Determination Optimum Inventory Level for Material Using Genetic Algorithm

Watheq Hayawi Laith
Lecturer
College of Administration and Economics -University Of Sumer
wahe36 @ yahoo.com

Sawsan Sabeeh Al-Zubaidy
Assistant Professor
Department of Production Engineering and Metallurgy-University Of Technology
Sawsan2006@yahoo.com

Mahmoud Abbas Mahmoud
Assistant Professor
Department of Production Engineering and Metallurgy-University Of Technology
dr.mahmoudalnaimi@yahoo.com

ABSTRACT

The integration of decision-making will lead to the robust of its decisions, and then determination optimum inventory level to the required materials to produce and reduce the total cost by the cooperation of purchasing department with inventory department and also with other company's departments. Two models are suggested to determine Optimum Inventory Level (OIL), the first model (OIL-model 1) assumed that the inventory level for materials quantities equal to the required materials, while the second model (OIL-model 2) assumed that the inventory level for materials quantities more than the required materials for the next period. This study was applied in Wasit Company for Textile Manufacturing in the Textile Factory, where it produces five products, which are printed striped, plain, poplin, dyed poplin and Naba weave. The products are made from cotton and they are passing through several stages to transfer to the final product. A genetic algorithm is used to determine the optimum quantity of the purchase a cotton and colors for each month and with minimum cost. Where the purchasing and transportation costs were either constant or variable with respect to purchased quantities while holding cost is kept constant. The results showed that the total cost of the first model is minimum than the second model because the holding cost for this model is less from the second model, while the purchasing and transportation costs from two models are equals. The percentage of purchasing cost for cotton is the biggest value, more 99% of purchasing cost for two models.

Keyword: Inventory Level, Genetic Algorithm, Decision-making.

تحديد مستوى الخزين الامثل للمواد باستخدام الخوارزمية الجينية

م. واثق حياوي لايذ
كلية الادارة والاقتصاد
جامعة سومر

أ.م.د. سوسن صبيح الزبيدي
قسم هندسة الانتاج والمعادن
الجامعة التكنولوجية

أ.م.د. محمود عباس محمود
قسم هندسة الانتاج والمعادن
الجامعة التكنولوجية

الخلاصة

تكامل أتخاذ القرارات سيؤدي الى ترصين هذه القرارات ومن ثم تحديد مستوى الخزين الامثل للمواد المطلوبة والتي تكفي لعملية الإنتاج وأن تقليل الكلفة الكلية من خلال التنسيق بين قسم المشتريات وقسم الخزين وكذلك مع بقية أقسام الشركة الأخرى.
تم اقتراح نموذجيين لتحديد مستوى الخزين الأمثل للمواد المطلوبة، في النموذج الأول تم افتراض أن مستوى الخزين يساوي المواد المطلوبة بينما في النموذج الثاني تم افتراض أن مستوى الخزين أكثر من المواد المطلوبة للفترة اللاحقة.
هذه الدراسة طبقت في شركة واسط لصناعة المنسوجات في معمل النسيج، حيث ينتج خمس منتجات وهي البازة والسادة والبوبلين والبوبلين المطبوع ونسيج النبأ. المنتجات تصنع من القطن ويمر بعدة مراحل ليصبح منتج نهائي وقد استخدمت الدالة الجينية لتحديد أمثل كمية مشتراه من القطن والالوان لكل شهر وباقل كلفة حيث كانت كلف الشراء والنقل أما ثابته أو متغيرة مع الكمية المشتراة، بينما كانت كلف الاحتفاظ ثابتة. بينت النتائج ان الكلفة الكلية للنموذج الأول كانت أقل من النموذج الثاني لكون كلفة الاحتفاظ لهذا النموذج أقل بينما كلف النقل والشراء متساوية في النموذجين.
نسبة كلفة الشراء لمادة القطن تجاوزت 99% من كلفة الشراء وللنموذجين.

