-O	**10,550**	**10,550**	**98**	**10,452**			
0.6	Pamiang	10,923	10,923	-	10,923	2,000	15,100	1,254,238
	Pang Ma-O	10,550	10,550	598	9,952			
0.7	Pamiang	10,923	10,923	-	10,923	2,000	14,700	1,256,618
	Pang Ma-O	10,550	10,550	1,098	9,452			
0.8	Pamiang	10,923	10,923	-	10,923	2,000	14,300	1,258,998
	Pang Ma-O	10,550	10,550	1,598	8,952			
0.9	Pamiang	10,923	10,923	-	10,923	2,000	13,900	1,261,378
	Pang Ma-O	10,550	10,550	2,098	8,452			
1.0	Pamiang	10,923	10,923	-	10,923	2,000	13,500	1,263,758
	Pang Ma-O	10,550	10,550	2,598	7,952			

Source: Calculated.

Table 6.5 shows the form of optimal operation of the GCSC of Arabica coffee under the GCSC model resulting in the minimized cost at the feasible degree (α) of 0.5 and considering the demand for green coffee beans at 15,500 kilograms at the RPF level. In this case, the collaboration among the farmers in each area leads to the reduction in production cost because the farmers buy large amount of fertilizers and other inputs bringing about the lower price and discount while the farmers have also jointly prepared wastewater treatment systems or managed the waste from coffee cherries peels together contributing to the reduction in cost of waste disposal. Moreover, the sharing of processing or drying spaces enables the farmers to jointly transport their coffee products to the assemblers leading to time saving and transportation cost reduction.

Thus, the optimal operation from the farmer cluster's functioning in each area results in the minimized cost of 1,251,858 baht with 10,922 kilograms of parchment coffee in Pamiang area and 10,550 kilograms of parchment coffee in Pang Ma-O area to be delivered to their assemblers in each area. The Pamiang RPDC would transport all the collected parchment coffee to the RPF whereas the Pang Ma-O RPEC would send 10,453 kilograms of parchment coffee to the RPF and store the rest at the center. The RPF would process the parchment coffee into green coffee beans for delivery to the consumers by retaining 2,000 kilograms of parchment coffee as inventory to prevent stock run-out. The optimal operation in the GCSC can be summarized as in Figure 6.2.

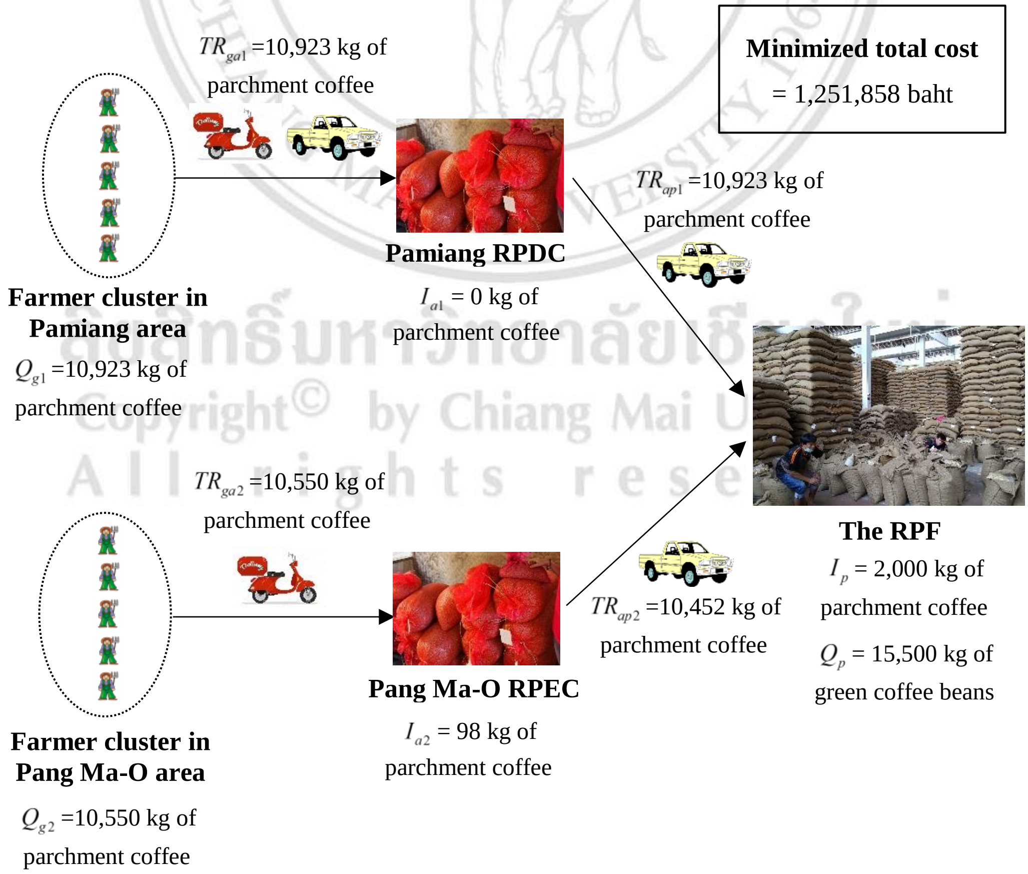


Figure 6.2 Operational optimization in the GCSC model

6.2.3 Comparison between non-GCSC and GCSC models in the operational perspective

The results of the non-GCSC model in Section 6.2.1 and the GCSC model in Section 6.2.2 are compared to find the most suitable model. The finding indicates that although the decision variables, such as the amount of parchment coffee of the farmers, the amount of parchment coffee transported from the farmers to the assemblers, the amount of the parchment coffee transported from the assembler to the RPF, the amount of the parchment coffee inventory of the assembler, the amount of the parchment coffee inventory of the RPF, and the amount of green coffee beans of the RPF, of both models are alike, the costs of them are not the same. The horizontal collaboration among the farmers to share the information, share the resources, jointly make the decision and co-transport via the establishment of the farmer group leads to the reduction in the production costs, the waste disposal costs and the transportation cost.

