Inventory and Transportation Models for Multi-item Single-Supplier through Purchasing Consortium for the Fishpond Manager

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Abstract. Purchasing Consortium (PC) is the merger of two or more organisations with separate legal entities or independently or through the third party using division and union of the purchase volume, information, and resources owned. This merger aims to increase the bargaining power so that the product or service purchase price can be lower than a supplier. This research tried to conduct modelling to minimise the annual total cost of several buyers doing multi-item through PC at single supplier offering a fixed discount rate by shipping union. In this study, an analytical method was employed to solve the problems using the optimisation approach. From numerical experiment results, by making purchases through PC with shipping unification, the total cost generated was better compared to the purchase without going through PC or PC without shipping union.

1. Introduction
Purchasing Consortium (PC) is a strategy in purchasing in which the merger of two or more organisation with separate legal entities either independently or through the third party [4]. The merger was done using division and union of the purchase volume, information, and resources owned [7]. By doing the union, it is expected that the bargaining power can be increased so that the benefits from a supplier can be obtained [1].

There are several benefits obtained by purchasing through PC. These benefits include reducing the cost of purchasing products, reducing the risk of shipping, reducing the transaction cost and increasing productivity, flexibility of inventory, better access to the resources or markets, providing high quality products, reducing logistics cost, workload and transaction cost, establishing better relationship with the supplier through commitment to make contracts, sharing experience and information in order to improve product and service quality [9]. In addition to these benefits, there are other benefits from PC establishment including the maximisation of existing expert staffs [2] and a decrease in shipping lead time [3].

Gresik is one of the areas in East Java where most of the population earns a living as farmers, especially in Duduk Sampoean District. The fishpond managers always do the activity of purchasing fertiliser, especially urea and TSP as well as other medicines. However, usually, they still purchase individually in small quantities. Therefore, this research compiled inventory and transportation model to minimise the annual total cost from each member on multi-item purchases with fixed discount.

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scheme [6]. The form of PC adopted from research [7] and [5] was first buying in concentration phase. In this type of PC membership, all members got the same work portion. Analytic method was employed to generate a minimum annual total cost. The components of value analysed including the cost of purchasing, ordering, storage, PC operating, and transportation.

2. Method
In Figure 1, the conceptual model used in this research is presented. Some buyers who need similar items formed PC to be able to meet the discount quota set by the supplier (K). Every j-th buyer had i-th demand item of Rj. Consortium collected the demand for each piece for all buyers. After that, the total purchasing quota of i-th item (Qi) was calculated to be ordered from the supplier. Since the purchase was made in large quantities, the discount quota from a supplier can be fulfilled. The supplier gave a discount of r from the total purchase. The price for i-th item from supplier is Pi. The i-th item proportion given by the j-th buyer is Qi with the cost of i-th item is Pi. Also, each buyer received saving obtained from the collaboration based on each buyer contribution. Item shipping was done separately. 

Notation
The notations used in this research model include:

- \( P_i \) = Item cost per unit of purchase for items i-th
- \( R_j \) = Annual demand of i-th item of buyer j
- \( C_{odPCS} \) = Ordering cost from PC to supplier
- \( C_{odRPC} \) = Ordering cost from buyer to PC
- \( C_{odRS} \) = Ordering cost from buyer to supplier
- \( C_{opPC} \) = PC operating costs

\[ Q_{ic} \] = Order quantity in units per year for i-th item by PC
\[ Q_{ij} \] = Order quantity in units per year for i-th item by PC
\( F \) = Storage cost fraction per year
\( m \) = \( R_i/Q_i \) = Order frequency in one year
\( T \) = \( 1/m \) = Time between orders
\( d_{oj} \) = Distance from supplier to j-th buyer without shipping union
\( n \) = Number of items
\( l \) = Number of buyers
\( K \) = Minimum number of purchases with discount from supplier in IDR

![Figure 1. Conceptual model of single supplier multi-item purchase on PC](image-url)
nrd$_j$ = Vehicle rental duration (days) on the j-th buyer
$r$ = Discount offered by the supplier for purchases nominal $\geq$ K
$\phi^{j, bili}_{i}$ = Saving obtained by j-th buyer due to joining PC in making a purchase
$C_v$ = Transportation cost per distance unit
$C_{rent}$ = Vehicle rental fee

2.1 Assumption
The assumptions used in this research model are:
1. The relationship of purchasing quota increase with the amount of discount obtained was assumed proportional (Fixed discount rate)
2. All PC members were expected to make an order on all types of product at the same time
3. Transportation costs are considered beared entirely by the buyer
4. One supplier was supplying all items to all buyers
5. Backorder is not allowed
6. Items bought from the supplier were directly sent to the buyers
7. The capacity of transport vehicle was ignored

2.2 Mathematical Model

2.2.1 Purchasing without going through PC. The following joint replenishment model is derived from the EOQ single item concept [8].

The total costs for Buyer $j$ as follows:

$$TC_j(m) = \sum_{i=1}^{n} P_i R_{ij} + C_{od} m + \frac{F \sum_{i=1}^{n} P_i R_{ij}}{2m} + m \left( nrd_j * C_{rent} + 2C_{tr} d_{oj} \right)$$ \hspace{1cm} (1)

By lowering $TC_j$ toward $m$, the optimum order frequency for each buyer will be obtained as follows:

$$\frac{\partial TC_j}{\partial m} = 0$$

$$C_{od} = \frac{F \sum_{i=1}^{n} P_i R_{ij}}{2(m^*)^2} + \left( C_{rent} + 2C_{tr} d_{oj} \right) = 0$$

$$m^* = \sqrt{\frac{F \sum_{i=1}^{n} P_i R_{ij}}{2(C_{od} + (nrd_j * C_{rent}) + 2C_{tr} d_{oj})}} \hspace{1cm} (2)$$

By inputting $m^*$ to the $TC_j(m)$, the maximum total cost of each buyer will be obtained. The limitation used in this scenario is:

$$\sum_{i=1}^{n} \frac{P_i R_{ij}}{m} < K \quad untuk \ semua \ j$$

$$2(C_{od} + C_{rent} + 2C_{tr} d_{oj}) > 0$$

The first limitation is the discount quota limitation. Equation 1 and 2 are only applicable if the total item purchase is less than K. While the second limitation is used to guarantee that equation 2 has a result.

