Material Procurement Model Considering Life Time and Minimum Order Quantity

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Abstract

This paper presents the results of developing models to determine the size of material ordering by considering life time and minimum order quantity (MOQ). This topic was inspired by real problem at an aerospace company located in Bandung. The faced real problem is how to minimize waste in material procurement due to short of material life time and minimum order quantity from suppliers. The waste is caused by a lot of unused material (eventualy expired and causing high expired cost), added with high of ordering costs, storage costs and stockout costs. Until now the authors have not found the appropriate model. On the basis the authors developed or modified a new model. The developed model is deterministic category by assumption of material demand, lead time and costs involved are considered fixed or unchanged. The developed model are combination between optimal and heuristic approach. The developed model will get optimal solution when the normal situation faced, but for the specific situation the best solution will be found by heuristical approach.
Authors believe this research will be very useful for companies, as well as for scientific development related to optimization in the field of inventory control and material management.

Keywords:
Life time, expired cost, minimum oder quantity.

1. Introduction

Every business system has the goal of generating profits as much as possible by lowering costs as low as possible. One of the costs that caused the greatest waste in business activities was the logistics cost, which included a material procurement cost of about 40%, Bower Sox. [2].

An Aerospace company which located in Bandung Indonesia (apearless named of company) is one company that always trying to find the best way to manage its inventory. The complexity of the problems are being faced by the company today is very high. The type and number of demands vary greatly, material characteristics were vary also including life time, unit price, lead time ordering, and minimum order quantity from the vendor.

Based on observations in the Material Planning Department that handles planning of non metal raw materials is still a serious problem, that is still many materials that have overstock and stockout caused by the incompatibility between the needs with the amount of material ordered. When the number of ordered material are larger than the level of usage (slow moving) it will cause the buildup (overstock) in the warehouse. While for material with fast moving usage category more than ordered size will cause material to be depleted (stockout).

The difficulty faced today is determining the size of material ordering by considering the life time and minimum order quantity that can minimize the cost due to deficiency or due to excess. Researchers believe that the complexity of material procurement issues can occur in almost all other businesses that may be more complex than the problems at the site. The problem of procurement of perishable commodities in supermarkets with different characteristics may be more complex. Most of agricultural materials have short life time such as fruits and vegetables.

Until now researchers have not found the same model or appropriate models with the problems faced. Based on that, the researcher developed material procurement model by considering life time and minimum order quantity.

2. Review of Literature

Inventory is idle resources whose existence is indispensable to support further process or production process. The existence of inventory in a business unit needs to be arranged in such a way that the smoothness of the fulfillment of the needs of the user can be guaranteed, but the costs incurred as small as possible (Nur Bahagia, 2006) [7]. Inventory has a high economic value, its means to have inventory requires a large investment cost which proportional to the amount and value of each unit stored. In addition, having inventory has cost consequences related to procurement costs, storage costs as well as costs associated with the system or management. 40% of the total cost for business actitivy used for the logistics activities, Bower Sox [2], Arifin [11].
The objective of inventory management is to have the appropriate amounts of materials in the right place, at the right time, and at low cost. Inventory costs are associated with the operation of an inventory system. Some of inventory costs are frequently considered in decision making of inventory problem are, 1. Purchase cost, 2. Order/set-up cost, 3. Holding cost, and 4. Stockout cost. Tersine [6].
In this research, researcher have found out a lot of references as a comparison and found inspiration to develope new model. Some of them are from Wise Ellhasya, Hendro Prassetiyo and Lisye Fitria, Journal Online National Institute of Technology, Bandung 2014, on the Design of Control Systems of Cake Raw Material Supply Using Single Single Item Supplier Method and Multi Item Single Supplier (Case Study at PT Bonli Cipta Sejahtera / J & C Cookies Bandung). The second is from Laila Nafisah, Puryani. F. X, and Ketut Bayu Lukito, Proceedings of Nasional Seminar on Technology Management XIV, Surabaya 2011.
The researcher also found the two of international journals considered to have a closeness that is from Linh N K. Duong, Lincoln C Wool, A multi criteria inventory management system for perishable & subtitutable products, 2nd International Materials, Industrial and Manufacturing Engineering Conference, MIMEC, 2015, ScienceDirect, ELSEVIER.
Another else is from Dharmendra, SR Singh, Mennu Gupta, Manufacturing Inventory Model for Deteriorating Items with Maximum Lifetime under Two-level Trade Credit Financial, International Journal of Computer Application (09/3-8887) Volume 121, No.15 July 2015.
Some of the above references are used as a comparison, as well as a source of inspiration for researchers in developing the model. Also it was give a confidence for researchers that the model developed in this paper does not yet exist.

