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**A MODEL FOR EVALUATING SUPPLY CONTRACT WITH MINIMUM  
QUANTITY COMMITMENT AND FLEXIBILITY**

  
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# A MODEL FOR EVALUATING SUPPLY CONTRACT WITH MINIMUM QUANTITY COMMITMENT AND FLEXIBILITY

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## ABSTRACT

Concept of supply chain management emphasizes the need for coordination and collaboration between firms to achieve a win-win situation for all the firms involved. The win-win situation in a coordinated supply chain was resulted from various sources, such as coordinated order process and delivery process. Supply contract is coordination mechanism that makes supply chain player's decisions in order process, coherent among each other. Model in this paper studied a type of supply contract that is suitably used in an agriculture product manufacturer. The manufacturer has a specific demand distribution, and often material supplied by multi supplier whose plant location is far away from the manufacturer's site. The distinguishing characteristic of this type of problem is capacitated delivery thus encourage supplier and manufacturer to create not only an order commitment but also a delivery commitment. The objective is to determine an order quantity to selected supplier and shipping schedule at minimum cost. A solution procedure is provided for the general problem and consideration is given to specific demand distribution.

## KEY WORDS

Supply Contracts, Minimum Quantity Commitment, and Delivery Commitment

## 1. Introduction

Supply chain management deals with the management of material, information, and financial flows in a network consisting of suppliers, manufacturers, distributors and customers. Managing flows in this network is a major challenge due to the complexity of space and time of the network, the circulation of products that flow through this network, and the presence of multiple decision makers who each own and operate a piece of this network and optimize a private objective function. One of important criteria that will use to measure the performance of the

supply chain is coordination. We say that a network is coordinated when a single decision maker optimized the network by combining information from the related decision makers [1].

*Win-win situation* in a coordinated supply chain involve some process, such as purchasing process. In general usage, the term of purchasing describes the process of buying; learning of the need, locating and selecting a supplier, negotiating price and other pertinent terms, and following up to ensure delivery [2].

The evolving focus on purchasing as a key capability in organizations has stimulated a new perspective regarding its role in supply chain management. The emphasis has shifted from adverbial, transaction-focused negotiation with suppliers to ensuring that the firm is positioned to implement its manufacturing and marketing strategies with support from its supply base. In particular, considerable focus is placed on ensuring supply, inventory minimization, quality improvement, supplier development, and lowest total cost of ownership [3].

- One of the core objectives of purchasing is to ensure that a continuous supply of materials, parts and components is available for use.
- One goal of modern purchasing is to maintain possibility of supply continuity with the minimum inventory investment.
- Purchasing must maintain a quality perspective in dealing with suppliers to ensure that customer requirements are met in a cost-effective manner.
- Successful purchasing depends on locating or developing suppliers, analyzing their capabilities, selecting and working with those suppliers to achieve continuous improvement.
- The purchase price of a material or item remains very important. It is one part of the total cost equation in

their organization. Service costs and life cycle costs must also be considered.

Purchasing activity would be performed when the buyer need material or product from the supplier, in the case the buyer is a manufacturer or retailer. For example, an agriculture product manufacturer needs coating oil as support material for its production. The manufacturer requires supply of coating oil which should always delivers on the right time and the right quantity. The supplier will deliver coating oil at the buyer's requirement. For that objective, supplier and manufacturer agree upon some supply contracts [4].

*Supply contract* is a coordination mechanism which gives an incentive to all parties in supply chain purchasing process. The incentive could be revenue or risk sharing. [5]. To gain these objective, broadly a supply contract should capture three types of flow, namely, material, information and financial.

In practice, the set of parameters over which supply contracts are observed can be classified into the following categories [1]:

- a) Horizon length: This specifies the duration for which the contract is valid;
- b) Pricing: This is interpreted broadly to incorporate all financial flows;
- c) Periodicity of ordering: This specifies how often a buyer can place orders;
- d) Quantity commitment: Quantity commitments by a buyer could be on orders, its demand, or capacity of the supplier;
- e) Flexibility: Whenever a buyer is required to make some commitments on the quantities to be purchased, often a supplier provides some flexibility to adjust these quantities;
- f) Delivery commitment: A supplier usually makes a commitment for the material delivery process;
- g) Quality: Quality restrictions could come in terms of defects rates, specifications, etc;
- h) Information sharing: This characterizes the information flow between a buyer and a supplier.

