Modeling of shallot supply decisions: the case of Indonesia

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Abstract. To optimize supply chain role, the players of supply chain need to integrate its function. One of the general problems in supply chain was the unbalanced quantity of sales and quantity of supply. This paper focused on modelling a simple method to manage the gap between the demand and the supply. The gap might cause an overstock or a loss. This paper propose a buffer quantity in order to handle the gap by using import decision. The case study was about shallot supply - demand in Indonesia. In this study we model the supply decisions of shallot in Indonesia. While the demand was quite stable over time, the supply was heavily affected by the yield from the farms. The shortage could result in the government importing shallot from other countries. Hence, the government also needed to have a proper buffering mechanism in order to ensure the supply was sufficient and the price was quite stable. The initial model of this research was built by stochastic parameters and the extended model to gain pricing mechanism was built by Shapley value principal with modification. The primary variables were supply quantity, demand quantity, buffer and purchased quantity (stock needed), actual consumption, and price for three players. The validation proved that the result of price at each player presented a significant difference. Therefore, the model could be applied to decide the stock quantity needed and to keep the price stable at each player especially at the end player which would influence the market price.

1. Introduction

Supply chain is a sequential activity, therefore a decision may cause a whole change among supply chain players. One of the general problems is the unbalanced quantity demand and supply. The aims of this research are to propose a model for buffer quantity in order to gain a particular stock quantity and to extend the initial model into pricing mechanism. This research took a study of shallot import in Indonesia so that the model would help the decision maker to control the supply and price by controlling purchased quantity. The goal of the initial model was modeling the stock needed by using a buffer stock obtained from import. Furthermore, the price mechanism was built to control the market price by cutting the supply chain structure. Therefore, this research used three players.

The study was about shallot import problem because it influenced the inflation in Indonesia. The reason was unstable price because of supply chain structure which involving many players and uncertain supply because of season and field condition. The complexity of supply chain increased with import-export activities, not only focused on the balance of sales and purchased quantity, but also widespread to social welfare. Bloechl [1] showed that trading benefits the two cooperating nations. Nevertheless,

there were still research opportunities that measure social welfare in the supply chain model of a commodity. Similar earlier research was the study by Crucini and Davis [2] which arranged the distribution of capital on short and long run import demand elasticity. While in this study, the focus of research was on the distribution of price allocation. This research used Shapley value modification which is game theory approach to control the price at each player in supply chain.

The research on game theory in the supply chain has been done previously by Zhang [3]. Choi and Messinger [4] examined the role of fairness in competitive supply chain relationships. The research used supply chain model among supplier-retailer with some replication which produced model where each supply chain player tended to choose almost the same margin. In addition, Lambo and Wambo [5] suggest on how uniformly shared expenses (solidarity expenses) were shared. The study looked at how the funds transfer between players using Nowak and Radzik model.

Sodhi and Tang [6] in their research provided a model of supply chain in which the follower was a supplier or distributor. The study aimed to make models that can be used as the basis for further research relating to "n-middleman". Research was motivated by the company's efforts to employ the weak (the poor). The model gave a reference to what the optimum price should be given by retail when there were as many n-middlemen and how much optimum price allocation would be obtained by upstream parties (farmers, fishermen, or other micro-entrepreneurs). The other related researches were Xu et al. [7]**,** Wahyudin et al. [8]**,** Macho-stadler et al. [9], Xiaofeng and Aiqing [10], Anglano et al. [11], Tan et al. [12], and Khmelnitskaya et al. [13].

This study had similarity with the research of Wahyudin et al. [8] which studied about shallot pricing policy. Shallot supply had often been a problem in Indonesia. While demand could be considered quite stable over time, the supply from domestic farming was very much affected by various factors, including the weathers. In some season, the yield was very good, in others it could be as low as 50% of the normal yield. The government often had to import from other countries. The fluctuated supply also results in fluctuated price. This paper was an attempt to model the supply decision of shallot where import was decided when domestic supply was deemed insufficient. We model the decision as a *Monte Carlo* simulation.