1.INTRODUCTION

The companies select a single or multiple suppliers to fulfill the demands, and replenishment order quantity is split into different portions for each supplier at the same time. From the previous study, basically, 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. 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, **Demirtas, and Üstün, 2008**. There are several studies that deal with optimum inventory level, Park et. al. developed a mathematical model in which the retailer placed orders based on the EOQ policy and allocated them to the multiple manufacturers. In their model, production allocation ratios and the shipment frequencies at the manufacturers, as well as the purchasing cycle length at the retailer, were formulated to minimize the average total cost at the manufacturers and retailer, **Park, et al., 2006**.

Sarker et. al. 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 the first-time-right production**, Sarker, et al., 2008**.

Wadhwa and Ravindran introduced multiple objective multiple supplier selection models 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. The shortage was not allowed and the multi-objective model was solved by preemptive goal programming, **Wadhwa, and Ravindran, 2010**.

Araújo and Alencar put forward a model for selecting suppliers and evaluating the performance of those already working with a company. A simulation was conducted in a food industry. This sector has a high significance in the economy of Brazil. The model enables the phases of selecting and evaluating suppliers to be integrated. This is important so that a company can have partnerships with suppliers who are able to meet their needs. Additionally, a group method is used to enable managers who will be affected by this decision to take part in the selection stage, **Araújo and Alencar, 2015**.

2. INVENTORY LEVEL

Effective forecasting is essential to achieve service levels, to plan allocation of total inventory investment, to identify needs for additional production capacity, and to choose between alternative operating strategies, where the accurate forecast is important to increase service levels, decrease inventory levels, and operating costs, **Russell and Taylor, 2009**.

The Just in time (JIT) methodology is far more geared toward towards the stabilization of the inventory levels throughout the supply chain than the traditionally fixed order quantity methodology, also known as the economic order (EOQ) model. Manufacturers need a strategy to decrease total costs for items and to increase customer satisfaction. The purchasing department receives the items from suppliers at the same time of the demand 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 thus, it covers just pull systems and short planning horizon. 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, **Eiliat, 2013**.

3. OPERATING COSTS
Operating costs consist of the following:

3.1 Ordering 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, **Onawumi, et al., 2009**. Conversely to the costs fixed per unit, the inventory costs fixed per order comprises only a portion 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, telephone calls, stock consolidator's fee, etc., **Bredenkamp, 2005**.

3.2 Holding Costs
Holding cost is defined as the cost associated with having one unit in inventory for a period of time. According to them, holding cost consists of four components, **Holstein and Olofsson, 2009**:
1. Capital cost.
2. Inventory service cost.
3. Storage space cost.
4. Inventory risk cost.

Capital cost considers as the major contributor to holding cost. The other components such as inventory service cost, storage space cost, and inventory risk cost are sometimes called out-of-pocket holding costs.

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, **Eiliat, 2013**.

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

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. This will lead to higher costs charged by the transporter due to smaller loads, **Burger, 2003**.

4. GENETIC ALGORITHM (GA)
The genetic algorithm is a stochastic search method for solving both constrained and unconstrained optimization problems that are based on the natural selection process that mimics biological evaluation. It explores the solution space by using concepts taken from natural genetics and evolution theory, **Baz, 2004**. 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 includes several genes. The gene represents an order quantity of item I at time point j. For example, if there are 12 items and 12- time points, we will have 144 genes (order quantity) in one chromosome as in **Fig.1**. The chromosomes evolve through successive iterations called generations, **Li, et al, 2010.**

A new generation is created by changing chromosomes in the existing population through crossover and mutation, **Baz, 2004**, as shown in **Fig.2**.

5. APPLICATION OF PROPOSED METHODOLOGY

This paper was applied in Wasit company for Textile Industries as a case study to determine optimum inventory level for material. Textile Factory produces five products (N=5) which are (printed striped, poplin, Nuba, and dyed poplin weaves), their representation with symbols is (A, B, C, D, and E) respectively, that will make on the same production line inside factory and need setup time to change arrangements this production line when altering the production to another product. The materials required for manufacturing of products (meter) are cotton (ton) and colors (gram) by used bill of materials as shown in **Fig.3**.

Determination of the materials required depend on quantities forecasted in the marketing department, where requested quantities from cotton to the year 2016 is shown in Table.1, making an approximation to near integer number more than requested quantities and also for color as shown in Table 2.

The purchasing department will make the plan to purchase the materials required for the entire year with minimum total cost (holding, purchasing, and transportation costs) depend on forecasting.