The most important reference is a book by Richard J Tersine, Principle of Inventory and Materials Management, Oklahoma University, Prentice-Hall, 1994. The former authors, Tersine developed model based on three of costs. These are purchased cost, order cost, and holding cost. Formulation cost model are

$$TC = RP + mC + \frac{RFP}{2m} = RP + \frac{C}{T} + \frac{RFPT}{2} \quad (1)$$

Where :
R = annual requirement for item
P = purchase cost for item
C = order cost per order.
T = order interval (in years)
F = Fraction hodling cost (%) per unit per years
m = number of cycle per year

In this paper the authors developed new model by adding expired cost as will be discussed at the result and discussion section.

3. Methodology

Globaly the steps of the research could be illustrated in the flow map as shown in the picture below:

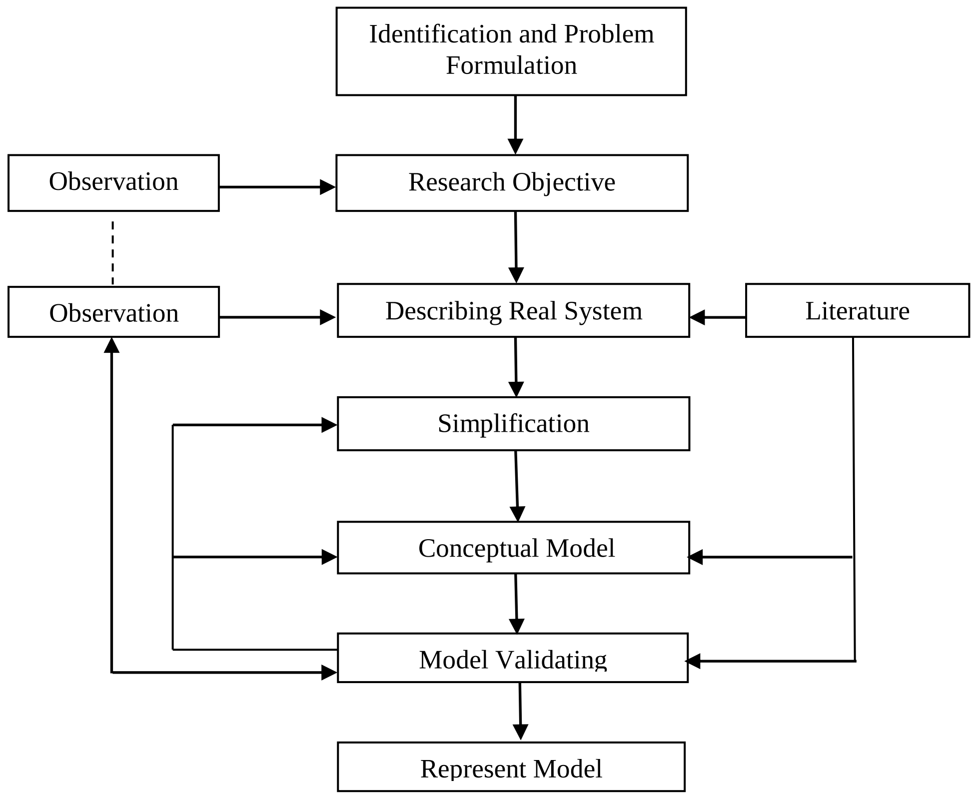

Figure 1. Steps of the Research

The above steps are important and must be executed properly so the results of research in accordance with the goals set. In this paper the researcher not gives explanation of each steps considering limitation number of pages. The development of the model refers to the basic model that has been developed by previous experts and is often arised in various references. One of the references is, "Inventory System and Material Management" from Richard J Tersine. Developed models include categories of deterministic models. This means that all the variables and parameters involved are assumed to be constant. Model validation was performed using empirical data from real cases in the study sites. The results of the model development presented directly in the following results and discussion section.

