CHAPTER 4

METHODOLOGY AND MODEL DEVELOPMENT

The methodology of this study includes group ordering, inventory management system, and truck loading.

4.1 <u>Group Ordering</u>

From product information in Chapter 3, the inventories under study have several items both construction and decorative materials and different suppliers. Supplier is defined for group ordering. The items that are manufactured from the same supplier are selected into the same group for ordering. Suppliers under study can be divided into three main suppliers: major suppliers, minor suppliers, and miscellaneous suppliers. Table 4.1-Table 4.3 show product groups followed by suppliers.

Major Supplier	Product
1. Siam Fiber-Cement	Roman Tile, Small Corrugated Sheet, Flat Sheet
2. Siam Gypsum Industry	Gypsum Board
3. Siam Cement	Grey Cement and White Cement

Table: 4.1: Three groups of products of major suppliers.

From table 4.1, Siam-fiber cement, Siam gypsum industry, and Siam cement are major suppliers. They are also major products that have frequency of daily transaction of sales data that are greater than other products of minor and miscellaneous suppliers.

Minor Supplier	Product
1. Siam Iron and Steel	Round Bar, Deformed Bar
2. CPAC Roof Tile	CPAC monier roof tile, CPAC monier Round-ridge collection
3 Nawaplastic Industry	PVC Pipe and Fittings
4. Thai Ceramic	COTTO Ceramic Tile
5. Siam Sanitary Ware	Sanitary Ware
6. Siam Nawaphan	Steel Door and PVC Door
7. Siam CPAC Block	CPAC Paving Block
8. Paint: JBP, TOA, CAPTAIN	Paint, Paint pan and roller, Paintbrush, Paint thinner. Sandpaper

Table 4.2: Eight groups of products of minor suppliers.

From table 4.2. there are eight minor suppliers that the products have less frequency of daily transaction of sales data than major products of major suppliers.

Miscellaneous Supplier	Product
1. Hardware	Screwdriver, Phillips screwdriver, electric drill, power saw, wrench, pliers, hacksaw, hatchet, monkey wrench, saw, hand drill, brace, chisel, and scraper
2. Tools	Hammer, vise, bit, level, plane, tool box, key, wire, nail, screw, washer, bolt, and nut.

Table: 4.3: Two groups of products of miscellaneous suppliers.

From table 4.3, hardware and tools are miscellaneous suppliers. So there are 13 product groups of three main suppliers.

4.2 Inventory Management System

The system that is considered involves continuous review and a replenishment is made whenever the inventory position drops to the order point (minimum) s or lower. A variable replenishment quantity is placed of sufficient magnitude to raise the position to the order-up-to-level (maximum) S. The (s, S) system is referred to as a min-max system because the inventory position, except for possible momentary drop below the reorder point, is always between a minimum value of s and a maximum value of S. This (s, S) system is appropriate for this study because the major product groups studied have more frequency of daily transaction sales. At the same time, the distributor checks stocks and calculates order quantities everyday that is likely to have a continuous review situation. In addition, this system is to control quantity of inventory. It is better than system that is to control quantity of inventory in periodic review. That is higher opportunity to have a shortage cost.

According to Silver E. A. and Peterson R. (1985, p 344), when all transactions are of unit size then every order is of size (S-s) and is placed when the inventory position is exactly at the level s. Thus an order point can be

$$Q = S - s \qquad (1)$$

Here we choose to neglect the undershoot (how far below s the inventory position is located when an order is placed). S and s are computed in a sequential procedure as follows:

