IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 8, August 2016

Decision Making to Select the Best Order Quantity (BOQ) from Supplier using Genetic Algorithm

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Abstract: Manufacturers need to have a good supply chain management system in order to achieve low inventory levels, short lead times and adjustability to meet customer demands at minimal total operation cost. The most important drawback of existing methods used to minimize inventory costs as Just-in-time (JIT) methodology or to minimize transportation and order costs as Economic Order Model (EOQ). This minimization strategy may not be able to give the best order quantity because of the relationship between inventory cost and transportation cost, In this paper, we used genetic algorithm (GA) to reduce the inventory and transportation costs together to determine the Best Order Quantity (BOQ). The main advantage of this new method, it is covers pull system, push systems, short planning horizon, and long planning horizon.

Keywords: Economic Order Model (EOQ), genetic algorithm (GA), Best Order Quantity (BOQ) Just-in-time (JIT).

1. INTRODUCTION

Companies select Single or multiple suppliers to fulfill the demand, and replenishment order quantity is split into different portions for each supplier at the same time. There are two types of supplier selection problem. In the first type of supplier selection, a single supplier can fulfill the entire buyer's demand. Only one decision should be made in this situation: which supplier is the best. In the other type of supplier selection, there exists no single supplier who can satisfy the entire buyer's needs. In this situation, the buyer has to split order quantities among suppliers for having a stable environment of competitiveness [1].

Davari and et al (2008) presented a multiple suppliers and multiple products model. There were three objectives to achieve, minimizing purchasing cost, rejected units and late delivered units [2].

Sarker and et al. (2008) consider EOQ-like batch sizing models that account for the possibility of rework being done during cycles, as well as after a certain number of cycles. Especially the latter deals with quite some far-going issues and hence provides some useful insights. Nonetheless, the paper stresses the need for flawless production, since rework will always be more expensive than first-time right production [3].

Wadhwa and Ravindran (2010) introduced a multipe-objective multiple-supplier selection model for low risk and cost products. The first objective was to minimize the total purchasing cost, which concluded total variable cost, fixed cost, inventory holding cost and the bundling discounts. The second objective was to minimize the reject units under supplier capacity constraint. Shortage was not allowed and the multi-objective model was solved by preemptive goal programming [4].

Nouha and et al.(2014) Calculating the lot sizing depend Economic Order Quantity (EOQ), and the second method is the Periodic Order Quantity method which is based on the notion of orders economic period and calculated with Wilson's formula[5].

2. INTEGRATED PURCHASING AND SUPPLY MANAGEMENT PROCESS

The supply management function has grown from a tactical function of purchasing/procurement into a key strategic role within organizations. Supply management exists to explore business opportunities and implement supply strategies that deliver the most value possible to the organization, its suppliers, and its customers. Strategic supply management is the organization's primary source for collecting market intelligence and developing cost-reduction programs. Given the strategic nature of the supply function, the top supply management professional is usually a member of the organization's senior management team. In this leadership role, supply management professionals must be knowledgeable and understand all areas of the business in order to develop strategies consistent with the organization's goals and successful business procedures.

The purpose of supply management is to support the transformation of raw materials and component parts into shipped or inventory goods. The function of inventory in general is to decouple the entire transformation process. During the transformation process, materials are combined with labor, information, technology, and capital. Figure (1) focus of integrated purchasing and supply management [6].