While pricing incorporates all financial flows, aspects of material flows are captured through periodicity of ordering, commitments quantity and delivery, flexibility, and quality, and information flows are captured by the type of information shared.

Supply contract is used not only to ensure delivery, but also to reduce materials-related costs such as unit purchase price, transportation, inventory and administration [6]. Supply contracts are often referred to as stockless purchasing, which implies that the firm does not carry inventory of purchased materials. The objectives

of supply contract and stockless purchasing are defined as follows [7]:

- Lower in inventory level
- Reduced the number of supplier
- Reduced administrative cost and paperwork
- Reduced the number of purchases of small dollar value and requisitions that purchasers have to handle and thus increase the amount of time available for other key activities.
- Provide the opportunity for larger dollar volume of business to supplier.
- Provide for timely delivery of material directly to the customer.
- Standardized purchase items where possible.

Recently, considerable interest in the production and operations management literature has focused on the operational, as opposed to legal, aspect of supply contracts, modeling the pricing, quantity, delivery, etc., of material from supplier to buyer. One type of supply contract is the commitment contract, which generally imposes some restriction on the buyer to purchase certain quantities of the product [1]. These contracts can use the form of an order commitment, in which the size of the order (either order quantity or dollar value) is specified; a demand commitment, which specifies the fraction of the buyer's demand to be procured from the supplier; or a capacity commitment, which specifies the fraction of the supplier's capacity to be reserved for the buyer. Moreover, an order commitment may be a total minimum contract, in which the buyer commits to a minimum cumulative purchase quantity over a horizon, or a periodical commitment, in which the buyer commits to purchase a certain quantity every period of the contract.

Literature which dealing with order quantity has been developed, one of them focuses on total minimum quantity commitment [8]. In this model a buyer guarantees that cumulative orders across all periods in the planning horizon will exceed a specified minimum quantity. In return, a supplier may offer price discount. In practice, a supplier provides a bidding package of per unit price and total minimum commitment pairs from which the buyer chooses a commitment at the corresponding price. It is reasonable to expect that as the total minimum commitment increases, the unit price would decline. In recent development, total minimum quantity commitment has been extended to total minimum quantity commitment with flexibility [1]. This model assumed that the buyer is able to purchase any additional quantity above the minimum committed at the same discounted price. However, a supplier may impose restrictions on the total purchases at the discounted price.

Total minimum quantity commitment contract assumed that delivery lead time is zero. Beside in practice, often a manufacturer has supplier that geographically far from manufacturer's plant. In this case delivery time would be an important factor, since it influences manufacturer's production performance. Thus, the model developed in this paper consider the situation in which a supplier offers a contract with total minimum quantity commitment with limited flexibility and delivery commitment incorporated into the contract.

Furthermore, total minimum quantity commitment with flexibility [1] assumed that material will be supplied by single supplier. In the case, when manufacturer faced the number of suppliers, evaluation and selection supplier problem appeared. Supplier evaluation and selection

supplier-order quantity solutions and data envelopment analysis to evaluating the efficiency of these super suppliers on multiple criteria.

Another paper [10] presents a multi objective mixed integer programming approach to simultaneously determine the number of suppliers to employ and the order quantities to allocate to these suppliers in a multiple-product, multiple-supplier competitive sourcing environment. The selection process is driven by the price, delivery, and quality objectives of the buyer and subject to the capacity constraints of the suppliers. In this context, the suppliers offer discounts on total amount of sales volumes not on the quantity or variety of products purchased from them.

Cakaravastia, *et.al* [11] develop an analytical model of the supplier selection process in designing a supply chain network. The constraints on the capacity of each potential supplier are considered in the process. The assumed objective of the supply chain is to minimize the level of customer dissatisfaction, which is evaluated by two performance criteria, price and delivery lead time. The