Table 6.6 shows the GCSC model bringing about the minimized cost at all levels of the feasible degree (α). Thus, the findings can be concluded that the optimal model of the Arabica coffee supply chain is the GCSC model that involves the collaboration among coffee farmers in each area.

Table 6.6 Comparison of the optimal operations between non-GCSC and GCSC models

Feasible degree	Total cost (Baht)	
(α)	Non-GCSC model	GCSC model
0.0	1,668,854	1,381,278
0.1	1,640,892	1,354,253
0.2	1,613,635	1,327,228
0.3	1,588,355	1,300,203
0.4	1,563,711	1,273,178
0.5	**1,545,254**	**1,251,858**
0.6	1,547,634	1,254,238
0.7	1,550,014	1,256,618
0.8	1,552,394	1,258,998
0.9	1,554,774	1,261,378
1.0	1,557,154	1,263,758

Source: Calculated.

6.3 Revenue sharing in the GCSC

Section 6.2 analyzes the optimal operation of the GCSC of Arabica coffee in the highland. The pattern of cluster used for setting the scenarios is the horizontal collaboration of the farmers causing the minimized total cost of the supply chain. Thus, in Section 6.3, the cluster in the form of the coordination between the farmers, the assemblers, and the RPF through the value sharing mechanism by using revenue sharing contracts as a tool to create the vertical cluster of the actors in the supply chain. The models used to analyze each scenario have extended the methods of Giannoccaro and Pontrandolfo (2004) representing the revenue sharing between one producer, one distributor and one retailer in the supply chain to the supply chains of various farmers, two assemblers, and one processor under the scenarios in Section 6.2. Thus, the results are divided into models, such as non-GCSC model without the revenue sharing contracts and the GCSC model with the revenue sharing contracts.

6.3.1 Profits in the non-GCSC model without revenue sharing contracts

In the case of no cluster and revenue sharing contracts in the highland Arabica coffee supply chain, the farmers, the assemblers and the RPF independently do their activities in supply chain to achieve their maximized profit. Thus, each farmer in Pamiang and Pang Ma-O areas would sell his parchment coffee in the quantities of q_{f1i} and q_{f2i} with the unit prices of p_{f1i} and p_{f1i} given by the assemblers and the RPF. After subtracting the production costs (c_{f1i}, c_{f2i}), the profits (π_{f1i}, π_{f2i}) of the farmers are equal to $p_{f1i}q_{f1i} - c_{f1i}q_{f1i}$ and $p_{f2i}q_{f2i} - c_{f2i}q_{f2i}$, respectively.

The assembler in each area would deliver the parchment coffee to the RPF. Therefore, the amounts of the parchment coffee transported to the RPF are about q_{a1}, q_{a2} with the prices p_{a1}, p_{a2} given by the RPF. After subtracting the costs of parchment coffee purchasing from the farmers in each area, $\sum p_{f1i}q_{f1i}, \sum p_{f2i}q_{f2i}$, and the cost of assemblers (c_{a1}, c_{a2}), the profits of the assemblers (π_{a1}, π_{a2}) are equal to $p_{a1}q_{a1} - \sum p_{f1i}q_{f1i} - c_{a1}q_{a1}$ and $p_{a2}q_{a2} - \sum p_{f2i}q_{f2i} - c_{a2}q_{a2}$, respectively.

The RPF would do processing to produce green coffee beans following the customers' orders. Based on the amount of parchment coffee obtained from the assemblers, the quantity of green coffee beans after transforming from parchment coffee into green coffee beans is equal to q_p with the purchasing cost from Pamiang and Pang Ma-O areas, $p_{a1}q_{a1}$ and $p_{a2}q_{a2}$, and production cost of green coffee beans, c_p. Thus, under the green coffee beans price, p_p, the profit of the RPF (π_p) is equal to $p_p q_p - p_{a1}q_{a1} - p_{a2}q_{a2} - c_p q_p$. The profits of the farmers, the assemblers, the RPF, and the supply chain are shown in Table 6.7.

Table 6.7 Profits in the non-GCSC model without revenue sharing contracts

Unit: Baht per kg of product

Supply chain	Profit for			
	Farmer	Assembler	RPF	Supply chain
Supply chain 1: Pamiang	34.78	12.75	31.80	79.33
Supply chain 2: Pang Ma-O	31.73	12.65	31.80	76.18
Average profits	33.28	12.70	31.80	77.78

Source: Calculated.

Table 6.7 shows the case in which the farmers do their activities, such as purchasing inputs by themselves, do no information sharing, and sell their outputs without cooperation, their costs of purchasing inputs and production, and their selling prices are different. The total profit of all farmers in Pamiang area is equal to 34.78 baht per kilogram, while the total profit of all sample farmers in Pang Ma-O is equal to 31.73 baht per kilogram. The supply chain profit is approximately 77.78 baht per kilogram.

6.3.2 Profits in the GCSC model with revenue sharing contracts

In this case, the farmers work in cooperation with other parties only in their communities. The scenario is simulated by letting the farmers group together and share the information with respect to both volume and price of coffee products resulting in single selling price of parchment coffee of the farmer cluster in each area (p_{f1}, p_{f2}).