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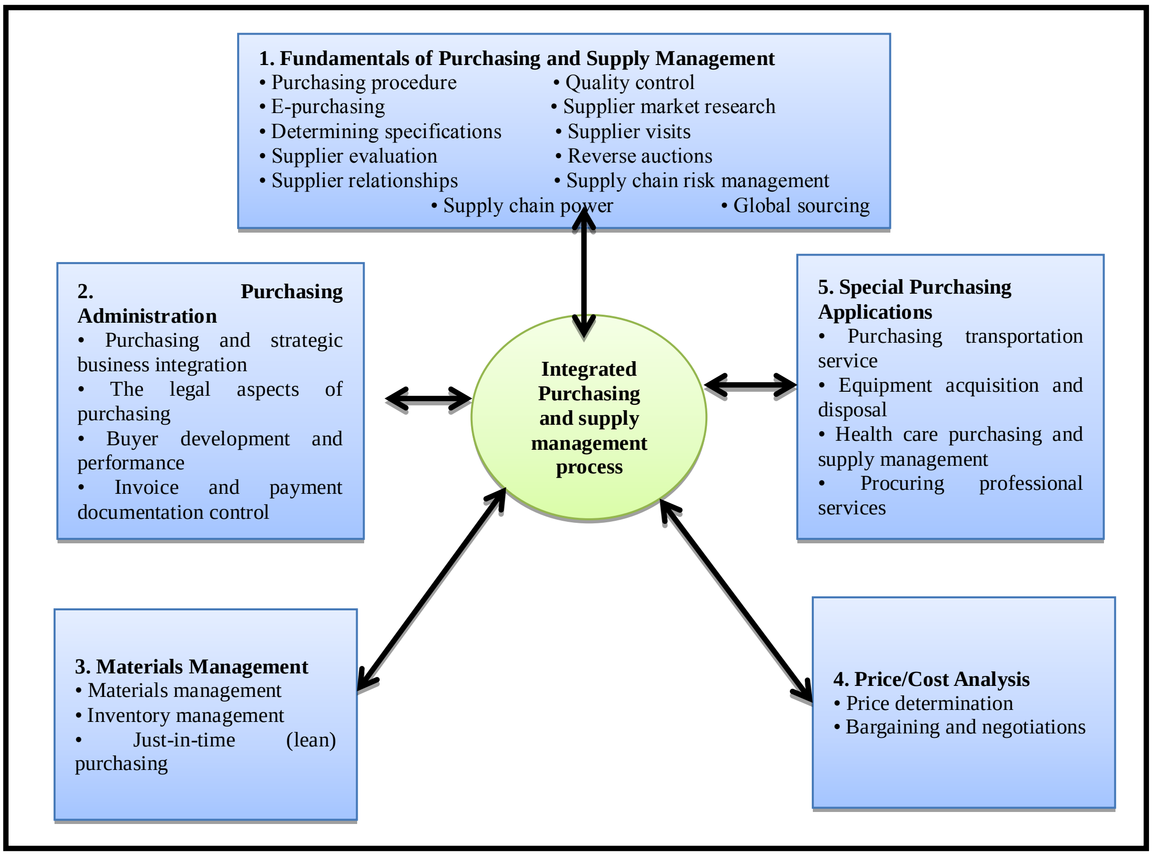

Figure (1) Integrated Purchasing and Supply Management Process [6]

3. INVENTORY AND TRANSPORTATION COSTS

The manufacturer needs to order the items to meet their demand targets at a minimal total cost. Each item has different known demand targets at different time points .It also has fixed cost for each order placed and fixed holding cost. For purchasing and shipping costs, the price is dependent on the number of items that would be order. The model determines the number of each item to be purchased, at each time point, to meet the demand targets at these time points, in order to minimize the total cost. Proposal model costs in this paper include as following:

3.1. Order Costs

The ordering costs is a fixed cost of tracking trucks from a supplier to inventory , labor costs of processing orders , inspection and returning of poor quality products [7].Conversly to the costs fixed per unit , the inventory costs fixed per order comprises only a porition of the acquisition cost of inventory. This is the cost incurred each time a stock replenishment order is placed and includes costs such as import duties ,telphone calls , stock consolidator's fee , etc. Ordering cost was considered as a fixed component and part of other fixed costs [8].

3.2. Holding Costs

Holding cost define as the cost associated with having one unit in inventory for a period of time. [9]: The working of the (EOQ) is shown in figure (2), where a replenishment order of quantity Q is placed the moment the inventory reaches a level R. the virtual stock level consist of the sum of the on-hand inventory of a product currently stored at a location , and the inventory that is en route to that specific location.