1. The Q expression of Eq.1 is set equal to the economic order quantity (EOQ).

2. Given this value of Q, the order point (s) value is then calculated.

3. Finally, the order-up-to-level (S) value is given by S = s + Q.

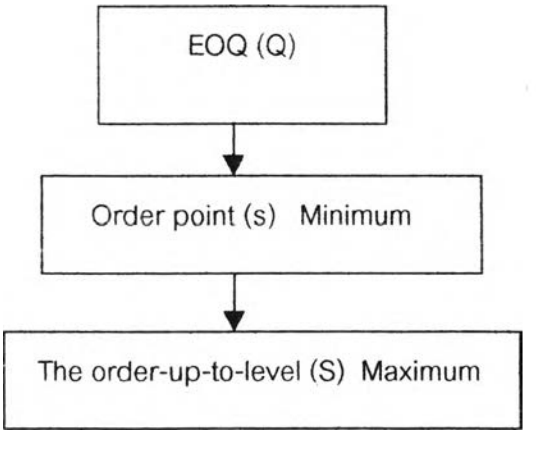

Figure 4.1: Flowchart of (s, S) calculation.

This (s, S) system studied is simple sequential determination. It starts from calculating the EOQ then specifies safety factor to calculate the order point (s) and the order-up-to-level (S). One disadvantage of this simple sequential system is a calculation of order quantity (EOQ) at the first time that will not consider a shortage cost. In fact, some items can have a shortage cost. It makes output of inventory level calculation that is not considered a cost of shortage at the first time.

4.2.1 The Concept of EOQ

Some of these may appear to be far removed from reality but the EOQ forms an important building block in the majority of decision systems that we advocate. According to Smith S. B. (1989, p.120) and Silver E. A. and Peterson R. (1985, p.174), the assumptions of EOQ concept as follows:

1. The demand rate is constant and deterministic. (r)
2. The order quantity (q) need not be an integral number of units, and there are no minimum or maximum restrictions on its size.
3. The unit variable cost does not depend on the replenishment quantity; in particular, there are no discounts in either the unit purchase cost or the unit transportation cost.
4. The cost factors do not change appreciably with time; in particular, inflation is at a low level.
5. The item is treated entirely independently of other items; that is, benefits from joint review or replenishment do not exist or are simply ignored.
6. The replenishment lead time (L) is of zero duration: as we will see later, extension to a known nonzero duration creates no problem.
7. No shortages are allowed.
8. The entire order quantity is delivered at the same time.
9. Inventory holding cost (h) is based on average inventory.
10. Ordering or setup cost (k) is constant.

At the same time, an expression for total cost per unit time as a function of order quantity can be developed as follows:

Number of orders per unit time	=	r / q
Ordering cost per unit time	=	kr / q
Average inventory	=	$q / 2$
Inventory holding cost per unit time	=	$hq / 2$

Total cost as a function of q is given by

$$C(q) = kr/q + hq/2$$

The value of q that minimizes C(q) can be derived and yields the following:

$$q^* = \sqrt{2kr / h}$$

where * indicates that this is the optimal value of q.

The relationship of the ordering cost, holding cost, and total cost is shown as functions of the order quantity below.

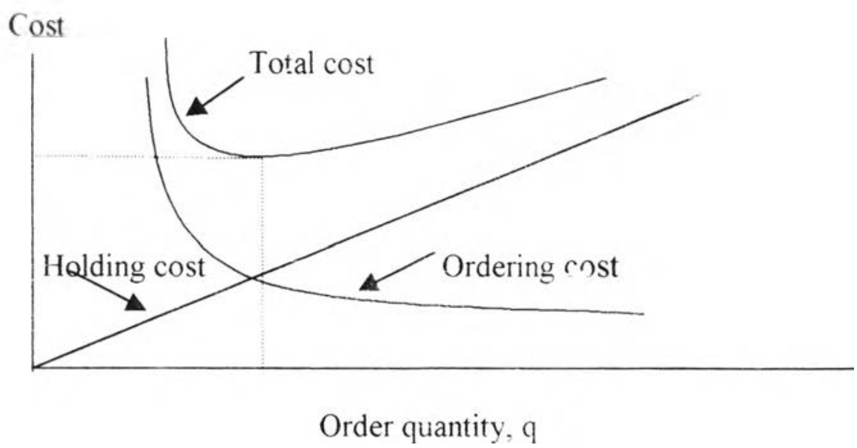

Figure 4.2: Ordering, holding, and total costs as a function of order quantity.