In addition, the scenario also has set the revenue sharing contracts between the farmer clusters, the assemblers, and the RPF by defining the independency between supply chains in the two areas. So, the revenue of the RPF, $p_p q_p$, after deducting the share to the assemblers, ϕ_p, is the remaining portion for itself about $(1-\phi_p)$. The revenue sharing proportion from the RPF is divided between the assemblers in Pamiang and Pang Ma-O areas with the proportions of $\alpha\phi_p$ and $(1-\alpha)\phi_p$, respectively. In terms of the assembler in Pamiang area, its revenue $(p_{a1}q_{a1})$ would be shared by the farmers in the area with the proportion of ϕ_{a1} leaving its proportion to be received about $(1-\phi_{a1})$. At the same time, the assembler in Pang Ma-O would share its revenue to the farmer clusters in the area at the amount of ϕ_{a2}, thus getting the net revenue around $(1-\phi_{a1})p_{a2}q_{a2}$. The revenue sharing contracts in the Arabica coffee supply chain result in the profit of the RPF at about $(1-\phi_p)(p_p q_p) - p_{a1}q_{a1} - p_{a2}q_{a2} - c_p q_p$, whereas the assemblers in Pamiang and Pang Ma-O areas would receive the profit around $(1-\phi_{a1})\left[p_{a1}q_{a1} + \alpha\phi_p(p_p q_p)\right] - p_{f1}q_{f1} - c_{a1}q_{a1}$ and $(1-\phi_{a2})\left[p_{a2}q_a + (1-\alpha)\phi_p(p_p q_p)\right] - p_{f2}q_{f2} - c_{a2}q_{a2}$, respectively. For the farmer clusters, the farmer cluster in Pamiang would gain $p_{f1}q_{f1} + \phi_{a1}\left[p_{a1}q_{a1} + \alpha\phi_p(p_p q_p)\right] - c_{f1}q_{f1}$ whereas the profit of the farmer cluster in Pang Ma-O area is equal to $p_{f2}q_{f2} + \phi_{a2}\left[p_{a2}q_{a2} + (1-\alpha)\phi_p(p_p q_p)\right] - c_{f2}q_{f2}$. The profits of the farmer clusters, the assemblers, the RPF, the supply chain are shown in Tables 6.8 - 6.10.

The results from the value sharing analysis lead to the optimal proportion of the share value from the RPF to the assemblers and from the assemblers to the farmer clusters. In Table 6.8, let the weight of value share from RPF to Pamiang and Pang Ma-O assemblers be equal to $(\alpha = 0.5)$, there are 8 feasible alternative contracts which do not cause the losses of all three parties. The decision regarding contract selection depends on the goal of the stakeholders in supply chain. If the goal of the supply chain is the profit maximization of the farmers in Pamiang and Pang Ma-O areas, the appropriate contracts of revenue sharing are associated with the share of revenue about 10% from the RPF to the assemblers and 10% from the assemblers to the farmer clusters. These contracts bring about the maximized profit of the farmer clusters in Pamiang and Pang Ma-O areas at 60.34 and 58.50 baht per kilogram, respectively. When comparing with the farmer clusters' profits in the non-GCSC model, mentioned in the Section 6.3.1, the revenue sharing contracts contribute to the higher profits about 73.49% for the Pamiang farmer cluster and 85.31% for Pang Ma-O farmer cluster. The appropriate contracts of revenue sharing under the goal of profit maximization of the farmers are shown in Figure 6.3.

Table 6.8 Profits in the GCSC with revenue sharing contracts model

(Let $\alpha = 0.50$)

Unit: Baht per kg of product

Proportion of sharing			Area	Profit of			
ϕ_p	ϕ_{a1}	ϕ_{a2}		Farmer cluster	Assembler	RPF	Supply chain
0.00	0.00	0.10	Pamiang	47.46	12.75	31.80	91.20
			Pang Ma-O	57.92	0.64		
0.00	0.10	0.00	Pamiang	59.46	0.75	31.80	91.20
			Pang Ma-O	45.92	12.64		
0.00	**0.10**	**0.10**	**Pamiang**	**59.46**	**0.75**	**31.80**	**91.20**
			Pang Ma-O	**57.92**	**0.64**		
0.10	0.00	0.00	Pamiang	47.46	21.55	9.80	73.67
			Pang Ma-O	45.92	12.64		
0.10	0.00	0.10	Pamiang	47.46	21.55	9.80	74.10
			Pang Ma-O	58.80	0.64		
0.10	0.10	0.00	Pamiang	60.34	8.67	9.80	73.67
			Pang Ma-O	45.92	12.64		
0.10	**0.10**	**0.10**	**Pamiang**	**60.34**	**8.67**	**9.80**	**74.10**
			Pang Ma-O	**58.80**	**0.64**		

Source: Calculated.

However, although the result from revenue sharing mentioned in Table 6.8 and Figure 6.3 brings about the increasing profit of the farmer cluster, the supply chain profit decreases. Considering in another view, if the goal of supply chain is the profit maximization of the supply chain, the suitable form of revenue sharing is only the share of revenue about 10% from the assemblers to the farmer clusters. The farmer clusters in Pamiang and Pang Ma-O areas would gain the profit at about 59.46 and 57.92 baht per kilogram, respectively. The revenue sharing contracts bring about the maximized profit in supply chain at 91.20 baht per kilogram that is higher than the supply chain profit in the non-GCSC situation (Table 6.7) approximately 17.71%. Figure 6.4 shows the proper revenue sharing contracts under the goal of profit maximization of the supply chain.