In comparing the virtual stock level of the (EOQ) model to that of the JIT model, shown in figure (3) , it can be seen that the JIT model's virtual stock level fluctuates far less than that of the (EOQ) model . It should also be noted that the average stock level of a product in the JIT methodology is very close to the maximum number of unit stored , compared to the (EOQ) model where the average stock level is almost half of the maximum number of unit stored . [10].

3.3.Purchasing Costs:

It is the primary concern of any manufacturing organization to get an item at the right price. But right price need not be the lowest price. It is very difficult to determine the right price; general guidance can be had from the cost structure of the product. [11].

3.4. Transportation Costs:

Transportation costs will at first decline as the number of facilities increase, but will eventually increase as the number of facilities increase as a result of inbound and outbound transportation costs.

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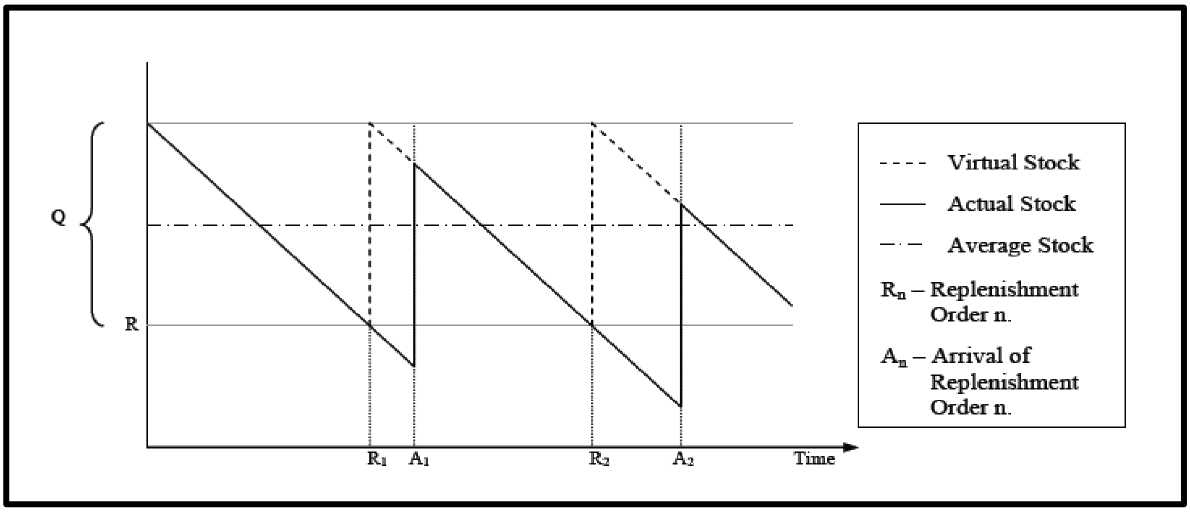

Figure (2) The fluctuation of inventory levels in the economic order quantity inventory control model [10].