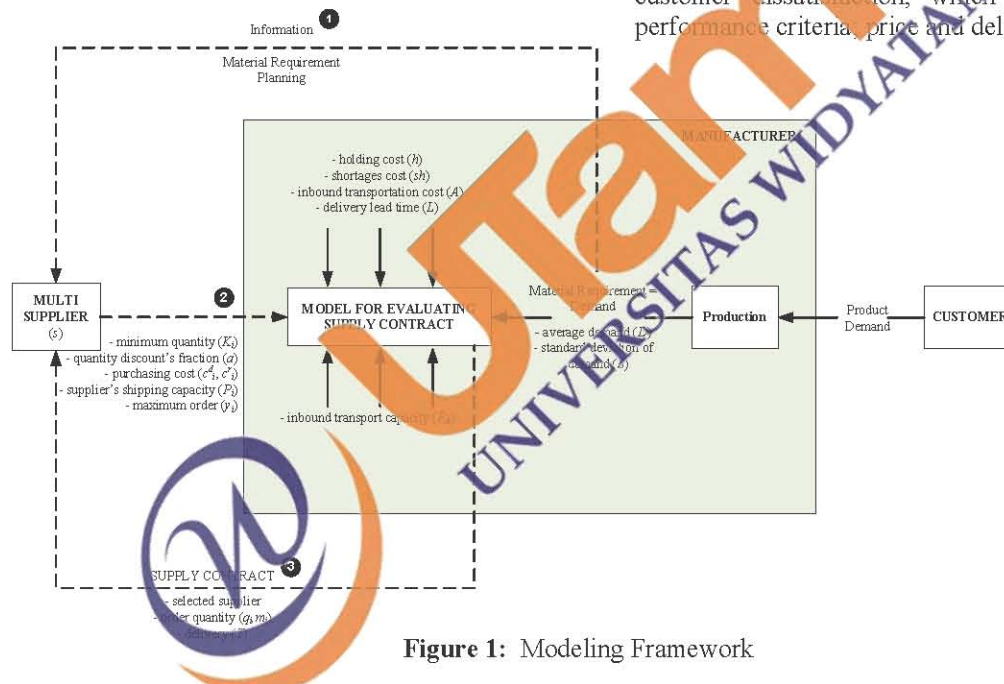


Figure 1: Modeling Framework

decisions are taking on increased importance today. If a manufacturer has reduced its supply base considerably, and if remaining suppliers usually receive longer-term agreements, the willingness or ability to switch suppliers is diminished. This makes selecting the right suppliers an important business decision [7].

Many supplier evaluation and selection methods have been proposed, one of them has developed by Weber *et.al* [9]. The paper presents an approach for evaluating the number of suppliers to employ in a procurement situation using; multi objective programming to developing

overall model operates at the operational level and the chain level of decision-making. The structure of the chain depends on the product specifications and on the customer's order size. An optimal solution can be obtained by using a mixed-integer programming technique.

On another paper, Cakaravastia *et.al* [12] develop the integration of AHP Liberatore and a multiple objective model to support subcontractor selection decision, which consider past performance evaluation, which include some intangible factors and price and delivery time

bidding evaluation in MTO situation. The method focuses on integration of procurement and manufacturing decision in a manufacturer.

In the case of supporting material purchasing in agriculture product manufacturer, supplier evaluation and selection process initially performed by conducting laboratory sample analysis and practical test. For supplier who has fulfills the qualification will be a competence suppliers, and they will receive a tender offering in each purchasing process period. Besides, suppliers request a bid to manufacturer which will be evaluated by manufacturer. Order quantity and delivery time commitment which settled in the contract, would be utilized in certain periods of production process. Payment method used cost and freight (CFR), where the seller pays for transportation to the port of shipment, loading and freight. In the other side, the buyer pays for the insurance and transportation of the goods from the port of destination to its factory (inbound transportation cost).

According to the explanation above, this paper extends model total minimum quantity commitment contracts with flexibility [1] by considering delivery time, inbound transportation cost, multi supplier and multi constraint. To solve multi supplier problem, this paper refers supplier evaluation base model developed by [9] and [11].

## 2. Modeling Framework

Material flows from supplier to manufacturer as a buyer. Supply contract committed to ensure material supply to manufacturer at the beginning of horizon contract. This model considered multi sourcing mechanism, Figures 1 illustrated a supply contract modeling framework.

## 3. Model Development

This paper concerns with a single-product problem in which at the beginning of the horizon the buyer commits to buying a minimum quantity  $K$  over the entire horizon. The model assumed that the purchasing, holding, and shortage costs incurred by the buyer are proportional in their respective quantities and are stationary over time; and the salvage value is zero. Thus, cumulative purchases through the horizon must equal at least  $K$  liter. This model accommodates multi supplier, thus each supplier has  $K_i$ .

The model assumed that the buyer is able to purchase any additional quantity above the minimum committed at the same discounted price. A buyer is required to commit to a total minimum quantity of  $K^L$  of purchases to avail of a discounted price  $c$ . The supplier extends this discounted

price to purchase up to a fixed fraction  $a$  above the minimum; that is, purchases up to  $K^{U}=(1+a) K^L$  are available at discounted price. Any further purchases above  $K^U$  are available at regular price  $c_r$ . The fraction  $a$  is the flexibility that a supplier offers to the buyer to adjust his total purchases over the horizon of the contract. There are two types of purchases for each supplier: one at discounted price denoted by  $q_i$  and the other at regular price denoted by  $m_i$ .