4. Result and Discussion

As we said before the development of the model begins with a basic model developed in Richard J Tersine's Principles of Inventory and Materials Management. In the book the model only takes into account the three types of costs, namely purchase costs, ordering costs, and storage costs (eq. 1). The model included to the category of deterministic models. The model developed in this paper adds expired cost due to the amount of ordering of MOQ set by the vendor too much while the life time is shorter. Graphically the model by considering the minimum order quatity and life time is described as follows.

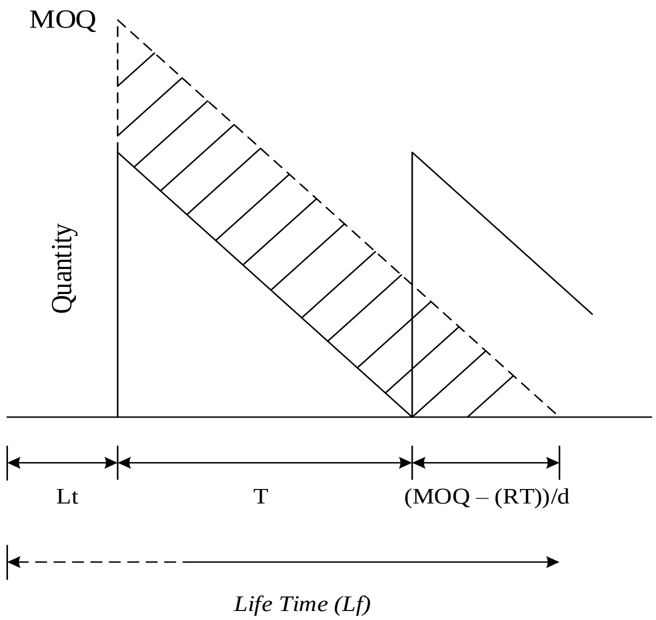

Figure 2. Developed Model of EOI-*single item*

Where,
Lt = lead time of traveling
Lf = life time of material
MOQ = minimum order quantity
d = daily demand rate
T = lenght of usage cycle

Models developed to determine the order interval are expected to be no shortage. Therefore the minimization cost model requires $Lt + T < Lf$, whereas if $Lt + T > Lf$ there will be deficiency due to expiration. If the amount of material used in life time is $(Lf - Lt).d$, and if $MOQ - (Lf - Lt).d > 0$ the material will expire so the total cost for one year is:

$$TC(T) = PR + mC + \frac{PFR}{2m} + m.Kd(MOQ - (Lf - Lt).d) \qquad (2)$$

Or can be expressed,

$$TC(T) = PR + \frac{C}{T} + \frac{PFRT}{2} + \frac{1}{T}.Kd(MOQ - (Lf - Lt).d) \qquad (3)$$

Subject to $Lt + T \leq Lf$

where:
P = purchase cost per unit
R = Annual Demand in units
C = order cost
H = holding cost per unit per year
Q = order quantity
F = frcation holding cost
$m = \frac{1}{T} =$ number of order per year

$\frac{R}{2m} =$ average of inventory in unit

$T = \frac{1}{m} =$ order interval (in year)

$d = \frac{R}{N} =$ daily demand rate

$Kd =$ Expired cost

To obtain the minimum cost, the above equation is derivated to T set equal zero.

$$\frac{dTC(T)}{dT} = -CT^{-2} + \frac{PFR}{2} - Kd(MOQ-(Lf-Lt).d)T^{-2}$$
$$= -\frac{C}{T^2} + \frac{PFR}{2} - \frac{Kd(MOQ-(Lf-Lt).d)}{T^2}$$
$$\frac{PFR}{2} = \frac{C + Kd(MOQ-(Lf-Lt).d)}{T^2}$$

So that obtained optimal order interval by considering expired cost,

$$T^* = \sqrt{\frac{2(C + Kd(MOQ-(Lf-Lt).d))}{PFR}}$$

To keep $Lt + T < Lf$, the optimal T value formulation needs to be validated, so the use of the model must follow some steps below.