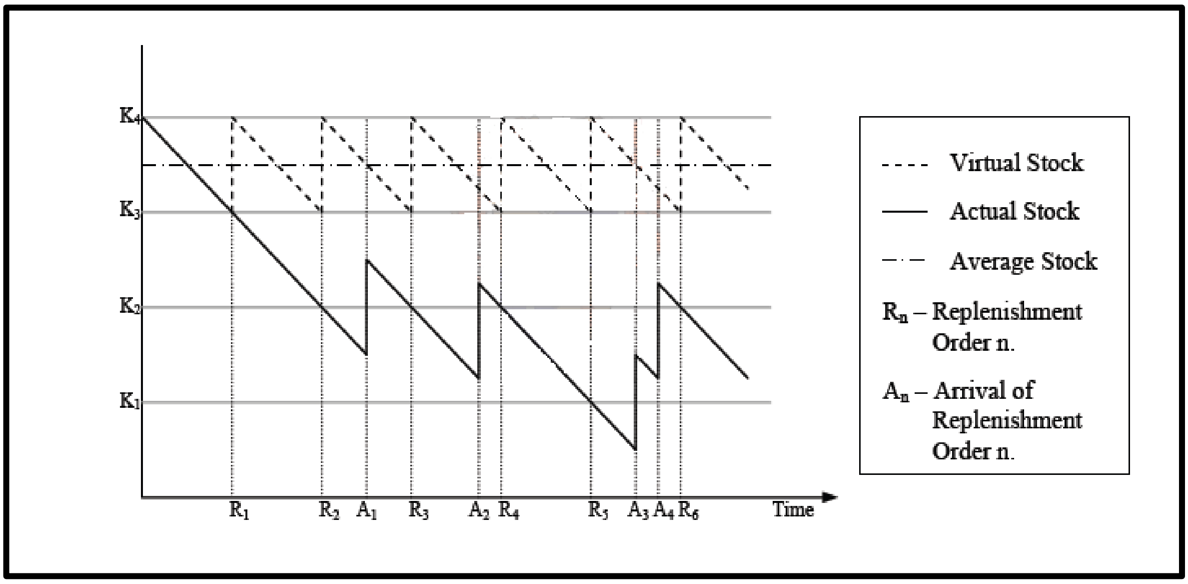

Figure (3) The fluctuation of inventory levels in the Just-In-Time inventory control model [10].

The total cost of transporting products must be measured and not only the cost of moving the products to the warehouse. With fewer locations saving can be obtained by making use of bulk distribution from the manufacturer or supplier. There will however be a certain point where there are too many warehouses and fewer inventory of the various item lines will have to be shipped to the warehouse to ensure that there are no items that are overstocked [12].

4. THE PROPOSAL MODEL TO DETERMINE THE BEST ORDER QUANTITY

Volatile customer expectations and rapidly changing markets cause short lifecycle items .Manufacturers need a strategy to decrease the risk of short lifecycle items and to increase efficiency. Receiving the items from suppliers at the same time of the demand target is one of the keys of decreasing the risk for the manufacturers.

Just –In-Time (JIT) model is one of the ways for achieving this goal, but it may not be the optimal solution. The first reason is, in the JIT model the manufacturers order the items whenever they need to meet the demand targets thus, it covers just pull systems and short planning horizon.

Anew model covers pull system, push systems, short planning horizon, and long planning horizon. In pull systems the demand targets for items at each time point are know but may be non-constant during a planning horizon. The manufacturers respond the demand targets an determine order quantities during a planning horizon. In push systems the demand targets and the planning horizon are know and constants.

The second reason is, by increasing order quantities, the price and shipping cost per item will be decreased, although in a JIT model , the price breaks for purchasing and transportation costs may not happen at all time points. Manufacturers need to have a good supply chain management system in order to achieve low inventory levels, short lead times and adjustability to meet customer

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demands at minimal total operation cost. This cost is made up of inventory and transportation costs that are often minimized separately. This minimization strategy may not be able to give an optimal order quantity because of the relationship between inventory cost and transportation cost. In this paper, inventory and transportation cost are minimize together to determine optimal order quantities.

4.1. Assumptions:

The assumptions that are:
1-Items are always available for shipment.
2- Each item has constant holding and ordering costs.
3- The purchase and transportation costs are vary with order quantity.
4- The demand are known and non-constant.
5- The period between time points of planning horizon could be measured in hours, days, months, etc.