6. PROPOSED ALGORITHM TO DETERMINE OPTIMUM INVENTORY LEVEL

Purchasing department study purchasing of materials and determine the best order quantity depending on purchasing, transportation, and holding costs for materials, that can be illustrated in Tables 3, 4 and 5 respectively according to plans of this company for the year 2016.

The assumptions that are used in this algorithm are:

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

The selection of the best order quantity in the textile factory can be classified into two models depending on inventory amounts. **The first model** will attempt reducing the inventory level, therefore will lead to reducing holding cost.

This model will be explained in the section (6.1), that assumed the inventory amounts will equal the demand for next month and will be symbolled as (OIL-Model 1). **The second model** will assume the inventory amounts will exceed the demand for next month to reduce purchasing and transportation costs. This model will be explained in the section (6.2), and the symbol to this model is (OIL-Model 2).

6.1 OIL-Model 1

In this paper used through a hybrid algorithm that compared advantages JIT and EOQ to reduce all costs together to determine the optimum inventory level and it solve by GA where calculate from equation (1) and (2).

$$V_i^j = V_i^{j-1} + Q_i^j - D_i^{j-1}\ , \ \forall j \in J \setminus \{0\} \tag{1}$$

$$Q_i^j \geq 0\ , and\ Q_i^0 = 0,\ \forall i \in I \tag{2}$$

Where:

V_i^j = Inventory level for material *i* at time *j*.

Q_i^j = Quantity order for material *i* at time *j*.

D_i^j = Demand for material *i* at time *j*.

The company warehouse has a limited stock capacity for each material $i \in I$ depend on lower and an upper number of units for all materials. The inventory level of material *i* should be greater than or equal to the demand of production department at each time point j when there is no shortage of materials, thus:

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

The price of each material decreases when the number of material increases. The purchasing cost of order quantity is:

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

Where:

P_i^j= Purchasing cost for material *i* in time *j*.

p_i^k = The set of price breaks of material *i*, where k={1,2,3,….}

The transportation cost for shipping the materials decrease when the number of materials increases, therefore transportation cost of order quantity is:

$$If\left(Lower \leq D_i^j < Upper\right) then\ T_i^j = r_i^m Q_i^j \ ;\ \forall\, i, j \quad (5)$$

Where:

T_i^j= Transportation cost for material *i* in time *j*.

r_i^m = The set of price breaks of transport material *i*, ether m={ 1,2,3,….}.

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

$$H\left(Q_i^j\right) = h_i V_i^j \ ;\ \forall\, i, j \quad (6)$$

Let $C\left(Q_i^j\right)$ be the total cost, that is the summation of purchasing, holding and transportation costs. Form equations (4), (5) and (6) we have:

$$\text{Minimize Z= } C\left(q_i^j\right) = \sum_{i \in I} \sum_{j \in J} \left(P\left(Q_i^j\right) + H\left(Q_i^j\right) + R\left(Q_i^j\right)\right) \quad (7)$$

The solutions are given after 500 runs in MATLAB program. 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 to1563661500 dinars at run number 178 as shown in **Fig.4**, the order quantities for this factory can be shown in Table.6 and Tables 7 shows inventory levels (V_i^j). Tables 8, 9, and 10 show the holding, purchasing, and transportation costs for all items in a year 2016. Figure (5) gives a summarized the percentage of the holding, purchasing and transportation costs.

6.2 OIL-Model2

This model uses the same equations as the first model except that the equation number (1) has changed to become:

$$V_i^j \geq V_i^{j-1} + Q_i^j - D_i^{j-1} , \qquad \forall j \in J \setminus \{0\} \quad (1)$$

The order quantities for this factory can be shown in Table .11.The solutions are given after 500 runs in MATLAB program. 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 1592049000

dinars at run number 151 as shown in **Fig. 6.** Tables 12 shows inventory levels.
Tables 13, 14, and 15 show the holding, purchasing, and transportation costs respectively for all items in the year 2016.
Fig.7 gives a summarized the percentage of the holding, purchasing and transportation costs. The percentage of purchasing cost is the biggest value, 87% and the percentage of purchasing cost for cotton is the biggest value, more 99% of purchasing cost.
Decision maker in production department will make the plan to execute accepted demands with minimum setup time for the entire year and determine the best sequence of products and to all demands by coordination with another department to integrate decision making inside the factory.