The steps in progress for the EOI model-single item are as follows:

a) Make sure that the supplier specifies the MOQ or not.

b) If the supplier sets MOQ, to count the initial T value (Optimal Order Interval) with the formula

$$T^* = \sqrt{\frac{2(C + Kd(MOQ-(Lf-Lt).d))}{PFR}} \quad (4)$$

And the otherwise,

$$T = \sqrt{\frac{2C}{PFR}} \quad (5)$$

c) To avoid the shortage of material due to the short life time which would affects the production loss then the above T must meet $Lt + T \leq Lf$, but if $Lt + T > Lf$, then T must be replaced with new revised T *revised* $= Lf - Lt$.

d) Calculating initial order size for choosen T order interval $Q = R \times T$

e) If at step a supplier sets *MOQ*, compare order size *(Q)* with Minimum Order Quantity *(MOQ)*.

If $Q > MOQ$, set Q as an alternative to order size.

But if $Q < MOQ$, Then set *MOQ* as the size of the order to be done. Proceed to step f.

f) Check if $Lt + T + ((MOQ - RT) / d) < Lf$, then the material does not expire, in otherwise the material will be expired. Expired cost is calculated by $m.Kd(MOQ-(Lf-Lt).d)$.

Some of assumptions used in the development of EOI-single item model are as follows,

1. The level of demand is known with certainty and constant over time.
2. The developed model is used for single item category.
3. The ordering interval is always the same each period.
4. The ordered materials come simultaneously according to the number of orders
5. Proportional purchase cost with the number of items purchased (no discount factor).

6. The cost of storage depends on the average number of items stored.

Examples of model implementation,
For convenience the author does not mention the name of the material, but only lists the required parameters in the developed model application.

R = 7800 units
P = $ 10
C = $ 3
Lt = 1 month
Lf = 3 month
MOQ = 1500 units
Kd = $ 12
F = 6,5 %

Calculation steps,

1. $$T^* = \sqrt{\frac{2(30 + 12(1500 - (3-1)650))}{10x6.5\%x7800}} = 0.979 \quad \text{year} \cong 11.74 \ \text{month}$$

2. Checking whether *Lt + T (month) < Lf,*
   1 + 11,74 > 3, it mean using *T* = 11,74 month material will be expired and shortage, it need revise *T*, so that *T revised* = *Lf – Lt* = 3 – 1 = 2 month or 0,083 years.

3. Calculating order size *Q* = *R.T* = 7800 x 2/12 = 1300 units.
   For *Q* < *MOQ*, then order quantity are *MOQ* = 1500 units.

4. Checking *Lt + T + (MOQ-R.T)/d) < Lf*
   1 + 2 + 0,3 > 3, this shows the material will expire as much as 200 units for 0.3 months and will cause an expired loss of $ 2400.

Model Validating

Validation is performed to test whether the optimal *T* formulation above (eq.4) resulting the least cost. Validation process by substituting the value of *T* on the total cost model (eq.3) until the cost curve is obtained as shown below. The smallest cost is at the ordering interval *T* = 0.98 years, therefore the optimal *T* obtained from the formula above equals *T* = 0,979 or 0,98 years.