4.2. Parameters and Variables

We have a planning horizon with n time points ,where the period between time point could be measured in hours , days , weeks , months or years , depending on the application . The set of all time points is J={ 0,1,2,3,.., n }. At time point $j \in J$, which is the beginning of time period j , item $i \in I$ has demand D_i^j and inventory level V_i^j where i is the index set of all items to be delivered by the supplier to the manufacturer and the initial inventory level V_i^0 is know .The plant warehouse has limited stock capacity for each item $i \in I$ depend on lower and upper number of units for all item.The inventory level of item at the beginning of time period $j \in J$ is:

$$V_i^j = V_i^{j-1} + Q_i^j - D_i^{j-1}, \forall j \in \{0\} \quad (1)$$

$$Q_i^j \geq 0, and\ Q_i^0 = 0, \quad \forall i \in I \quad (2)$$

The inventory level of item i should be greater than or equal to the demand at each time point j when there is no shortage in items, thus:

$$V_i^j \geq D_i^j, \forall i \in I, \forall j \in J \quad (3)$$

The price of each item decrease when the number of item increases. The purchasing cost of order quantity is:

$$if Lower \leq D_i^j < Upper\ then\ P_i^j = p_i^k Q_i^j; \forall i,j \quad (4)$$

Where:
P_i^j = Purchasing cost for item i in time j.
p_i^k = The set of price breaks of item i ,weher k={ 1,2,3,….} .
The transportation cost for shipping the items decrease when the number of item increases. Transportation cost of order quantity is:

$$if(Lower \leq D_i^j < Upper) then\ R_i^j = r_i^m Q_i^j \ ; \forall i,j \quad (5)$$

Where:
R_i^j = Transportation cost for item i in time j.
r_i^m = The set of price breaks of item i, where m= {1,2,3, .}
The ordering cost for item i at time point j is:

$$O(Q_i^j) = o_i Q_i^j \ ; \forall i,j \quad (6)$$

Where:
o_i= Ordering cost for item i.
The total ordering cost for during whole planning horizon is :

$$O(q_i^j) = \sum_{i \in I} \sum_{j \in J} o_i q_i^j \ ; \forall i,j \quad (7)$$

Item i has a unit holding cost h_i per time period. The total holding cost for storing order quantities of item i between time points j and j+1 is:

$$H(Q_i^j) = h_i V_i^j \ ; \forall i,j \quad (8)$$

The total holding cost for during whole planning horizon is :

$$\sum_{i \in I} \sum_{j \in J} H(Q_i^j) = \sum_{i \in I} \left(h_i V_i^0 + \sum_{j \in J} h_i V_i^j \right) \quad (9)$$

Let $C(Q_i^j)$ be the total cost, that is the summation of purchasing, ordering, holding and transportation costs. Form equations (6),(7),(8) and (9) we have :

$$C(Q_i^j) = \sum_{i \in I} \sum_{j \in J} \left(P(Q_i^j) + O(Q_i^j) = H(Q_i^j) R(Q_i^j) \right) (10)$$

For finding the optimumQ_i^j , we need to minimize the total cost , $C(q_i^j)$. Thus, the model is to:

$$\text{Minimize Z= } C(q_i^j) \quad (11)$$

Subject to:

$$\sum_{j=0}^{J} Q_i^j + V_i^0 \geq \sum_{j=0}^{J} D_i^j \ ; \forall i,j \quad (12)$$

Q_i^j > =0 and integer variable
The genetic algorithm starts with an initial set of solutions which is known as a population. The individuals of the population are called chromosomes which are evaluated according to a predefined fitness function, in our case the total cost. Each chromosome include several genes .The gene represents an order quantity of item i at time point j.

4.3. Solution of the Model

The genetic algorithm (GA) module in matlab's global optimization toolbox is used to solve equation (14); the

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genetic algorithm is a stochastic search method for solving both constrained and unconstrained optimization problems that is based on natural selection process that mimics biological evaluation. It explores the solution space by using concepts taken from natural genetics and evolution theory [13] .

GA starts with an initial set of solutions which is known as a population .The individuals of the population are called chromosomes which are evaluated according to a predefined fitness function, in our case the total cost .Each chromosome include several genes .The gene represents an order quantity of item I at time point j [14] . Anew generation is created by changing chromosomes in the existing population through crossover and mutation [13].