7. CONCLUSIONS

The best order quantity in the textile factory depends on reducing each holding, purchasing, and transportation costs together by using GA, can be classified to two models depend on inventory amounts.
The main conclusions of this paper are:
1. The total cost of (OIL-Model 1) less than (OIL -Model 2), where total cost for (OIL -Model 1) equals to1563661500 and for (OIL-Model 2) equal to 1592049000 dinars.
2. The holding cost of (OIL -Model 1) less than (OIL -Model 2), where holding cost for (OIL -Model 1) equals to12188000 and for (OIL -Model 2) equals to 40575500 dinars.
3. The percentage of purchasing cost 89% , Transportation cost 10% and holding cost 1% from the total cost of (OIL -Model 1).
4. The percentage of purchasing cost 87% , Transportation cost 10% and holding cost 3% from the total cost of (OIL -Model 2).
5. The percentage of purchasing cost of cotton is the biggest value, more 99% of purchasing cost for two models.
6. The proposed methodology can be applied to another industrial company, especially organizations which work in a dynamic environment more than Wasit company.

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List of Abbreviations

Abbreviations	Meaning
OIL	Optimum Inventory Level
OIL -Model 1	Optimum Inventory Level with inventory
OIL –Model2	Optimum Inventory Level without inventory
JIT	Just In Time
EOQ	Economic Order Quantity
GA	Genetic Algorithm

q_1^1	q_1^2	....	q_1^{12}	q_2^1	....	q_2^{12}	....	q_{12}^{12}

144 genes

Figure 1. Chromosome with 144 genes.

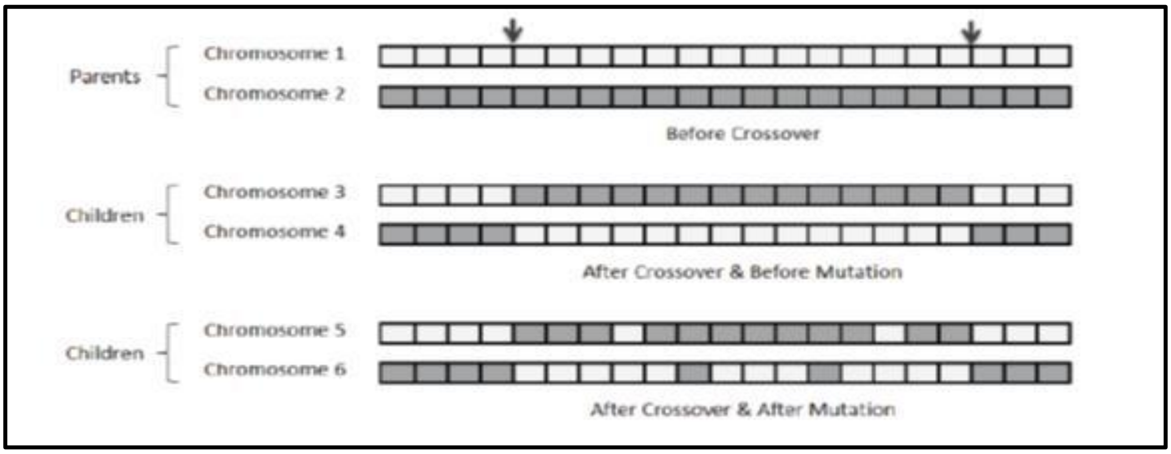

Figure 2. Crossover and mutation.