Total Cost of the system is:

$$TC_S(m) = \sum_{j=1}^{l} TC_j(m) \hspace{1cm} (3)$$

2.2.2 Purchasing through PC. The following joint replenishment model is derived from EOQ single item concept [8].
The total costs experienced by the entire system include:

\[ TC_s = (1 - r) \sum_{i=1}^{n} \sum_{j=1}^{l} P_i R_{ij} + (C_{od}^{PCS} + C_{od}^{RBP})m + C_{op}^{PC} + \left( \frac{F(1-r) \sum_{i=1}^{n} \sum_{j=1}^{l} P_i R_{ij}}{2m} \right) \]

\[ + m \left( \sum_{j=1}^{l} n d r_j * C_{rent} \right) + C_{cr} \sum_{j=1}^{l} 2d_{0j} \]  

By derived TC toward \( m \), the optimum order frequency on the PC will be obtained as follows:

\[ \frac{\partial TC}{\partial m} = 0 \]

\[ (C_{od}^{PCS} + C_{od}^{RBP}) - \frac{F(1-r) \sum_{i=1}^{n} \sum_{j=1}^{l} P_i R_{ij}}{2(m^*)^2} + \left( \sum_{j=1}^{l} n d r_j * C_{rent} \right) + 2C_{cr}d_{0j} = 0 \]

\[ m^* = \sqrt{\frac{F(1-r) \sum_{i=1}^{n} \sum_{j=1}^{l} P_i R_{ij}}{2(C_{od}^{PCS} + C_{od}^{RBP} + (\sum_{j=1}^{l} n d r_j * C_{rent}) + C_{cr} \sum_{j=1}^{l} 2d_{0j})}} \]  

Condition:

\[ 2(C_{od}^{PCS} + C_{od}^{RBP} + (\sum_{j=1}^{l} n d r_j * C_{rent}) + C_{cr} \sum_{j=1}^{l} 2d_{0j}) > 0 \]

Equation 8 is a discount quota limit. Since the purchase was made through PC, the total purchase by the PC can meet the discount quota from the supplier (K). While equation seven was used to guarantee that equation 6 has a result.

2.3 Data and Parameter

The following is the parameter and data used in the model

**Table 1. Buyer Data**

| i-th Buyer | 1           | 2           | 3            |
|------------|-------------|-------------|--------------|
| i-th Item  | 1           | 2           | 3            |
| Item price (Pi) | 130.000 | 110.000 | 130.000 |
| (Rij) | Demand     | 100         | 100          | 15           | 12           | 9            | 3            | 6            | 6            | -            |

In this research, there were three buyers making purchases on the same item with different needs as can be seen in Table 1. The parameter data used in this model can be seen in Table 2.
Table 2. Parameter Model Data

| Parameter Model Data                                      | Value  |
|-----------------------------------------------------------|--------|
| Storage cost fraction per item (F)                        | 0.3    |
| Vehicle rental fee (Crent)                                | 100,000|
| Transportation cost per Km distance (Ctr)                  | 10,000 |
| Ordering cost from buyer to supplier (Cod_BPC)            | 25,000 |
| Ordering fee from PC to supplier (Cod_PCS)                | 25,000 |
| The percentage of discount from the supplier              | 1.5%   |

3. Result and Discussion

From the numerical experiments that have been conducted, the following results are obtained:

Table 3. Numerical experiment results

| Scenario | m   | BD       | BPS       | BIS       | BO        | Bop        | Total Cost   |
|----------|-----|----------|-----------|-----------|-----------|------------|--------------|
| 0        |     | Buyer 1  | 3.91      | 898,612   | 25,950,000| 996,287    | 97,675       | 33,441,939 |
|          |     | Buyer 2  | 1.34      | 295,161   | 2,940,000 | 328,702    | 33,541       |              |
|          |     | Buyer 3  | 0.94      | 207,602   | 1,440,000 | 230,981    | 23,379       |              |
| 1        | PC  | 2.93     | 1,968,947 | 29,875,050| 1,529,450 | 146,499    | 500,000      | 34,019,945 |
| 2        | PC  | 4.00     | 920,129   | 29,875,050| 1,120,157 | 200,028    | 500,000      | 32,615,364 |

From the results of numerical experiments in table 4, the results show that in cases in which the number of buyers is three people, the purchase made without going through PC (Scenario 0) have a smaller total cost compared to the purchase made through PC without shipping union (Scenario 1). However, the purchase through PC with shipping union (Scenario 2) has the smallest total cost compared to the other two scenarios.

Figure 2. Cost Comparison in Three Scenarios
4. Conclusion
The conclusions that can be drawn from this study include: In this research, it was found the importance of coordination regarding inventory, ordering, and transportation policy between several buyers who make a multi-item purchase at the same supplier by sharing information to minimise the total annual cost of each buyer. In the case of a multi-item at the single supplier in three buyers offered fixed discount scheme, scenario two by joint in both purchasing consortium and transportation showed a smallest total cost.

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