2. Decision Models

2.1. Research Model

This research was performed by a sequential model. Figure 1 describes that supply, consumption (demand), and import activities were processed on a quarterly basis. It was assumed that the short lead time controls the import decision so that the supply lead time was shorter than the planning period. Calculations in one period did not affect the calculation of other periods. However, it might occur a period when production (supply) quantity could be very high and thus terms would affect the excess of inventory or shortage. The model used normal distribution for the demand pattern, the formulation follows Chopra & Meindl [14].
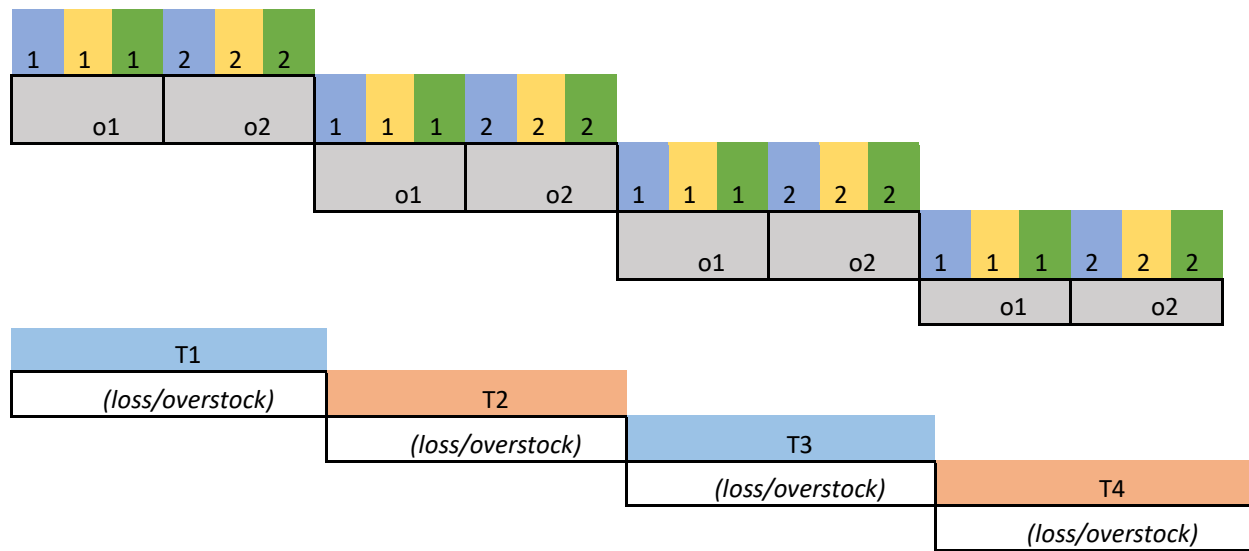
Figure 1. Construct of Simulation.

There were variables used in this research, the variables notation are:

q_a supply prediction

q_b consumption (demand) prediction

q_m actual supply

q_n actual consumption

I_i preliminary import decision

O_i overstock signal

r_I Cumulative Distribution Function of I_i

r_O Cumulative Distribution Function of O_i

q_y preliminary stock decision

B_i buffer quantity

Q_i buffer and purchased quantity (stock needed)

r_Q Cumulative Distribution Function of q_y

In addition, the other variables notation are $p_{retailer}, p_{wholesaler}, p_{supplier}$

After defining the variables, here were the steps of simulation

Step 1 Basic variables were generated by stochastic parameters

$$\boldsymbol{q_a, q_b, q_m, q_n}$$

Step 2 Observing preliminary import decision

$$I_i = q_b - q_a \tag{1}$$

Step 3 Calculating overstock signal

$$O_i = q_m + I_i - q_n \tag{2}$$

Step 4 Collecting report from *Monte Carlo* simulation,

$$\mu_I, \sigma_I^2, \mu_O, \sigma_O^2 \tag{3}$$

Step 5 Calculating CDF of I_i and O_i

$$r_I = F_I(I_i, \mu_I, \sigma_I^2) \text{ and } r_O = F_O(O_i, \mu_O, \sigma_O^2) \tag{4}$$

Step 6 Calculating preliminary stock decision

$$q_y = q_a - q_m - q_n \text{or} \tag{5}$$

$$q_y = q_a - O_i - I_i \text{ or} \tag{6}$$

$$q_y = q_a - \left(F_O^{-1}(r_O, \mu_O, \sigma_O^2) - F_I^{-1}(r_I, \mu_I, \sigma_I^2) \right) \tag{7}$$

Step 7 Collecting report from preliminary stock decision about recalculating of overstock/loss (update) obtained from preliminary stock decision. The report would be used to build the buffer parameters.