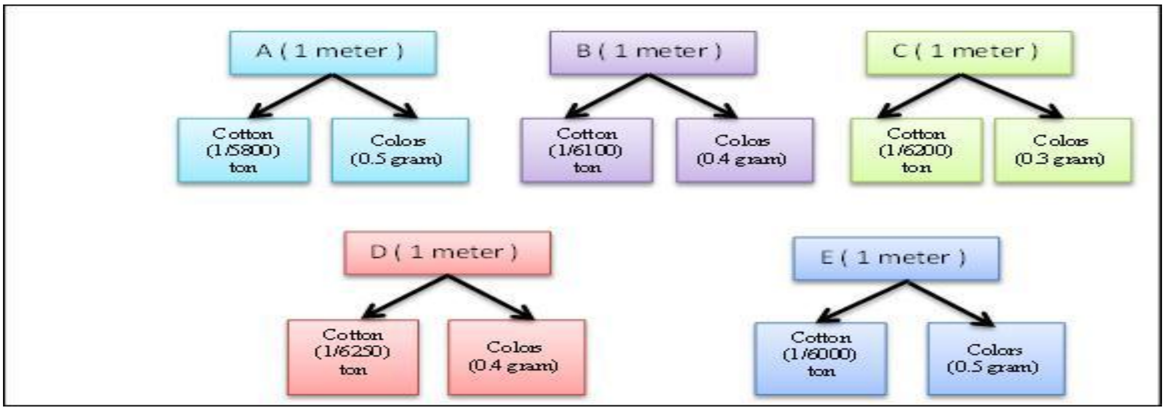

Figure 3. Bill of materials for products of textile factory.

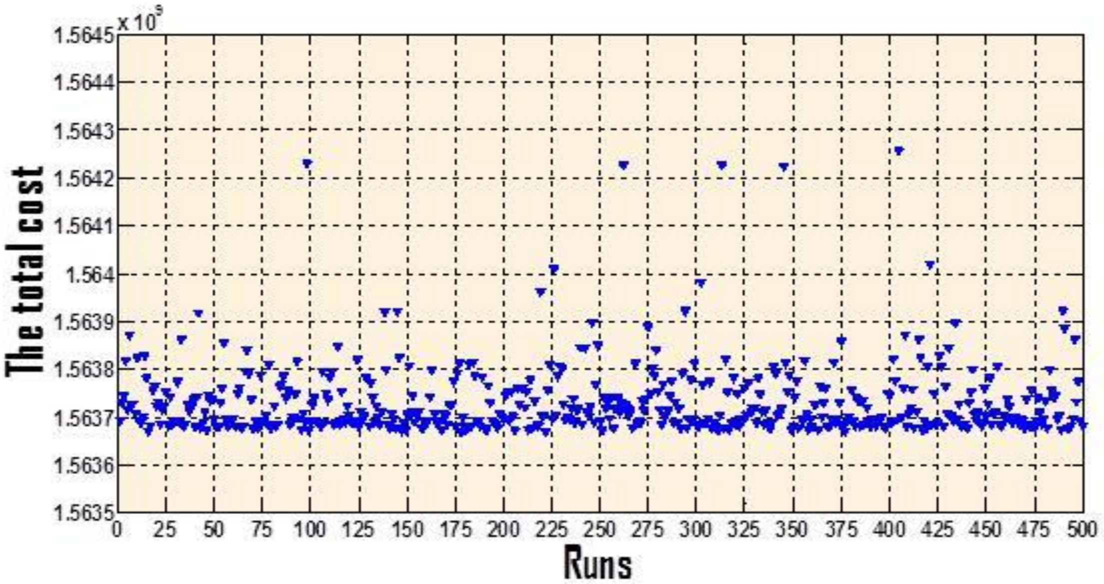

Figure 4. Comparing runs in the MATLAB programming for the first model.

Figure 5. Dividing total cost for the first model.

