Integrated Decision Making to Determine the Optimal Order Quantity for Raw Materials Using Genetic Evolutionary Algorithms

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Abstract

Decision Making in economic organizations, especially the productivity, is one of the problems that researchers are interested in. It is important for the organizations that seek global competition and the integration of their decision will lead to coordination of decisions between the departments of these organizations to determine optimal order quantity and establish a correct inventory policy to warrant production with least total costs (costs of transportation, holding and purchasing), these is the objective of any company to achieve an adequate and enough inventory level to meet the future needs. In this paper, integrated decision making with three stages, first stage is forecasting with demands to final products using time series, second stage determine required quantities for raw material to manufacture these final products, and formulated a mathematical model reduces the total cost in third stage, when the transportation and purchase are variable costs with order quantity, while in just-in-time model or economic order quantity model are a fixed demand and purchase cost. The aim of this paper is integrated decision making to reduce total cost of required raw materials for the manufacturing processes and without and determine the optimal order quantity using genetic algorithms. This study was applied in Wasit company for cotton products in the textile factory, the results shown Holt-Winter method is the best method to forecasting because has least mean absolute error and the percentage of purchasing cost 73%, Transportation cost 8%, and holding cost 19%. The percentage of purchasing cost of cotton is biggest value, more 99% of purchasing cost.

Keywords: Order Quantity; Forecasting; Inventory Control; Genetic Algorithm.

1. Introduction

The problem of inventory control appears when it needs for physical storage of goods and products for the purpose match with demand over time (short, medium, long), any project in the business field needs to keep inventory to ensure good continuity of operations. Efficient inventory control must not keep quantities in excess of the current or expected needs of the warehousing because this retention leads to undue costs, and the inventory represents a large financial investment [1].

Inventory control system can be defined as" a set of scientific operations and procedures that aim to make appropriate decisions about the quantity of storage for the purpose of facing fluctuations and changes that occur in the future [2]. On the other hand, genetic algorithms method, which is a random search method that uses probability to guide the process research, it an iterative process through which the optimal decision is searched on the basis of evaluation in each stage of the repetition [3], it used in this research to find the optimum order quantity that reduces the total cost.

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A. Research Problem

The main objective of having inventory control system is to achieve a sufficient and appropriate level of storage for the purpose of match with the future needs of the materials, that keeping stock actually leads to a basic function of treatment short-term fluctuations and seasonal needs.
The inventory is consider resources for productivity companies on different types and the most dangerous to their financial position and even to the overall activity of these companies, where it face two opposite types of goals, the first of which is the desire of manufacturers to store large quantities to cover the demand for raw materials, and the goal of the management of the institution that wants to store the least possible amount because it considers storage non-money invested, so it is very important to correctly determine the quantity demanded of raw materials.

B. Research Objective

This research aims to study the integration of decision-making for production companies and formulate a mathematical model that attempts to reduce the total cost of the raw materials required for manufacturing processes without inability to provide these quantities and determine the optimal demand quantity and control on inventory level using genetic algorithms, where reducing the inventory amount does not necessarily mean reducing the total cost of materials required in manufacturing.

C. Research Importance

The importance of this research being use a quantitative method for the decision-making process to determine the optimum order quantity, which reduces the total cost, that consists of the holding costs, transportation, purchasing and ordering costs. The cost of holding and ordering is fixed, but the costs of transportation and purchase can be fixed or variable in this research.

2. Decision-Making Process in Productive Enterprises

It is possible to acquire a lot of skills through learning, but it is not easy to acquire the ability to make the right decisions quickly, and the decision-maker is obligated to make the decision, even if this some mistakes, because not making a decision is the worst of all mistakes [1].

Decisions making is one of the essential tasks and basic functions of the decision maker. The amount of success achieved by any industrial or service organization or company depends on the ability and efficiency of decision makers and their understanding of decisions and methods of making them, and their concepts that ensure rationality and effectiveness of decisions, and realize the importance of clarity and time, and it works to follow up and evaluate its implementation [2].

Decision-making is an intertwined process in the departments of the industrial company, when the decision-maker exercises the planning function, he makes certain decisions at each stage of planning from developing the plan, whether when setting the objective, drawing policies, preparing programs, determining appropriate resources, or choosing the best methods and approaches to operate it. The decision maker also makes decisions in the design, manufacturing, marketing and other stages in any industrial company [2].

A. The Basic Steps for Decision Making

There are several approaches used for decision-making, the most important of which are [4]:

A. Experience.

B. Viewing.

C. Trial and error.

D. Scientific method.

The decision-making steps vary according to the complexity and nature of the problem, but in general, the most important steps based on scientific methods can be clarified as following [5,6]:

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1.The Problem defining

2. The Problem analysis

3. Alternatives determining

4. Alternatives evaluation

5. Choose best alternative

6. Implementation of the decision

B. Demand Forecasting Using Time Series

Demand forecasting is defined as an attempt to estimate the market need of a good or service or a mixture of goods during a future period of time. Demand forecasting is one of important activities that precede the production capacity planning process and production planning, where use available data in order to analyze it and correct decisions making to achieve the objectives of the production systems, affect forecasting results in a few other decisions that are taken within the production system, examples of this are decisions making to total production plans, determining storage levels, planning of material requirements, major production schedules, and manpower planning, determining the capital needed to finance the production process [7].