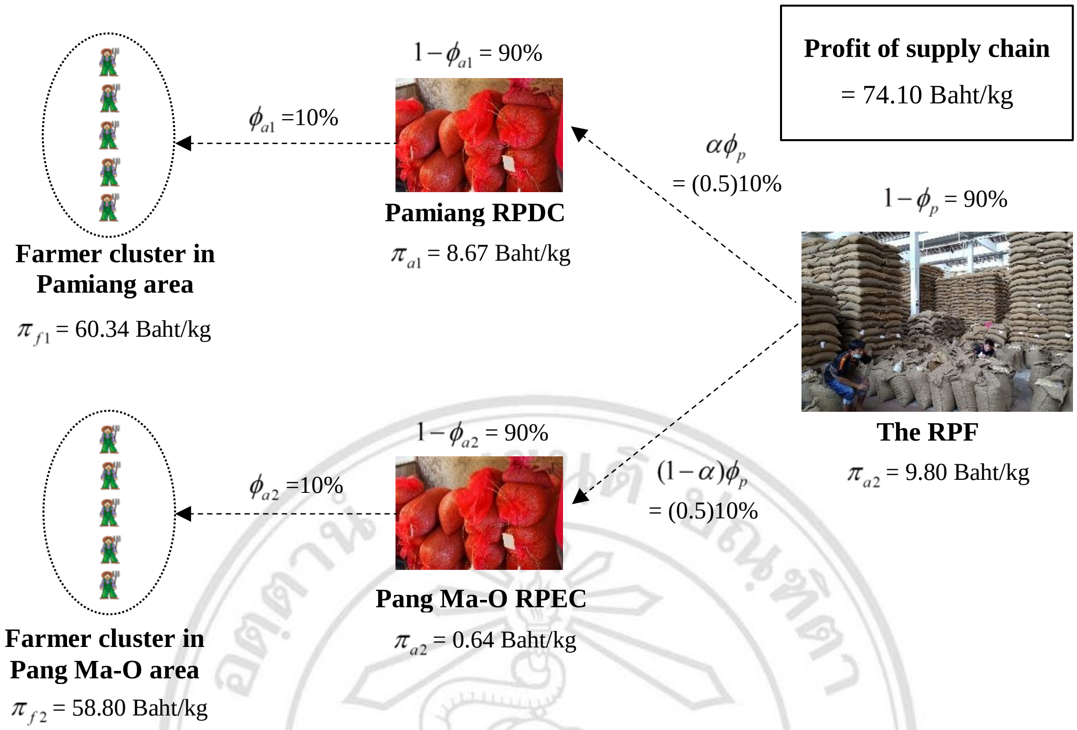


Figure 6.3 Appropriate revenue sharing contracts under the goal of profit maximization of the farmers

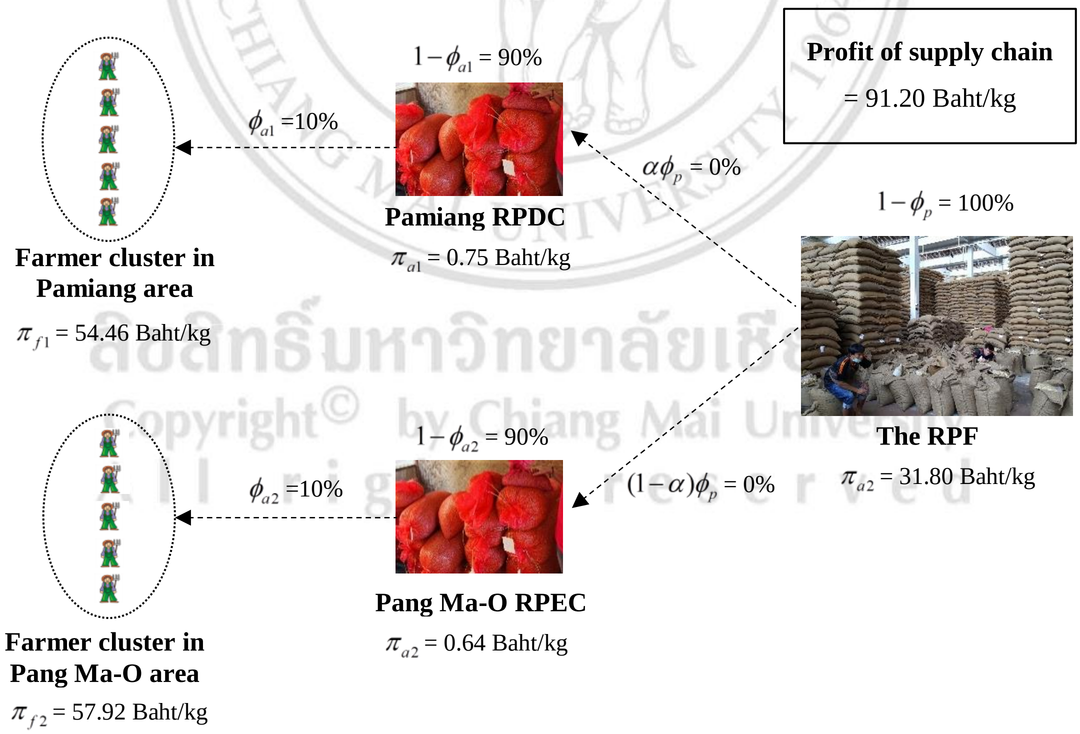


Figure 6.4 Appropriate revenue sharing contracts under the goal of profit maximization of the supply chain

Apart from the equal weight of revenue sharing (α) from the RPF to the assemblers in the two areas mentioned above, this research has defined the different weights of revenue sharing between two areas (Tables 6.9 and 6.10).

When letting $\alpha = 0.25$, the results in Table 6.9 show that for the goal of the profit maximization of the farmers, the proper pattern of revenue sharing contract is the revenue share about 10% from the RPF to the assemblers and 10% from the assemblers to the farmer clusters bringing about the maximized profit of Pamiang and Pang Ma-O farmer clusters around 59.90 and 59.24 baht per kilogram, respectively, and the profit of supply chain around 72.08 baht per kilogram. On the other hand, if the goal of GCSC is the supply chain profit maximization, the suitable form of revenue sharing contracts is the revenue share about 10% only from the assemblers to the farmer clusters resulting in the maximized profit of supply chain at 91.20 baht per kilogram.