Table 1. Finding *T* optimation

T	TC (T)
0,92	82973,50
0,93	82970,45
0,94	82968,01
0,95	82966,14
0,96	82964,85
0,97	82964,10
0,98	82963,89
0,99	82964,20
1,00	82965,00
1,01	82966,29
1,02	82968,05
1,03	82970,27
1,04	82972,94

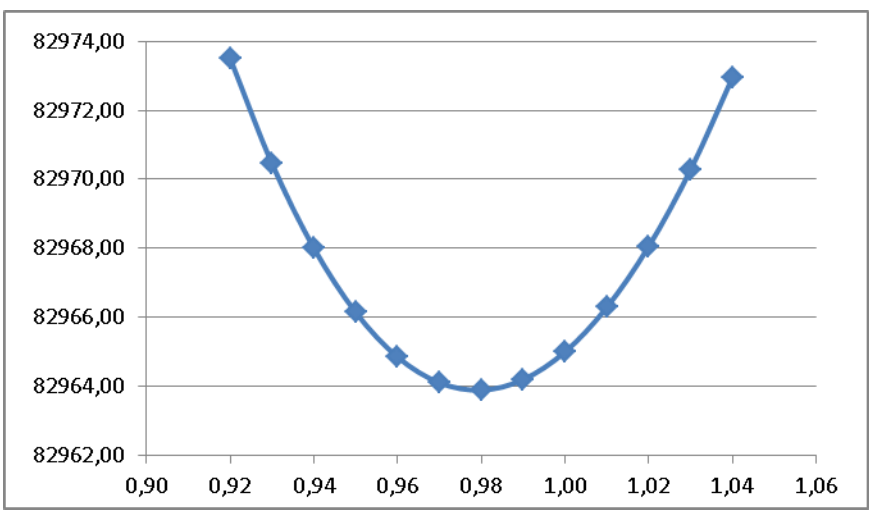

Figure 3. Optimization curve

Under ideal conditions the optimal T value is obtained at T = 0.979 for a total cost of $ 82,963.89. However, for life time material is very short Lf = 3 months, then the value of T becomes improper which will cause the amount of expiration is very big and will cause material shortage. Because the developed model does not accommodate the deficiency, the decision is T revised = 2 months. With the decision will result in a total cost of $ 93,593.10, there is a difference with the cost at an optimal T of $ 10,629.21. The cost differencies are an avoidable loss due to determined minimum order quantity by vendor and short life time of materials.
If life time is long enough, for example Lf = 10 months, then by order of MOQ = 1500 does not cause expired material. So that optimal ordering interval is obtained

$$T = \sqrt{\frac{2(30)}{5070}} = 0.108 \text{ years or } 1.3 \text{ month}$$

With T = 1,3 month, the requirement of $Lt + T < Lf$ are satisfied.
Order size can be calculated $Q = R \times T$ = 7800 x 0,108 = 842,4 unit

Because of $Q<MOQ$, the order size is 1500 units. Consequently, if the order interval is performed every 1.3 months each cycle will occur the remaining 657.6 units. This residual value will accumulate which will result in large storage costs. So the solution offered to order at interval $T = MOQ/R$ = 1500 / 7800 = 0,192 years or 2,3 month.

At optimal order interval will get the cost below,

$$TC(T) = PR + \frac{C}{T} + \frac{PFRT}{2} = 78000 + \frac{30}{0.108} + \frac{5070}{2} = 78551.5$$

While the total cost with a 2.3 month or 0.192 year booking interval is $ 78642.97. There is a difference of $91,47 due to the minimum order quantity set by the company.
If the MOQ set by the company is small enough eg MOQ < 800 units, then ideal conditions can be achieved with a 1,3 month order interval with an order size of 842,4 units.

5. CONCLUSION

The developed model resulted optimal formulation for the T order interval, followed by an advanced calculation or algorithm to meet eligibility requirements.
The developed algorithm starts from finding the optimal value by considering life time and minimum order quantity by considering purchase cost, order cost, storage cost, and expired cost.
From the developed model above, the optimum T by considering life time and minimum order quantity can be achieved maximally (100%) when the life time of material is relatively long and MOQ is relatively small.
If the condition is not obtained then the optimal value will change following the eligibility requirements in accordance to algorithm developed.

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