Step 8 Calculating buffer

$$B_i = q_y - q_b - F_B^{-1}\big(F_y(q_y, \mu_y, \sigma_y^2), \mu_B, \sigma_B^2\big) \qquad (8)$$

where μ_B was set based minimum, average, or maximum value of buffer parameters

Step 9 Calculating buffer and purchased quantity (stock needed)

$$Q_i = q_y + B \qquad (9)$$

$$Q_i = 2q_y - q_b - F_B^{-1}\big(F_y(q_y, \mu_y, \sigma_y^2), \mu_B, \sigma_B^2\big) \qquad (10)$$

Step 10 Calculating CDF of buffer and purchased quantity

$$r_Q = F_Q(Q_i, \mu_n, \sigma_n^2) \qquad (11)$$

Step 11 Calculating the price for each player

$$p_{retailer} = F_{retail}^{-1}(1 - r_Q, \mu_{pretail}, \sigma_{pretail}^2) \qquad (12)$$

$$p_{wholesaler} = F_{wholesale}^{-1}(1 - r_Q, \mu_{pwholesale}, \sigma_{pwholesale}^2) \qquad (13)$$

$$p_{supplier} = p_{retailer} - \frac{p_{retailer} - p_{wholesaler}}{1 - (r_Q/\beta)} \qquad (14)$$

where β was the denominator to decrease r_Q degree

Firstly, the value of the variables was generated using *Monte Carlo* simulation for 10000 periods to obtain the prediction of production quantity (supply) and the prediction of consumption quantity (demand), the gap between those two variables was used as the preliminary of import decision. This model assumed that the import decisions had been made before actual production took place. Then, those three variables were compared with the actual supply and the actual demand using stochastic parameters. All of the variables were reported and analyzed. Figure 2 shows this preliminary model briefly. The second step, the model was evaluated. Adopting the model of normal distribution, overstock/loss which had been obtained from the first model would be calculated to evaluate the import decision. The number of import decision which had been evaluated known as buffer. Figure 3 shows the second step of this initial model.
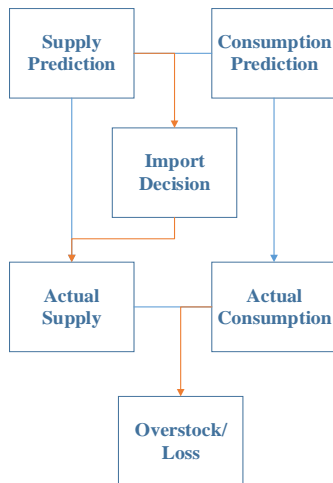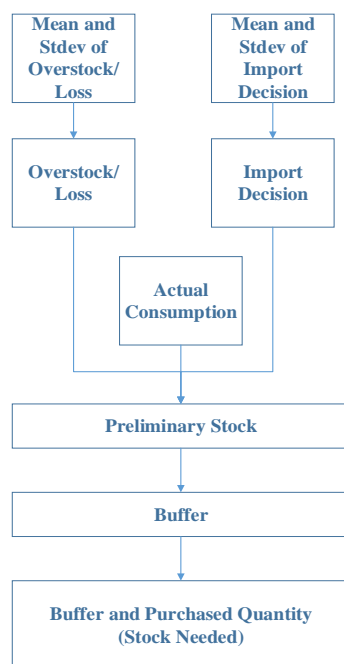

Figure 2 Preliminary Model.