Horizon's contract assumed a finite horizon comprising  $N$  periods and the periods have identical durations. For a material, the demand is a random variable with known probability density function. The demand in each period is independent of the demands in the other periods. The demand for a material depends upon the demand for the buyer's products that include the material.

The following costs are considered in this model:

- Purchasing cost, proportional to the quantity purchased (both at discounted price and at regular price).
- Inventory holding cost, proportional to the quantity carried.
- Shortage cost, proportional to the unsatisfied demand.
- Inbound transportation cost, to carry material from port to plant, proportional to the quantity and capacity.

The sequence of events and actions taken by the buyer are as follows: (1) The buyer informed material requirement planning for next horizon to the supplier; (2) The supplier bids package that consist  $Y, K, c_i^d, c_i^r, P^L$  and  $P^U$ ; (3) The remaining bidding package for each supplier are observed, and the buyer make a decision by optimized the problem; (4) The result of optimization process are informed to selected suppliers. The results consist quantity order and delivery commitment, which determined by the optimal time between arrivals. Delivery commitment for each supplier assumed has a same value. (5) Supply contract are signed by the buyer and the suppliers (6) Demand is observed and is satisfied as much as possible; (7) excess demand is backlogged.

The model developed in this paper use the following notation:

- **Index:**
  - $i$  supplier  $i = 1, \dots, s$
- **Parameters**
  - $N$  horizon contract length (month)
  - $K_i$  minimum remaining quantity that the buyer must purchase to supplier  $i$  through horizon (liter) - has lower and upper bounds
  - $a_i$  quantity discount's fraction of supplier  $i$

- $K_i^U$  maximum quantity of supplier  $i$  that available at discounted price
- $c_i^d$  purchasing cost at discounted price supplier  $i$  (US\$ per liter)
- $c_i^r$  purchasing cost at regular price supplier  $i$  (US\$ per liter)
- $h$  holding cost (US\$ per N month /liter)
- $sh$  shortages cost (US\$ per liter)
- $A$  buyer's inbound transportation cost (US\$ per trip)
- $D$  demand expectation during horizon (liter)
- $S$  standard deviation of demand (liter)
- $L$  delivery lead time (month)
- $Y_i$  maximum order can satisfies by supplier  $i$  (liter)
- $P_i^U$  maximum shipping capacity of supplier  $i$  (liter)
- $P_i^L$  minimum shipping capacity of supplier  $i$  (liter)
- $P_A$  maximum capacity inbound transport (liter)
- $DL$  demand expectation during  $T + L$  period (liter)
- $SL$  standard deviation of demand during  $T + L$  period (liter)
- $x$  random variable of the demand during  $T + L$  period (liter)
- $ss$  safety stock (liter)

▪ **Variables**

- $T$  time between arrivals (month)
- $R$  inventory maximum allowed (liter)
- $v_i$  0 jika subkontraktor  $i$  tidak terpilih, 1 jika subkontraktor  $i$  terpilih
- $q_i$  order quantity at discounted price (liter)
- $m_i$  order quantity at regular price (liter)
- $TC$  total expected cost (US\$ per N month)

The total buyer's purchasing cost formulated by summarizing of purchasing, holding, shortages and inbound transportation costs.

- a) **Purchasing cost**, there are two types of purchases for each supplier: one at discounted price denoted by  $q_i$  and the other at regular price denoted by  $m_i$ .

- discount purchasing cost

$$\sum_{i=1}^s (c_i^d \times q_i) \quad (1)$$

- regular purchasing cost

$$\sum_{i=1}^s (c_i^r \times m_i) \quad (2)$$

Total purchasing cost not more than maximum boundary ( $W$ ) that defined by buyer, and order quantity which can be satisfied by supplier not more than maximum boundary ( $Y_i$ ).

- b) **Holding cost** is obtained by multiplying holding cost per liter per period with average inventory in liters; where safety stock is included in average inventory. With backorders, there is no loss of sales, since the buyer awaits  $R$  if stock is not available. The expected safety stock is defined as [13]

$$\begin{aligned} ss &= \int_0^{\infty} (R - x) f(x) dx \\ &= R \int_0^{\infty} f(x) dx - \int_0^{\infty} x f(x) dx \\ &= R - \bar{x} \end{aligned} \quad (3)$$

Where  $f(x)$  is probability density function of lead time demand and  $\bar{x}$  is lead time demand.