Table 6.9 Profits in the GCSC with revenue sharing contracts model (Let $\alpha = 0.25$)

Unit: Baht per kg of product

Proportion of sharing			Area	Profit of			
ϕ_r	ϕ_a	ϕ_b		Farmer cluster	Assembler	RPF	Supply chain
0.00	0.00	0.10	Pamiang	47.46	12.75	31.80	91.20
			Pang Ma-O	57.92	0.64		
0.00	0.10	0.00	Pamiang	59.46	0.75	31.80	91.20
			Pang Ma-O	45.92	12.64		
0.00	**0.10**	**0.10**	**Pamiang**	**59.46**	**0.75**	**31.80**	**91.20**
			Pang Ma-O	**57.92**	**0.64**		
0.10	0.00	0.00	Pamiang	47.46	17.15	9.80	71.43
			Pang Ma-O	45.92	12.64		
0.10	0.00	0.10	Pamiang	47.46	17.15	9.80	72.08
			Pang Ma-O	59.24	0.64		
0.10	0.10	0.00	Pamiang	59.90	4.71	9.80	71.43
			Pang Ma-O	45.92	12.64		
0.10	**0.10**	**0.10**	**Pamiang**	**59.90**	**4.71**	**9.80**	**72.08**
			Pang Ma-O	**59.24**	**0.64**		

Source: Calculated.

Moreover, when letting $\alpha = 0.75$, the results in Table 6.10 demonstate that in Pamiang and Pang Ma-O areas, the suitable pattern of revenue sharing contract is the revenue share about 10% from the RPF to the assemblers and 10% from the assemblers to the farmer clusters resulting in the maximized profit of the farmer clusters in Pamiang area about 60.78 baht per kilogram, the maximized profit of the farmer clusters in Pang Ma-O area at about 58.36 baht per kilogram, and the profit of supply chain around 76.13 baht per kilogram. However, if the goal of an agreement to share revenue is the highest profit in the supply chain, the right form of revenue sharing is only 10% of revenue share from the assemblers to the farmer clusters. The total profit of supply chain is equal to 91.20 baht per kilogram when letting $\alpha = 0.75$.

Table 6.10 Profits in the GCSC with revenue sharing contracts model (Let $\alpha = 0.75$)

Unit: Baht per kg of product

Proportion of sharing			Area	Profit of			
ϕ_r	ϕ_a	ϕ_b		Farmer cluster	Assembler	RPF	Supply chain
0.00	0.00	0.10	Pamiang	47.46	12.75	31.80	91.20
			Pang Ma-O	57.92	0.64		
0.00	0.10	0.00	Pamiang	59.46	0.75	31.80	91.20
			Pang Ma-O	45.92	12.64		
0.00	**0.10**	**0.10**	**Pamiang**	**59.46**	**0.75**	**31.80**	**91.20**
			Pang Ma-O	**57.92**	**0.64**		
0.10	0.00	0.00	Pamiang	47.46	25.95	9.80	75.91
			Pang Ma-O	45.92	12.64		
0.10	0.00	0.10	Pamiang	47.46	25.95	9.80	76.13
			Pang Ma-O	58.36	0.64		
0.10	0.10	0.00	Pamiang	60.78	12.63	9.80	75.91
			Pang Ma-O	45.92	12.64		
0.10	**0.10**	**0.10**	**Pamiang**	**60.78**	**12.63**	**9.80**	**76.13**
			Pang Ma-O	**58.36**	**0.64**		

Source: Calculated.

6.3.3 Optimal revenue sharing model for highland Arabica coffee supply chain

From the two models above, when comparing the best results of each model to choose the best form of revenue sharing contracts, the result in Table 6.11 indicates that if the goal of the contracts is profit maximization of the farmers, the GCSC model with the revenue sharing contracts, which is the 10% of revenue share from the RPF to the assemblers and the 10% of the assemblers to the farmer cluster, is the best choice. However, this alternative model brings about the reduction in supply chain profit that indicates the decrease in total social welfare and total benefit. Thus, the orientation toward farmers' profit maximization is not the best choice for participation agreement.

Table 6.11 Optimal revenue sharing model for highland Arabica coffee supply chain

Unit: Baht per kg of product

Model	Proportion of sharing			Profit of			
	ϕ_p	ϕ_{a1}	ϕ_{a2}	Farmer cluster	Assembler	RPF	Supply chain
Non-GCSC	0.0	0.0	0.0	33.28	12.70	31.80	77.78
GCSC [a]	0.1	0.1	0.1	59.58	4.72	9.80	74.10
GCSC [b]	**0.0**	**0.1**	**0.1**	**58.70**	**0.70**	**31.80**	**91.20**

Source: Calculated.

Note: [a] is the GCSC in the case of maximized farmer profit orientation.

[b] is the GCSC in the case of maximized supply chain profit orientation.

In another alternative, if the revenue sharing contracts focus on the maximum profit of the supply chain, the optimal form is the 10% of revenue share from the assemblers in each area to the farmer cluster in the same area without the revenue sharing of the RPF. This form leads to the maximized profit of the farmers at approximately 58.70 baht per kilogram raising their profit relative to the non-GCSC by 79.12% and increasing the profit of supply chain relative to the non-GCSC by 17.71%. This simulation reveals the highest social welfare resulting from the GCSC.

In deciding to select the best model for revenue sharing contracts, the GCSC with revenue sharing contracts in the case of maximized supply chain profit orientation is appropriate. The contract should be the 10% revenue share only from the assemblers to the farmer cluster. Although this form does not lead to the highest profit of the farmers, it not only contributes to the maximum profit of the supply chain indicating the highest social welfare but also brings about the second highest earnings of the farmers as known as the second best choice.

The optimal solution presented above provides the understanding of appropriate form offered to the relevant organizations such as the RPF, the HRDI, the Pamiang RPDC and the Pang Ma-O RPEC for developing the GCSC of Arabica coffee in their responsible areas. However, there is question about whether or not the GCSC is a tool for enhancing the competitiveness of the farmers. This issue is assessed in the next section.

6.4 Competitiveness of coffee farmers in the GCSC

The results from the analysis of the optimal supply chain in Section 6 .2, and the proportion of revenue sharing that causes the maximum profit in Section 6.3, lead to the best model characterized as the supply chain model which has the farmer clusters in each area and revenue sharing contracts. This model causes the cost minimization and increases the farmers' profits. Consequently, this section shows the analysis of farmer competitiveness by using the composite index based on the supply chain operations Reference (SCOR), diamond model, and environmental friendly aspect. The data used for analyzing the farmers' competitiveness is the opinion data, or what are expected by farmers to take place. The non-GCSC model without the revenue sharing and the optimal GCSC model mentioned in Table 6.11 are used for comparison of the competitiveness of the farmers.