4.2.2 <u>Establishing Safety Stock levels</u>

The EOQ concept assumed that demand is constant and known. In the majority of cases, demand is not constant but varies from day to day. So safety stock must be maintained to provide some level of protection against stockouts. Calculation of safety stock is assumed that it is not involved with EOQ calculation. Value of safety stock is set that it is equal to all period of time. Safety stock can be defined as the amount of inventory carried in addition to the expected demand. The amount of safety stock depends on the service level desired. The service level is a statement of the percentage of time there is no stockout. Table 4.4 shows safety stock factors, % of service levels, and % of stockouts.

$$SS = z\sigma_L$$

The term $z\sigma_L$ is the amount of safety stock. The greater the safety stock, the sooner the order is placed.

Safety stock factor (z)	% of service level	% of stockout
0	50.0	50.0
0.5	69.1	30.9
1.0	84.1	15.9
1.1	86.4	13.6
1.2	88.5	11.5
1.3	90.3	9.7
1.4	91.9	8.1
1.5	93.3	6.7
1.6	94.5	5.5
1.7	95.5	4.5
1.8	96.4	3.6
1.9	97.1	2.9
2.0	97.7	2.3
2.1	98.2	1.8
2.2	98.6	1.4
2.3	98.9	1.1
2.4	99.2	0.8
2.5	99.4	0.6
2.6	99.6	0.5
2.7	99.6	0.4
2.8	99.7	0.3
2.9	99.8	0.2
3.0	99.9	0.1

Table 4.4: Safety factors, % of service levels, and % of stockouts.

4.2.3 <u>Order Point System</u>

When the quantity of an item on hand plus on order in inventory falls to a predetermined level (order point), an order is placed. Usually, the quantity ordered is precalculated and based on economic-order-quantity concept. If it is necessary to provide against a stockout, safety stock can be added. According to Chase R. B. et al (1998, p.595), the danger of stockout may occur during the lead time, between the time an order is placed and the time it is received. So the item is ordered when the quantity of inventory position falls to a level equal to the demand during the lead time plus a safety stock determined by the desired service level. In addition, inventory position of item is assumed that it is higher than order point in the first period of time.

The order point is $s = \bar{d}L + SS$

Where

$\bar{d}$	=	Average daily demand
L	=	Lead time in days (time between placing an order and receiving the items)
z	=	Number of standard deviations for a specified service level (safety stock factor)
σ	=	Standard deviation of usage during lead time

4.2.4 Order-Up-To-Level

The values of order quantity (EOQ) and order point (s) are the result of order-up-to-level (S). That is defined as a maximum value of each item.

$$S = s + EOQ$$

The values of order quantity (EOQ), order point (minimum), and order-up-to-level (maximum) are defined as an integer.

4.3 Algorithm of Truck Loading

A heuristic approach is used in algorithm of truck loading. The algorithm is based on a set of decision rules that is closely related to the practical situation.

4.3.1 A Set of Decision Rules

1. When any item in the group drops to order point (minimum), that item is ordered and loaded into the truck that is equal to order quantity (EOQ) that is defined as a starting order quantity.

2. If capacity of truck loading is available, other items will be considered by ratio to order. This ratio to order consider only available stock level of items with minimum level (order point) when they are compared with order quantity (Max – Min = EOQ)

$$\textbf{\textit{Ratio To Order (RTO)}} = \frac{\text{Inventory position - Minimum}}{\text{Maximum – Minimum}}$$

If an item has lower RTO than other items, it is concerned before and ordered that is equal to Maximum minus Inventory position. Inventory position is on hand inventory plus on order inventory.

3. Consider RTO of other items and load into truck that must not exceed a maximum loading capacity.

4. If RTO of any item is equal to other items, any item is considered and ordered that is equal to Maximum minus Inventory position.

4.3.2 Constraints

1. The items (two or more) are ordered and loaded from the same group of items. It means ordered items are manufactured from the same supplier.