5. NUMERICAL EXAMPLE

The proposal model to determine the best order quantity will illustrates with this example that contain on ten materials and twelve months.

The demands on material to this example are given in table (1) and first column of the table include the initial inventory levels V_i^0.

Table (2) shows the price costs and table (3) shows the transportation costs .

Table (1) Material Demands of the Example

$i \in I$	$j \in J$												
	V_i^0			D_i^3									
1	45	0	120	0	0	120	0	0	120	0	0	120	0
2	60	50	50	50	50	50	50	50	50	50	50	50	50
3	0	250	0	0	0	250	0	0	0	250	0	0	0
4	20	135	135	135	135	0	0	0	0	135	0	135	0
5	55	0	100	0	100	0	100	0	100	0	100	0	100
6	25	50	250	50	250	50	250	50	250	50	250	50	250
7	0	100	200	300	100	200	300	100	200	300	100	200	300
8	25	80	150	100	80	150	100	80	150	100	80	150	100
9	22	75	75	75	75	75	75	75	75	75	75	75	75
10	35	85	45	85	45	85	45	85	45	85	45	85	45

Table(2) The Relation Between Price Costs Per Unit and Material Order Quantity of the Example

Material $i \in I$	Price Costs								
	1	2	3	4	5	6	7	8	9
1	1-50	51-100	101-150	151-200	201-250				
	10	9.5	9	8.5	8				
2	1-100	101-200	201-300	301-400	401-500	501-600			
	25	23	21	19	18	14			
3	1-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800	
	18	16.5	15	13.5	12	10	9	7.5	
4	1-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900
	23	22	21	20	19	17	15	13.5	12
5	1-100	101-200	201-300	301-400	401-500	501-600			
	35	32	28	26	23	21			
6	1-200	201-400	401-600	601-800	801-1000	1001-1200	1201-1400	1401-1600	1601-1800
	50	48	44	40	38	36	34	32	30
7	1-300	301-600	601-900	901-1200	1201-1500	1501-1800	1801-2100	2101-2400	
	36	32	30	27	25	22	20	18	
8	1-200	201-400	401-600	601-800	801-1000	1001-1200	1201-1400		
	18	17	15	12	11	10	8		
9	1-200	201-400	401-600	601-800	801-1000				
	20	18	16	14	12				
10	1-200	201-400	401-600	601-800	801-1000				
	18	16	15	14	13				

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified

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Table (3) Transportation Costs Per Unit of the Example

Material	$r_i^m - r_i^{m-1}$						
i ∈ I	0-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-4000
1	**100**	**95**	**90**	**85**	**80**	**70**	**60**
2	**250**	**230**	**200**	**180**	**170**	**150**	**150**
3	**200**	**165**	**150**	**135**	**120**	**100**	**90**
4	**230**	**220**	**210**	**200**	**180**	**170**	**150**
5	**300**	**270**	**250**	**240**	**230**	**210**	**200**
6	**120**	**115**	**100**	**90**	**75**	**70**	**65**
7	**300**	**280**	**260**	**240**	**250**	**220**	**200**
8	**180**	**170**	**150**	**120**	**110**	**100**	**90**
9	**200**	**180**	**160**	**140**	**120**	**110**	**100**
10	**250**	**225**	**200**	**180**	**170**	**160**	**150**

Table (4) and (5) show fixed ordering cost o_i and holding cost h_i per month respectively .

Table (4) Ordering Cost of the Example

i	1	2	3	4	5	6	7	8	9	10
o_i	40	35	60	80	90	200	150	120	300	250

Table (5) Holding Cost of the Example

i	1	2	3	4	5	6	7	8	9	10
h_i	4	3.5	6	8	9	20	15	12	30	25

6. SOLUTION OF THE NMERICAL EXAMPLE

The best order quantities for this numerical example can be shown in table (6).The solutions are given in Matlab programming after 300 runs and each run gives various total cost with a various set of order quantities,then compares them to give best order quantities with minimal total cost that equal to 2172975 $.