6.4.1 Competitiveness of the farmers in the non-GCSC model

This is the case of no changes toward the green activities, no revenue sharing contracts, no cluster of farmers in the supply chain and coffee farmers deciding to produce and market output at their own discretion using the traditional production and marketing methods. This has resulted in a significant difference in the use of inputs, waste management, transportation and marketing, particularly the output price received. In some cases, the farmers can sell their parchment coffee up to 110 baht per kilogram while some farmers can do so at the price as low as 90 baht per kilogram. In addition, the independent operation by coffee farmers in production and marketing activities results in the different perception of information. Furthermore, individual farmer is able to access information at different capacity. These will hinder the competitiveness of the farmers. So, this research has designed the index to measure competitiveness of farmers by letting the farmers self-assess and analyze the available production, marketing and financial data.

The results shown in Table 6.12 and Figure 6.5 indicate that the farmers in Pamiang area have an advantage in terms of quality of product with the average index score of 0.68. Because the farmers in Pamiang area have grown Arabica coffee for more than 10 years, they have developed the production techniques to increase the coffee product quality. Moreover, in Pamiang area, there are many government and private agencies supporting and transferring the knowledge. So, the farmers here would be able to access the production techniques and technologies to a greater extent than those in other areas. Parchment coffee has to pass the quality inspection standards both in physical and chemical standards and high proportion of parchment coffee produced by Pamiang farmers can pass the quality assessment. The advantage in terms of quality of coffee products results in reliability, and competitiveness of farmers.

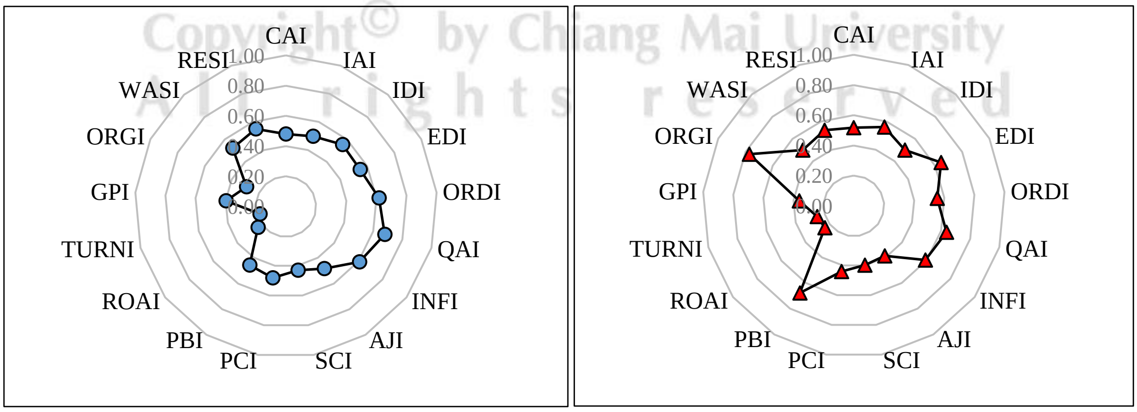
For Pang Ma-O area, the results reveal that the indicators of the environmentally friendly relation, especially the use of organic or biological input in production has the highest average index score of 0.77 because of the agreement among the community members about forest and watershed conservation. Thus, Pang Ma-O coffee is associated with organic or bio-material production. One effect of reducing the use of chemicals, especially chemical fertilizers, is the lower capital used in production which leads to faster payback. The average score of payback is 0.68.

However, considering the indicators having the lowest scores, the results show that the turnover ratio of the farmers in Pamiang area has the lowest score of 0.18 whereas the ROA of the farmers in Pang Ma-O area has the lowest score of 0.24. These results point out the weakness of the competitiveness of the farmers in the assets and profitability. The average value of the index ensures that farmers should have the ability to increase the profitability of their performance by reducing costs or increasing revenues from production. This research proposes the alternative models for farmers to achieve the objective of reducing costs or increasing revenues from production through cooperation with the cluster of farmers and the revenue sharing contract between the farmers and other stakeholders in the supply chain.

Table 6.12 Competitiveness of the farmers in the non-GCSC model

Dimension	Indicator		Score	
			Pamiang	Pang Ma-O
Competitive position:				
- Supply	• Capital accessibility	CAI	0.48	0.52
	• Production factors accessibility	IAI	0.50	0.56
- Supply	• Scale of internal demand	IDI	0.55	0.50
	• Scale of external demand	EDI	0.55	0.64
Supply chain performance:				
- Trust	• Orders replenishment	ORDI	0.62	0.55
	• Product quality	QAI	**0.68**	0.64
- Flexibility	• Information flow	INFI	0.61	0.59
	• Adaptation	AJI	0.48	0.39
- Cost	• Cost of supply chain	SCI	0.43	0.40
	• Cost of product	PCI	0.48	0.44
- Asset and profitability	• Payback period	PBI	0.46	0.68
	• ROA	ROAI	0.23	**0.24**
	• Turnover	TURNI	**0.18**	0.25
- Green relation	• Green productivity	GPI	0.40	0.36
	• The use of organic/biomass in production	ORGI	0.29	**0.77**
	• Waste disposal	WASI	0.52	0.50
	• Extravagant energy control	RESI	0.55	0.54

Source: Calculated.