2. Only weight (not volume) of 10-wheel truck is considered for loading capacity.

3. The maximum loading capacity of truck plus its own vehicle weight must not exceed the specified gross weight (21 tons) that is restricted by the Highway Department. Maximum loading capacity of 10-wheel truck considered is 13 tons. Total weights of one order of items must not exceed the maximum loading capacity.

4. Order quantity of item must not exceed a maximum level (order-up-to-level) of that item.

5. Transportation cost is fixed per trip. Transportation cost of product groups considered are 2,600 baht per trip.

The flowchart of truck loading algorithm is shown on the next page.

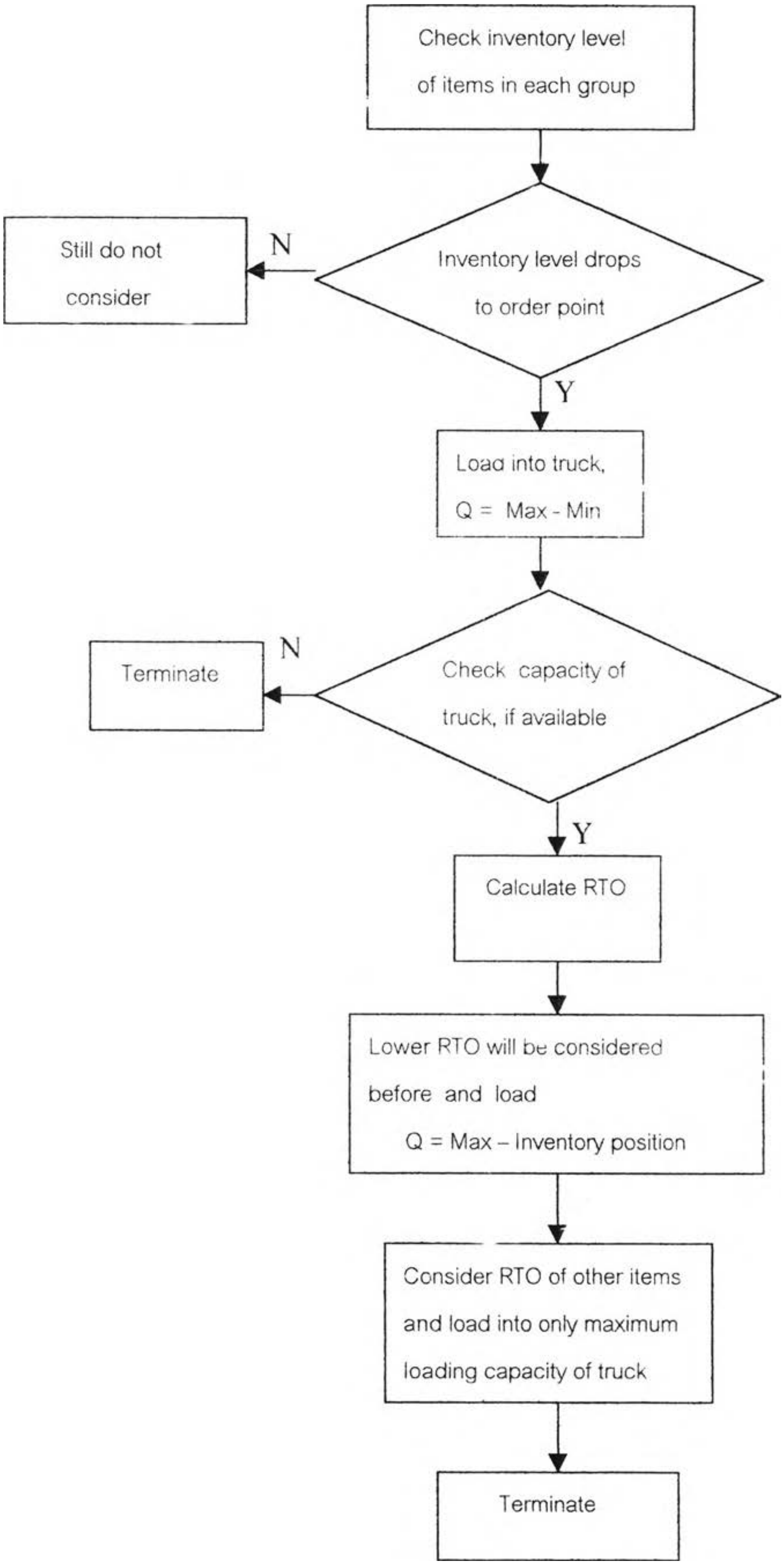

Figure 4.3: Flowchart of truck loading algorithm.

4.4 Parameter Estimation

The input parameter estimation data required for studying inventory system and truck loading algorithm are as follows:

1. Unit Variable Cost
   The unit prices of the items are not constant during the period over that the data have been collected. The most recent unit price of each item at the time of purchase is used in this study. This price must be updated whenever there is a change.

2. Inventory Holding Cost
   In general, the costs of holding inventory are made up of a number of components including Storage facilities, Handling, Taxes, Insurance, Deterioration, Obsolescence, Shrinkage, Interest on Capital, Administration which can be estimated separately. Storage facilities cost is not included. The distributor has its own warehouse and it is not used for rent. At the same time, an inventory change will not affect the amount of space the distributor uses for storage. The distributor does not have the cost of taxes on inventory. Materials can keep in so long time and they always have selling transaction. Loss cost (pilferage and breakage) is relatively low. The costs of deterioration, obsolescence, and shrinkage are also not included. In this study, two major product groups of construction materials are concerned for inventory holding cost. Interest on capital cost is added to take into account the money that is required to maintain the investment in inventory. Handling cost would be included equipment and labor cost. Premium on insurance is the fire premium of warehouse. Administration cost would be the cost of checking stocks and managing document of inventories. According to Smith S. B. (1989, p.113), holding costs are the costs