Then holding cost can be stated as follows:

$$O_s = h \times \left( \frac{T \cdot D}{N \cdot 2} + ss \right) \quad (4)$$

$$O_s = h \times \left( \frac{T \cdot D}{N \cdot 2} + \left( \int_0^{\infty} (R - x) f(x) dx \right) \right) \quad (5)$$

- c) **Shortages cost** is obtained by multiplying shortage cost per unit per arrival cycle with expectation of shortages unit per cycle.

The expectation of shortages unit per arrival cycle is:

$$\int_R^{\infty} (x - R) f(x) dx \quad (6)$$

Then, shortages cost during horizon can be stated as follows:

$$O_k = \frac{sh \cdot N}{T} \int_R^{\infty} (x - R) f(x) dx \quad (7)$$

d) **Inbound transportation cost** is obtained by multiplying transportation cost per trip with delivery frequency, where delivery frequency is obtained by dividing purchase quantity by maximum capacity inbound transport

$$O_i = A \times \left\lceil \frac{T \cdot D}{N \cdot P_A} \right\rceil \times \frac{N}{T} \quad (8)$$

Base on the considered costs in this model the formulation of the buyer's purchasing cost can be stated as follows:

$$TC = \left( \sum_{i=1}^s (c_i \times q_i) + \sum_{i=1}^s (c_{ri} \times m_i) \right) + \left( h \times \left( \frac{T \cdot D}{N \cdot 2} + \left( \int_0^{\infty} (R-x)f(x)dx \right) \right) \right) + \left( \frac{sh \cdot N}{T} \times \int_R^{\infty} (x-R)f(x)dx \right) + \left( A \times \left\lceil \frac{T \cdot D}{N \cdot P_A} \right\rceil \times \frac{N}{T} \right) \quad (9)$$

The optimization problem for agriculture product manufacturer's case can be formulated by:

$$\text{Min } TC(q_i, m_i, R, T) \quad (10)$$

s.t.

$$\sum_{i=1}^s (q_i + m_i) = D \quad (11)$$

$$q_i \geq K_i^L \times v_i \quad \forall i \quad (12)$$

$$q_i \leq K_i^U \quad \forall i \quad (13)$$

$$(q_i - 1) - (v_i \times M) \leq 0 \quad \forall i \quad (14)$$

$$(q_i - 1) + M \times (1 - v_i) \geq 0 \quad \forall i \quad (15)$$

$$m_i \leq (Y_i - K_i^U) \times v_i \quad \forall i \quad (16)$$

$$v_i \in (0,1) \quad (17)$$

$$\left( \sum_{i=1}^s (c_i \times q_i) + \sum_{i=1}^s (c_{ri} \times m_i) \right) \leq W \quad (18)$$

$$T \cdot (q_i + m_i) \geq P_{si}^L \quad \forall i \quad (19)$$

$$T \cdot (q_i + m_i) \leq P_{si}^U \quad \forall i \quad (20)$$

$$\frac{D}{P_A} \in \text{integer} \quad (21)$$

The constraints are defined as follows:

- 1) Total order quantity among horizon is required not less than total minimum quantity commitment that agreed by supplier.
- 2) Total order quantity consists of two types of purchases: one at discounted price and the other at regular price.
- 3) A buyer committed to a total minimum quantity of purchases to avail of a discounted price. The supplier extends this discounted price to purchase up to a fixed fraction  $a$  above the minimum; any further purchases above  $K^U$  are available at regular price.
- 4) Order quantity at each cycle has to positive, and limited by supplier's shipping capacity.
- 5) Order quantity at each cycle delivered from manufacturer's port to plant by inbound transportation equipment which had limited capacity.

Furthermore, to solve the problem, we provide a following algorithm.

- 1) Determine minimum quantity for each supplier ( $K_i$ ) which committed based on information of material requirement planning.
- 2) Calculate an optimum time between arrivals ( $T$ ).
- 3) Determine order quantity for selected supplier's base on  $T$  optimum.
- 4) Determine delivery commitment base on  $T$  optimum.

#### 4. Numerical Example

We now describe some numerical studies to evaluate the total purchasing costs of buyer. The parameters used for the computational study are presented in Table 1.