(a) Pamiang (b) Pang Ma-O

Figure 6.5 Competitiveness of the farmers in the non-GCSC model

6.4.2 Competitiveness of the farmers in the GCSC model

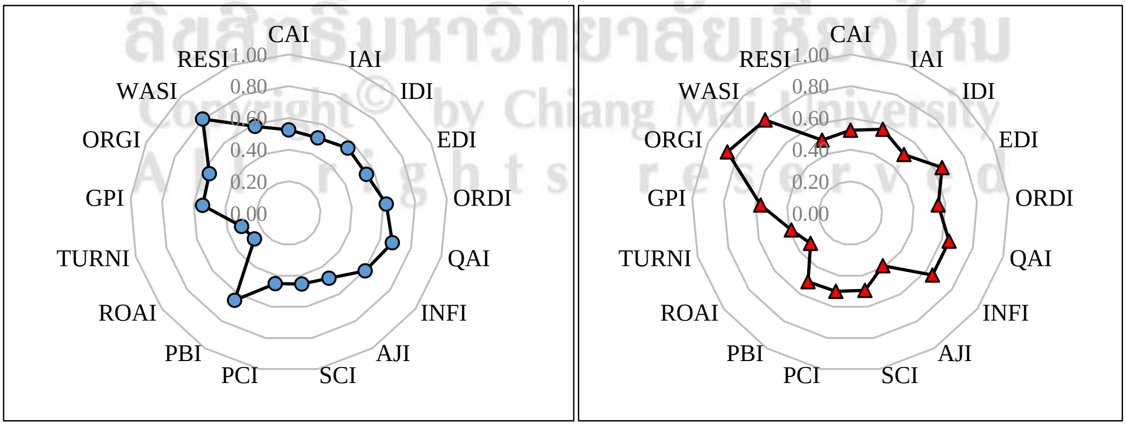
The results of the analysis in Section 6.1 and Section 6.2 show that the model having farmer cluster in each area with the revenue sharing agreement but which has no linkage between the chains is the best model for suggesting to the farmers. The changes in supply chain activities such as green production, green waste management, and green transportation, as well as the existence of cluster of the farmers bring about the decrease in the unit costs of production and transportation and the increase in the cost of waste disposal investment. These scenarios are stimulated under the available data of production, transportation, and marketing of the farmers and the interviews with the experts and the farmers about the expectation of outcomes. The results of the farmers' competitiveness under the selected model are presented in Table 6.13 and Figure 6.6.

The index of competitiveness in each area shown in Table 6.13 and Figure 6.6 has a bearing that the environmentally friendly operations and cooperation as the cluster of the farmers in Pamiang area result in the rise in the ability to manage the waste from the production as seen from the highest expected score of 0.80. The farmers in Pamiang area have no systems of waste disposal from the production. The wastes from peels of coffee cherries are dropped on coffee plantations or piled around residential areas causing a foul smell and GHG emissions. In fact, coffee husks can be used to make compost. Meanwhile, the wastewater from fermentation process is released to the natural sources without separating the fermenting sludge and sewage leading to the pollution. According to Von Enden and Calvert (2002); Central Coffee Research Institute (2003) and Suwasa Kantawanichakul (2011), wastes generated from wet processing of parchment coffee are in two types namely liquid wastes which are part of the peel and flesh of coffee and fermented water of parchment coffee, and solid wastes including the peels. The release of both wastes to nature without prior treatment brings about water and air pollutions because the organic compounds in coffee peels and fermenting wastewater affect the chemical oxygen demand (COD) and the biological oxygen demand (BOD), which will contribute to the decrease in dissolved oxygen in water causing the sewage. The farmers, therefore, agree with the concept of the treatment of wastes from production.

Table 6.13 Competitiveness expectation of the farmers in the GCSC model

Dimension	Indicator		Score	
			Pamiang	Pang Ma-O
Competitive position:				
- Supply	• Capital accessibility	CAI	0.52	0.52
	• Production factors accessibility	IAI	0.51	0.57
- Supply	• Scale of internal demand	IDI	0.55	0.50
	• Scale of external demand	EDI	0.55	0.64
Supply chain performance:				
- Trust	• Orders replenishment	ORDI	0.62	0.55
	• Product quality	QAI	0.68	0.65
- Flexibility	• Information flow	INFI	0.60	0.65
	• Adaptation	AJI	0.48	0.39
- Cost	• Cost of supply chain	SCI	0.45	0.50
	• Cost of product	PCI	0.45	0.50
- Asset and profitability	• Payback period	PBI	0.65	0.51
	• ROA	ROAI	**0.27**	**0.32**
	• Turnover	TURNI	0.31	0.39
- Green relation	• Green productivity	GPI	0.54	0.57
	• The use of organic/biomass in production	ORGI	0.56	**0.87**
	• Waste disposal	WASI	**0.80**	0.80
	• Extravagant energy control	RESI	0.59	0.49

Source: Calculated.

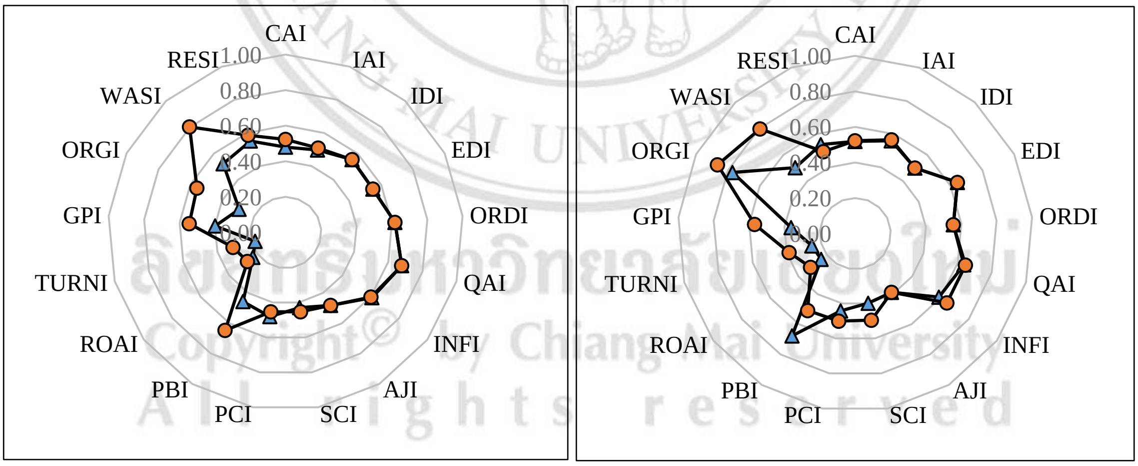


(a) Pamiang (b) Pang Ma-O

Figure 6.6 Competitiveness of the farmers in the GCSC model

For farmers in Pang Ma-O, the result shows that the use of organic or biological materials in the production process remains the predominant factor in creating competitiveness with the average index score of 0.87. Because the environmentally friendly production is the traditional trajectory of the farmers in this area, the encouragements for farmers to continue manipulating green production are possible in practice.