that increase with the size of inventory. If the costs are not a function of the size of the inventory, they should not be included in holding cost. In addition, if the lot sizes for a group of items were increased or decreased, none of these costs would change that they are sunk costs. Handling, insurance, and administration costs are not increased with the size of inventory. When the size of inventory is changed, these costs are not changed. It means that these costs should not included in inventory holding cost of this study. So interest on capital, which is the largest component of holding cost, is only one holding cost studied.

   Interest on Capital Interest charge is added to take into account the money that is required to maintain the investment in inventory. Interest rate is defined at 18%. A value of average inventory level of two product groups is 8,057,399.89 baht.

   $\therefore$ Interest on Capital invested in inventory = 0.18 x 8,057,399.89
   = 1,450,331.98 baht/year

Therefore, average inventory holding cost is calculated by the cost of holding inventory per year compared with average weight of inventory.

The cost of holding inventory = 1,450,331.98 baht/year

Average weight of inventory = 1,022,146.15 kg.

Inventory holding cost = 1,450,331.98 / 1,022,146.15

≈ 1.42 baht/kg/year

≈ 1,420 baht/ton/year

The cost of holding inventory = 1,450,331.98 baht/year

Value of average inventory level = 8,057,399.89 baht/year

Inventory holding cost ≈ 0.17999

≈ 18.00% per year

3. Ordering Cost

They include of many costs for purchase items such as preparation of purchase order, expediting (telephone and telegraph), and transportation. In this study, ordering costs are composed of preparation of purchase order, expediting of telephone and facsimile, counting items and calculating order quantities, and transportation cost. The transportation cost is only one considered because other costs are a few costs.

4. The Desired Service Level

This service level against a stockout is specified. It is defined that is equal to 95 per cent. The distributor admits to be out of stock 5 per cent.

5. Lead time

This parameter varies depending on the circumstances of ordering. Under normal condition, the lead time between making the purchase request and receiving the items is usually three days for all items.

6. Unit Weight

Each item has its own weight. Weights of item are used to calculate loading capacity of 10-wheel truck.