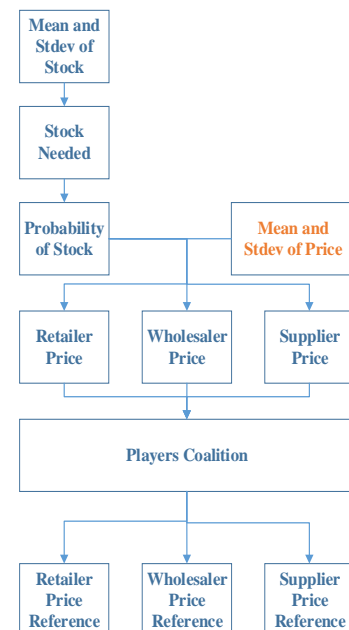**Figure 3** Buffer and Stock Model.

Figure 4 Price Allocation Model.

After completing the initial model, the size of buffers would be added to the preliminary stock decision. Those variables produce a new value known as a stock needed. The inverse of the number of stock needed would be calculated to build a price for each player. The price was generated by considering means of the actual price. Figure 4 shows the step to get the price at each player.

Furthermore, Shapley value methodology was adopted to build price allocation for each player. However, the coalition was built from the additional price at each player and the grand coalition was the total price at each player added by the average of price at each player. Therefore, the Shapley core was 0 and the grand coalition core for three players was the average of price at each player. It would shift the price cheaper than the initial price which had be obtained from the initial model. However, to calculate the ratio, this case should subtract the grand coalition core by the player's Shapley value before dividing by the grand coalition core.

All of those steps were experimented. The outcome would be discussed on the results and discussion section. The validation of the model proved that there were significant differences with the secondary data. Therefore, the model could be applied to decide the buffer quantity and to keep the price under control at each player.

3. Results and Discussion

3.1. Simulation Results
This research used the data which were collected by the government agencies who had responsibility to analyze the production in the field and the market price of shallot commodity. The report of initial model in Table 1 shows that the average and the standard deviation of overstock/loss vary substantially from one quarter to the other.

Table 1. Overstock/Loss Type in Preliminary and Correction Model.

		Average (Ton)	St.dev (Ton)
Overstock/Loss (Preliminary)	Quarter I	692	29109.810
	Quarter II	102	31897.761
	Quarter III	78262	37774.465
	Quarter IV	20182	8761.421
Overstock/Loss correction	Quarter I	-148	8291.334
	Quarter II	-88	11335.989
	Quarter III	-368	22365.497
	Quarter IV	-282	19220.397

Table 2. Buffer Parameters $\mu_\delta \sigma_\delta^2$.

Period	Decision	Buffer based on Minimum Value	Buffer based on Average Value	Buffer based on Maximum Value	St.dev
Quarter I	Stock	167778	272778	372888	29110
	Overstock/Loss Percentage	-10.95%	-0.15%	10.94%	3.10%
Quarter II	Stock	216915	333424	455080	31898
	Overstock/Loss Percentage	-13.34%	-0.15%	12.14%	3.46%
Quarter III	Stock	13045	329356	511360	43982
	Overstock/Loss Percentage	38.82%	0.62%	20.65%	7.09%
Quarter IV	Stock	241063	307516	375290	19254
	Overstock/Loss Percentage	27.02%	0.49%	17.88%	6.36%

From the model of overstock/loss correction, model of buffer and purchased quantity were made (stock needed). The quantity of buffer and purchased led the management to decide how large buffers were needed and how many quantities should be purchased in order to provide the ideal stock for the shallot market. Buffer and purchased quantity tended to give a positive number for the final overstock/loss. The decision was exactly influenced by the parameters of buffer quantity. Table 2 shows the parameters which were influencing the decision of buffer quantity.

The decision of stock needed was extended into the model of probability. That form was used to help calculate the price for each player in this shallot supply chain model. Pricing model showed the price decreasing in the case of quantity increasing. Those price were formed in each quarter. The purpose was to control the stability of price within the year by dividing the period whenever the quantity seemed not as normal as usual. Figure 5 shows the pricing model for quarter I as an example. All of the models in the other quarter were built using the same parameters by changing the quantity which depended on each quarter.
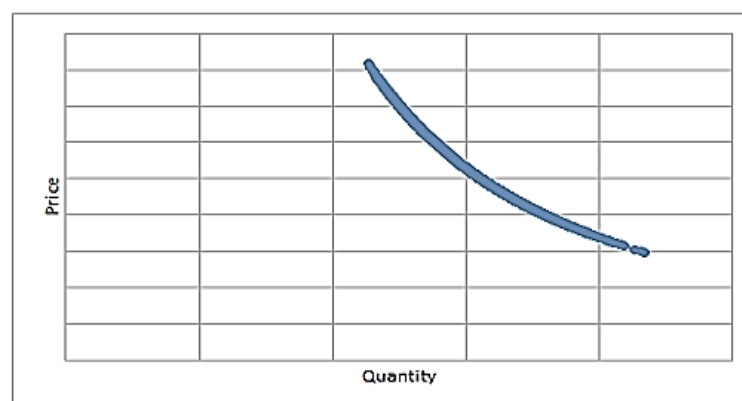