In terms of the indicator which is the weakness to enhance the competitiveness of the farmers (in Table 6.14), the results reveal that the farmers in Pamiang and Pang Ma-O areas still have the weakness in the assets and profitability dimension. The highland farmers have not done the accountancy of production and marketing, so they do not know their actual cost and unknown cost savings items. However, the cluster of individual farmers in each community and revenue sharing contracts between the farmers and other stakeholders in the supply chain bring about the increase in the accessibility in production inputs and markets, as well as the information sharing between the farmers and others. These lead to the average scores of asset and profitability indicator in both areas increase from 0.23 and 0.24 in the conventional model, non-GCSC, to 0.27 and 0.32 in GCSC model, respectively, as shown in Figure 6.7.



(a) Pamiang

(b) Pang Ma-O

Non-GCSC without revenue sharing contracts

GCSC with revenue sharing contracts

Figure 6.7 Comparison of competitiveness indicators between the non-GCSC and GCSC models

6.5 Summary and discussion

From the perspectives of the GCSC performance, the operational optimization, the appropriate revenue sharing contracts and the competitiveness are summarized as follows:

1) Because the adoption of green practices by individual farmer is different, the cost of modification of conventional practices toward environmentally friendly operations is vague. Thus, the analysis of the optimal operation of the GCSC of Arabica coffee has applied the Fuzzy Mixed Integer Linear Programming (FMILP) to estimate the models. The results show that the optimal model is the GCSC model that brings about the reduction in the cost of supply chain approximately 18.99%.

2) Moreover, the revenue sharing contracts is used as a tool for establishing the coordination. There are two scenario models consisting of the non-GCSC without revenue sharing contracts and the GCSC with revenue sharing contracts. The results show that the decision of revenue sharing contracts selection depends on the goal of the stakeholders in the supply chain. If the goal of the contracts is the profit maximization of the farmers, the GCSC model with revenue sharing contracts, which is the 10% of revenue share from the RPF to the assembly centers and the 10% of assembly centers to the farmer clusters, is the best choice. In the other view, if the revenue sharing contracts focuses on maximizing the total profit of the supply chain, the optimal model is the 10% of revenue share from the assemblers in each area to the farmer cluster in the same area without the sharing of the RPF.

3) Results from the analysis above bring about the assessment of the expectation of farmers' competitiveness derived from the green adoptions and cluster practices. The farmer competitiveness was analyzed using the composite index which is constructed based on the supply chain operations reference (SCOR), diamond model, and environmental friendly aspect. The model of non-GCSC without revenue sharing contracts and the model selected, GCSC with revenue sharing contracts, are used to compare the competitiveness of

the farmers. The results demonstrate that the competitiveness of the farmers in Pamiang and Pang Ma-O areas increase in all indicators, both the competitive position and the operation aspects in the supply chain. The environmentally friendly operations and cooperation as the cluster of the farmers in Pamiang area result in the rise in the ability to manage the wastes from the production. Moreover, the use of organic or biological materials in the production process remains the predominant factor in creating competitiveness. However, the farmers in Pamiang and Pang Ma-O areas still have the weakness in the assets and profitability dimension.

The findings in Chapter 6 contribute to the optimal solution of GCSC performances for making the developing prototype of Arabica coffee supply chain in the highland. The simulations of non-GCSC and GCSC models reveal the three apparent major outcomes from the green and cluster participation as follows:

1) GCSC leads to the cost reduction

The findings from the operational optimization analysis by using FMILP show that the optimal model bringing about the cost minimization is the GCSC model. The horizontal cluster by collaboration among coffee farmers in the green production, green waste management, and green transportation reduces the supply chain cost approximately 18.99%. These results are also consistent with the study of Prakash and Deshmukh (2010) who found that the horizontal collaboration can reduce the total cost of the supply chain and the farmers can improve the real time decision making process by adopting the suitable practices.

2) GCSC brings about farmers' income and social welfare augmentations

In the vertical coordination which displays the relationship among the farmers, the Pamiang RPDC, the Pang Ma-O RPEC and the RPF, the revenue contract is the important tool for their linkages. The findings reveal the decision of revenue sharing contracts selection depended on the goal of the stakeholders in supply chain, either profit maximization of the farmers or profit maximization of the supply chain aspect. The solutions of both orientations bring about the increase in farmers' revenue. However, when considering the social welfare augmentations, the goal of supply chain profit maximization is the best choice in terms of increase in the total gain of supply chain and farmers' revenue. Although this income from the supply chain orientation does not contribute to the maximized profit of the farmer, the farmers obtain the second best benefits.

3) GCSC enhances the competitiveness

Although the competitiveness assessment is the ideal analysis with the opinion data, the findings are useful for indicating the various perspectives of the ability to compete with the others. The indicators help to know what to improve and whether they are better than the original, or not.

The findings show that the environmentally friendly operations and cooperation as the cluster of the farmers in Pamiang area result in the rise in the ability to manage the wastes from the production. Moreover, the use of organic or biological materials in the production process remains the predominant factor in creating competitiveness. However, the farmers in Pamiang and Pang Ma-O areas still have the weakness in the aspect of assets and profitability. The highland farmers have not done the accountancy of production and marketing, so they do not know their actual cost and unknown cost savings items. These issues are the obstacle for the competition in the future.