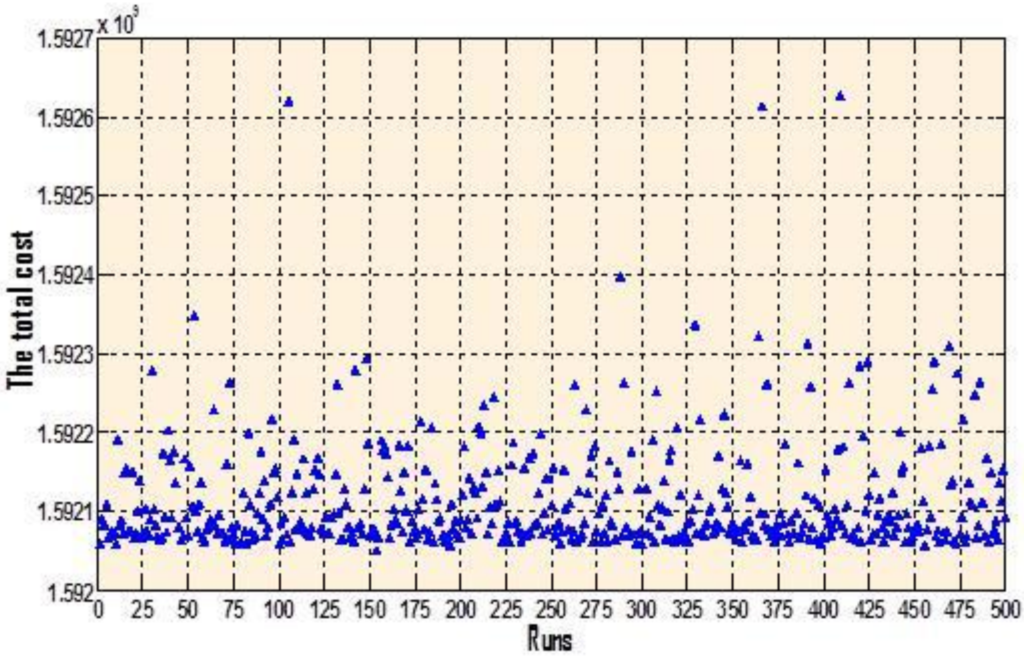

Figure 6. Comparing runs in the MATLAB programming for the second model.

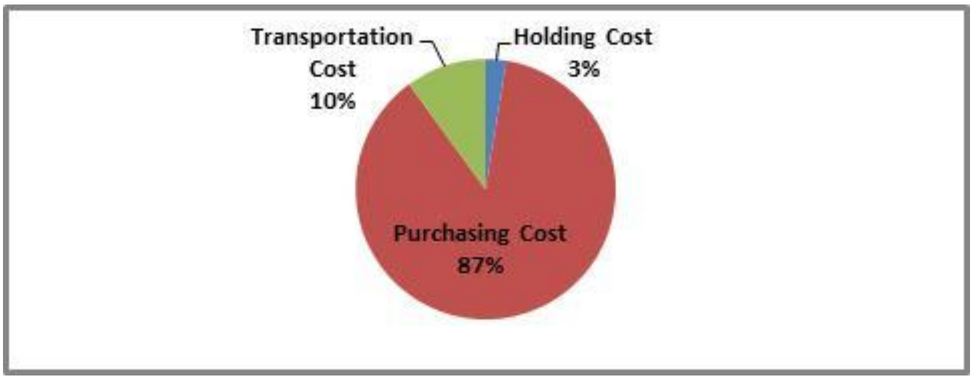

Figure 7. Dividing total cost for the second model.

Table 1. Materials required from cotton (ton) to the year 2016.

Products / months	A	B	C	D	E	Total
January	15.607	6.477	34.187	2.070	0.112	59
February	12.116	3.822	55.784	1.014	0.000	73
March	7.110	5.022	54.635	0.000	0.000	67
April	16.012	7.955	17.921	0.000	0.820	43
May	11.334	15.557	39.329	6.332	0.067	73
June	9.229	13.767	36.073	2.868	0.452	63
July	5.259	8.628	16.140	0.000	0.000	31
August	10.595	11.394	36.216	0.000	0.000	59
September	10.024	9.433	16.769	0.000	0.000	37
October	15.105	15.550	28.510	1.765	0.048	61
November	14.271	6.044	26.385	2.564	0.000	50
December	8.414	5.313	25.258	0.000	0.000	39

Table 2. Materials required from colors (kg) to the year 2016.

products / months	A	B	C	D	E	Total
January	45.26	15.8036	63.588	5.1752	0.002588	130
February	35.135	9.3256	103.758	2.5356	0.001268	151
March	20.62	12.2532	101.622	0	0	135
April	46.435	19.4108	33.333	0	0	100
May	32.87	37.9596	73.152	15.8296	0.007915	160
June	26.765	33.5904	67.095	7.1692	0.003585	135
July	15.25	21.0512	30.021	0	0	67
August	30.725	27.8016	67.362	0	0	126
September	29.07	23.016	31.191	0	0	84
October	43.805	37.942	53.028	4.4136	0.002207	140
November	41.385	14.7476	49.077	6.4096	0.003205	112
December	24.4	12.964	46.98	0	0	85

Table 3. The relation between price costs (thousand dinars) per unit and material order quantity.