**Table 1: Parameter Model**

| Parameters                       | Numbers                |
|----------------------------------|------------------------|
| Total demand                     | 308.908 liters         |
| Percentage discount fraction $a$ | 15%                    |
| Shortage cost                    | \$3 per liter          |
| Holding cost                     | US\$ 0.18              |
| Number of periods                | 6 months               |
| Inbound transportation cost      | US\$ 50 per liter      |
| Delivery lead time               | 0.5 months             |
| Shipping capacity:               |                        |
| – Supplier 1                     | 40.000 -200.000 liters |
| – Supplier 2                     | 45.000 -200.000 liters |
| – Supplier 3                     | 40.000 -200.000 liters |
| Max. capacity inbound trans.     | 50.000 liters          |

Demand distributions were assumed normal, where average lead time demand is 51.236 liters with standard deviation is 2.073 liters. Negative realizations of the demand were not considered.

Initially, before the contract is committed, each supplier provides bidding package that consist  $Y, K, K^U=K(a+1), c_i^d, c_i^r, P^L$  and  $P^U$  which presented in **Table 2**.

**Table 2: Bidding Package by Supplier's Candidate**

| Package | Supplier |         |         |
|---------|----------|---------|---------|
|         | 1        | 2       | 3       |
| $Y$     | 160,000  | 160,000 | 150,000 |
| $K$     | 120,000  | 125,000 | 115,000 |
| $K^U$   | 144,000  | 150,000 | 138,000 |
| $c_i^d$ | 0.832    | 0.842   | 0.825   |
| $c_i^r$ | 1.040    | 0.990   | 1.100   |
| $P^L$   | 40,000   | 45,000  | 40,000  |
| $P^U$   | 200,000  | 200,000 | 200,000 |

In this case, we can solve this problem by these following steps:

- 1) According to bidding package from each supplier, size of minimum quantity commitment determined as follows:  $K_1=120.000, K_2=125.000$  and  $K_3=115.000$ . In principal, total order quantity will be share equally to each selected supplier.
- 2) Define decision variables  $T, R, q_i$  and  $m_i$ . We used Mathcad v.11, with guess value for  $T$  variable approached by constraint (19).
- 3) Calculate buyer's purchasing cost.
- 4) Determine delivery commitment base on  $T$  optimum.

The computational results presented in **Table 3**, are demonstrating the performance of the model for different sourcing mechanism.

**Table 3: The Computational Results**

| Minimum quantity commitment            | Order quantity for selected supplier (liters) |         |         | Total buyer's purchasing cost (US\$) |
|----------------------------------------|-----------------------------------------------|---------|---------|--------------------------------------|
|                                        | 1                                             | 2       | 3       |                                      |
| K1=120.000<br>K2=125.000<br>K3=115.000 | 148,908                                       | 160,000 |         | 263,407                              |
|                                        | 160,000                                       |         | 148,908 | 264,922                              |
|                                        |                                               | 160,000 | 148,908 | 271,928                              |
|                                        | 308,908                                       |         |         | 293,670                              |
|                                        |                                               | 308,908 |         | 285,977                              |
|                                        |                                               |         | 308,908 | 304,207                              |
|                                        | 120,000                                       | 125,000 | 115,000 | 302,680                              |

According to a computational result, supply of material should be supplied by supplier 1 and 2 with total minimum quantity commitment from each selected supplier is 235.000 liters. For delivery commitment, the first arrival of material should be in the beginning of horizon, and time between arrivals is 0.25 months for single supplier, 0.28 months for 2 selected suppliers and 0.36 months for 3 selected suppliers. Suppliers have to prepare their production, and should finish 2 weeks before the arrival time; caused the delivery lead time is two weeks. The average numbers of material which arrive in manufacturer's plant at each cycle are 80.000 liter.

### 5. Conclusion

This paper provides a supply contract model which could be applied by fertilizer manufacturer in dealing with the supplier. This supply contract model characterized by:

1. Minimum quantity commitment in supplier side, so that the supplier has a certain selling level.
2. This model accommodates multi supplier, which each supplier offers a discounted rate of certain order and flexibility to the buyer for additional order quantity.
3. This model considered the inbound transportation cost beside the general purchasing cost.
4. Result of this contract is order quantity and delivery commitment with selected supplier.
5. Supplier shipping capacity affected the size of economic order quantity.

For further research, this model could be extended to other distribution demand. Analysis of different  $T$  for each supplier is in progress.

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