Table (6) Best Order Quantities

		j ∈ J											
		Q_i^1	Q_i^2	Q_i^3	Q_i^4	Q_i^5	Q_i^6	Q_i^7	Q_i^8	Q_i^9	Q_i^{10}	Q_i^{11}	Q_i^{12}
i ∈ I	**1**	**75**	**0**	**0**	**0**	**120**	**0**	**0**	**120**	**0**	**0**	**120**	**0**
	2	**0**	**40**	**50**	**50**	**100**	**50**	**50**	**50**	**50**	**50**	**50**	**0**
	3	**250**	**0**	**0**	**0**	**250**	**0**	**0**	**0**	**250**	**0**	**0**	**0**
	4	**115**	**135**	**135**	**135**	**0**	**0**	**0**	**0**	**135**	**0**	**135**	**0**
	5	**0**	**45**	**0**	**100**	**0**	**100**	**0**	**100**	**0**	**100**	**0**	**100**
	6	**25**	**250**	**50**	**250**	**50**	**250**	**50**	**250**	**50**	**250**	**50**	**250**
	7	**100**	**502**	**0**	**98**	**200**	**518**	**0**	**82**	**300**	**100**	**200**	**300**
	8	**55**	**150**	**100**	**80**	**150**	**100**	**80**	**150**	**100**	**80**	**150**	**100**
	9	**55**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**
	10	**50**	**45**	**85**	**45**	**85**	**45**	**85**	**45**	**85**	**45**	**85**	**45**

Tables (7) and (8) shows inventory levels (V_i^j) and holding costs which are calculated from equtions 4 and 5,respectively.

Table (7) Inventory levels

		j ∈ J												
		V_i^0	V_i^1	V_i^2	V_i^3	V_i^4	V_i^5	V_i^6	V_i^7	V_i^8	V_i^9	V_i^{10}	V_i^{11}	V_i^{12}
i ∈ I	**1**	**45**	**120**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	2	**60**	**10**	**0**	**0**	**0**	**50**	**50**	**50**	**50**	**50**	**50**	**50**	**0**
	3	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	4	**20**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	5	**55**	**55**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

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	6	25	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	302	2	0	0	218	118	0	0	0	0	0
	8	25	0	0	0	0	0	0	0	0	0	0	0	0
	9	22	2	2	2	2	2	2	2	2	2	2	2	2
	10	35	0	0	0	0	0	0	0	0	0	0	0	0

Table (8) Holding Costs

		j ∈ J													Holding Costs
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
i ∈ I	1	180	480	0	0	0	0	0	0	0	0	0	0	0	660
	2	210	35	0	0	0	175	175	175	175	175	175	175	0	1470
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	160	0	0	0	0	0	0	0	0	0	0	0	0	160
	5	495	495	0	0	0	0	0	0	0	0	0	0	0	990
	6	500	0	0	0	0	0	0	0	0	0	0	0	0	500
	7	0	0	4530	30	0	0	3270	1770	0	0	0	0	0	9600
	8	300	0	0	0	0	0	0	0	0	0	0	0	0	300
	9	660	60	60	60	60	60	60	60	60	60	60	60	60	1380
	10	875	0	0	0	0	0	0	0	0	0	0	0	0	875
Total Holding Costs															15935

Tables (8) ,(9) and (10) show the ordering costs, purchasing costs and transportation costs for all items in a year which are calculated from equtions 6 and 7 and 8,respectively.