Material $i \in I$	Price Costs 1	2	3	4
Cotton	1- ∞			
	2500000			
Colors	1-250	250-500	500-1000	1000-∞
	3500	3250	3000	2750

Table 4. Transportation costs (thousand dinars) per unit.

Material $i \in I$	r_i^m- r_i^{m-1} 0-100	100-250	250-5000
Cotton	300000	275000	250000
Colors	350	350	300

Table .5 Initial inventory level (V_i^0) *and* holding costs per unit.

Material	h_i (Dinar)	V_i^0
Cotton	50000	100 (ton)
Colors	500	150 (KG)

Table 6. Best order quantities for first model.

$i \in I$	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}
1	0	32	100	10	100	36	31	59	37	100	11	39
2	0	131	135	100	225	40	67	126	84	251	1	85

Table 7. Inventory levels for the first model.

$i \in I$	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}
1	100	41	0	33	0	27	0	0	0	0	39	0	0
2	150	20	0	0	0	95	0	0	0	0	111	0	0

Table 8. Holding costs (thousand dinars) for the first model.

$i \in I$	$j \in J$: 0	1	2	3	4	5	6	7	8	9	10	11	12	Holding Costs
1	5000	2050	0	1650	0	1350	0	0	0	0	1950	0	0	12000
2	75	10	0	0	0	47.5	0	0	0	0	55.5	0	0	188
Total holding costs														12188

Table 9. Purchasing costs (thousand dinars) for the first model.

$i \in I$	$j \in J$: 1	2	3	4	5	6	7	8	9	10	11	12	Purchasing Costs
1	0	80000	250000	25000	250000	90000	77500	147500	92500	250000	27500	97500	1387500
2	0	458.5	472.5	350	828.75	140	234.5	441	294	815.75	3.5	297.5	4336
Total purchasing costs (dinars)													1391836

Table 10. Transportation costs (thousand dinars) for the first model.

$i \in I$	$j \in J$: 1	2	3	4	5	6	7	8	9	10	11	12	Transportation Costs
1	0	9600	27500	3000	27500	10800	9300	17700	11100	27500	3300	11700	159000
2	0	65.5	67.5	50	127.5	20	33.5	63	42	125.5	0.5	42.5	637.5
Total transportation costs													159637.5

Table 11. Best order quantities for second model.

$i \in I$	$j \in J$: 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}
1	32	100	0	100	36	31	59	37	100	11	39	0
2	131	135	100	256	39	67	126	84	250	2	85	0

Table 12. Inventory levels for the second model.

		$j \in J$												
		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}
$i \in I$	1	100	73	100	43	100	63	31	59	37	100	50	39	0
	2	150	151	135	100	256	135	67	126	84	250	112	85	0

Table 13. Holding cost (thousand dinars) for the second model.

		$j \in J$													Holding Costs
		0	1	2	3	4	5	6	7	8	9	10	11	12	
$i \in I$	1	5000	3650	5000	2150	5000	3150	1550	2950	1850	5000	2500	1950	0	39750
	2	75	75.5	67.5	50	128	67.5	33.5	63	42	125	56	42.5	0	825.5
Total holding costs															40575.5

Table 14. Purchasing costs (thousand dinars) for the second model.

		$j \in J$												Purchasing Costs
		1	2	3	4	5	6	7	8	9	10	11	12	
$i \in I$	1	80000	250000	25000	250000	90000	77500	147500	92500	250000	27500	97500	0	1387500
	2	458.5	472.5	350	832	136.5	234.5	441	294	812.5	7	297.5	0	4336
Total purchasing costs														1391836

Table 15. Transportation costs (thousand dinars) for the second model.

		$j \in J$												Transportation Costs
		1	2	3	4	5	6	7	8	9	10	11	12	
$i \in I$	1	9600	27500	3000	27500	10800	9300	17700	11100	27500	3300	11700	0	159000
	2	65.5	67.5	50	128	19.5	33.5	63	42	125	1	42.5	0	637.5
Total transportation costs														159637.5