Figure 5 Pricing Model (10000 events)

Figure 6 shows the form of pricing model in another view. It also shows the relation between price and quantity. Furthermore, the price would be shifted in order to decrease the price as much as it could be, to obtain the new value of price which could be considered as the standard of market price. This final model would be explained in the next section.
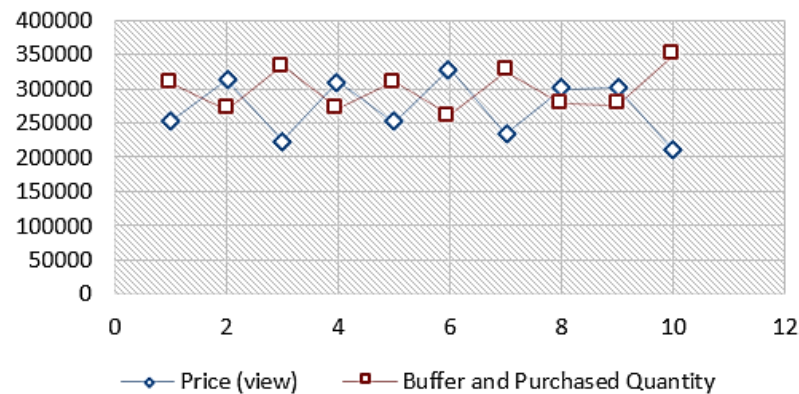

Figure 6 The Relationship between Price and Stock Needed

3.2. The Market Price Model

This model was built based on Shapley value principal, however the grand coalition was built by the average of each player price. The core of the other coalitions but grand coalition were 0. This model gave a satisfied result which can be seen in Table 3 that each player tended to have the same price within the year. Table 3 shows the result of the average price of shallot market price built by this model.

Table 3. Market Price.

Price	Quarter I (Rp/kg)	Quarter II (Rp/kg)	Quarter III (Rp/kg)	Quarter IV (Rp/kg)
Retailer	23207.46	23205.97	23511.48	23277.62
Wholesaler	17334.7	17333.25	1763.28	17404.1
Supplier	15069.15	15054.5	15413.69	14979.27

However, the modification of this model gave a little difference when calculating the ratio of Shapley value with the grand coalition but still had the same principal. When using the average price of each player based on the price obtained from the initial model, the difference between the value of grand coalition and the Shapley value of a player divided by the value of grand coalition would give a ratio that if all ratio were summarized, the result was 100%. Therefore, the principal of Shapley value was still confirmed by this modification. The validation model also showed there were significant differences between the price in finding and the secondary data.

4. Conclusions

The research findings showed that the average and standard deviation of overstock/loss based on import decision could be shifted especially for Quarter III and Quarter IV. During the Quarter III, the supply prediction was high and there was no decision of import, however the actual supply may fall and not as good as prediction, therefore the average was 78262 (indicate overstock) but the standard deviation also high 37774.465. It meant the range of overstock/loss in Quarter III had a high difference. By correcting the model, the average of overstock in Quarter III could be reduced to become -368 with the standard

deviation of 22365.497. Buffer parameters made another correction so that the loss occurrence might happen not too often. Furthermore, pricing model which had been built based on the stock decision provided report that the average price within the year was quite stable, no matter the fluctuation of the supply. Price at the *retailer* approximately was above Rp 23000,-/kg in each Quarter, price at the *wholesaler* was above Rp 17000,-/kg, and price at the shallot farmer (supplier) was Rp 15000,-/kg.

5. References

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