Table (8) Ordering Costs

		j ∈ J											Ordering Costs
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
i ∈ I	1	3000	0	0	0	4800	0	0	4800	0	0	4800	0	17400
	2	0	1400	1750	1750	3500	1750	1750	1750	1750	1750	1750	0	18900
	3	15000	0	0	0	15000	0	0	0	15000	0	0	0	45000
	4	9200	10800	10800	10800	0	0	0	0	10800	0	10800	0	63200
	5	0	4050	0	9000	0	9000	0	9000	0	9000	0	9000	49050
	6	5000	50000	10000	50000	10000	50000	10000	50000	10000	50000	10000	50000	355000
	7	15000	75300	0	14700	30000	77700	0	12300	45000	15000	30000	45000	360000
	8	6600	18000	12000	9600	18000	12000	9600	18000	12000	9600	18000	12000	155400
	9	16500	22500	22500	22500	22500	22500	22500	22500	22500	22500	22500	22500	264000
	10	12500	11250	21250	11250	21250	11250	21250	11250	21250	11250	21250	11250	186250
Total Ordering Costs														1514200

Table (9) Purchasing Costs

		j ∈ J											Purchasing Costs
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
i ∈ I	1	712	0	0	0	1080	0	0	1080	0	0	1080	0	3952
	2	0	1000	1250	2300	1250	1250	1250	1250	1250	1250	1250	0	13300
	3	3750	0	0	0	3750	0	0	0	3750	0	0	0	11250
	4	2530	2970	2970	2970	0	0	0	0	2970	0	2970	0	17380
	5	0	1575	0	3200	0	3200	0	3200	0	3200	0	3200	17575
	6	1250	12000	2500	1200	2500	12000	2500	1200	2500	1200	2500	1200	85750

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
ISO 3297:2007 Certified
Vol. 3, Issue 8, August 2016

					0				0		0		0	
	7	**3600**	**16064**	**0**	**3528**	**7200**	**16576**	**0**	**2952**	**10800**	**3600**	**7200**	**10800**	**82320**
	8	**990**	**2700**	**1800**	**1440**	**2700**	**1800**	**1440**	**2700**	**1800**	**1440**	**2700**	**1800**	**23310**
	9	**1100**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**1500**	**17600**
	10	**900**	**810**	**1530**	**810**	**1530**	**810**	**1530**	**810**	**1530**	**810**	**1530**	**810**	**13410**
Total Purchasing Costs														**285847**

Table (10) Transportation Costs

		j ∈ J												Transportation Costs
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
i ∈ I	**1**	**7500**	**0**	**0**	**0**	**12000**	**0**	**0**	**12000**	**0**	**0**	**12000**	**0**	**43500**
	2	**0**	**10000**	**12500**	**12500**	**12500**	**12500**	**12500**	**12500**	**12500**	**12500**	**12500**	**0**	**135000**
	3	**50000**	**0**	**0**	**0**	**50000**	**0**	**0**	**0**	**50000**	**0**	**0**	**0**	**150000**
	4	**333**	**391**	**391**	**391**	**0**	**0**	**0**	**0**	**391**	**0**	**391**	**0**	**2288**
	5	**0**	**146**	**0**	**325**	**0**	**325**	**0**	**325**	**0**	**325**	**0**	**325**	**1771**
	6	**100**	**1000**	**200**	**1000**	**200**	**1000**	**200**	**1000**	**200**	**1000**	**200**	**1000**	**7100**
	7	**290**	**1290**	**0**	**284**	**580**	**1331**	**0**	**238**	**870**	**290**	**580**	**870**	**6623**
	8	**179**	**488**	**325**	**260**	**488**	**325**	**260**	**488**	**325**	**260**	**488**	**325**	**4211**
	9	**220**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**3520**
	10	**200**	**180**	**340**	**180**	**340**	**180**	**340**	**180**	**340**	**180**	**340**	**180**	**2980**
Total Transportation Costs														**356993**

7. CONCLUSION

We have described model for determining the best order quantity of materials with minimum total cost from suppliers to any company. The cost in this paper consist from purchasing, ordering, holding and transportation costs. Ordering and holding costs are considered costs constant for each unit from materials, purchasing and transportation costs are considered variable costs. In this case, whenever increasing the quantity of materials lead to decrease the cost of the one unit. The results of this model explained its ability on assist the companies to determine the right order quantity at the right time with minimum total cost and uses with different time period such as days and months, etc.

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