There are several methods for forecasting using time series, including [7,8]:

- **Simple Average Method**

This method infers historical data and calculates the average using the following formula:

$$F_{t+1} = \frac{\sum_{i=1}^{N} Yt}{N}$$

Where:

N: the number of observations or the number of days, months or years

t: the time period

Y_t :the value of observations for time t

Y_{t+1} :the forecast value for the time t+1

- **Moving Averages Method**

This method involves calculating the average of values n from newly collected data in the series time to use in the forecasting process for the next period is calculated by the following formula:

$$\text{moving average} = \frac{\textbf{summed valuesn from data which collected newly}}{\boldsymbol{n}}$$

The idea of the moving average is possible to replace the old observations with new observations for their availability in the time series to calculate the new moving average. Therefore, this rate changes whenever new observations are used and the number of values included in the moving average is determined.

- **Moving Averages with Trend Method**

It is similar to the moving averages method, with assuming that there is a trend for the time series data, and it depends on several equations as follows:

$$F_t = \sum {}^{y_i}/_{n} \qquad for\ i\ from\ (t-n+1)\ to\ t$$

$$\acute{F}_t = F'_{t-1} + (6/[n(n^2-1)])[(n-1) \times t + (n+1) \times (t-n) - 2nF_{t-1}]$$

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$F_{t+h} = F_t + \acute{F}_t[(n-1)/2 + h]$

where h is a period of the future time.

- **Single Exponential Smoothing**

This method is one of the appropriate methods for performing the prediction process, which the recent data and uses the value of the exponential smoothing of the time series in a specific period for the purpose of predicting the values of the next period.

The exponential model is determined according to this method as follows:

$F_{t+1} = \alpha \, Yt + (1-\alpha)$

Where

α:coefficient of determination or smoothing and takes values that range $0 \leq \alpha \leq 1$.

- **Single Exponential Smoothing with Linear Trend**

It is similar to the single exponential smoothing method, with assuming that is a specific trend for the time series data, and it depends on several equations as follows:

$F_t = \alpha \, Yt + (1-\alpha)[F_{t-1} + T_{t-1}]$

$T_t = \beta[F_t - T_{t-1}] + (1-\beta)T_{t-1}$

$F_{t+h} = F_t + hT_t$

Where

β : the coefficient of determination or smoothing of the trend and takes values that range

$0 \leq \beta \leq 1, F_0 = y_1, T_0 = 0$

- **Holt Winter Method**

This method is based on three equations, each equation a specific to parameter that is related to one of the three components of the seasonal data model, namely stability, tendency and seasonality. Therefore, this method is similar to Holt's method, but includes three constants, each of which lies between (0, 1) These constants are:

$L_t = \alpha[Y_t/S_{t-c}] + (1-\alpha)[L_{t-1} + b_{t-1}]$

$b_t = \beta[L_t - L_{t-1}] + (1-\beta)b_{t-1} \quad S_t = \text{ɤ}[Y_t/L_t] + (1-\text{ɤ})S_{t-c}$

$F_{t+m} = [L_t + b_t]S_{t+m-c}$ for m=1,2,…,c

$F_{t+m} = [L_t + mb_t]S_{t+m-2c}$ for m=1,2,…,2c

C: Throughout the seasonal cycle

$F_0 = M = Average\ of\ the\ first\ cycle$

$S_t = Y_t/m \quad for\ to\ c$

C. The Importance of Inventory

Economic institutions keep many materials that help them in the continuation of the production process without stopping according to the planned programs, which requires the presence of stocks.

The importance of this stock is shown represents the most important assets where the bulk of the trade assets, and it also achieves a set of benefits as it enables the institution to compete in addition

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to stability due to its provision of various needs and requirements of materials, tools and others according to the use rates or demand. The importance of as follows [9,10]:

1- Inventory represents a high percentage of the total money amount invested in the enterprise, and it may reach more than 50% in industrial enterprises.
2- The large size due to the stock represents from the total amount of money invested, it affects the economies of the enterprise, where the holding cost of stock represents high percentages that cannot be underestimated.
3- The various departments of the institution can carry out their work and put their plans when depend on prepared storage policy prepared on scientific, storage works to achieve consistency and integration between the various departments of the institution.
4- Clear inventory policy based on scientific principle, will reduce the volume of investments in warehouse assets to the storage that allows continue the production process without there being a surplus in inventory and achieving a balance between production requirements and real stores.
5- Inventory management related to with other departments of the institution, therefore the inventory volume and high holding costs inventory will effect on total costs of production, which leads to an increase in the prices of final products, which effects on the continued retention of customers.
6- Inventory represents represent the least cash, therefore the errors related to its management cannot be treatment quickly, and poor management, if it exceeds will lead to the end of the institution.

D. Inventory Control

In the context of the above, it becomes clear to us the importance of inventory control, and its impact on improving the level of service to meet demand, and its impact on improving the profitability of the organization. Hence the need to follow the best methods of control and inventory follow-up. This leads us to clarify the role of Materials Requirement Planning (MRP) system that depends on information systems and use of computers.

Materials Requirement Planning (MRP) system mean planning of materials requirements, it computer-based information system for achieve purchase orders and scheduling inventory [2].

Material requirements planning (MRP) is a logical method for planning and controlling the stored materials involved in production processes, therefore the final product is analyzed into its component parts and the necessary parts are calculated from each part based on its use percentage in the part that precedes it multiplied by the number of units required of that part. Naturally, running out of storage from any of the parts involved in the production process leads to obstruction of the production process, and many industrial facilities have suffered from many problems before arriving at a use scientific method in planning storage for the materials involved in production [10].

3. Production System (Just In Time)

In light of the hard competition of companies and the great development in recent times of progress in all sectors and changing customers desires, this has led to the creation of organizations trying to costs reduce of their products and services while maintaining their quality and improving them continuously, therefore need arises for the Just-in-Time Production (JIT) system.

The just-in-time production (JIT) system is a philosophy that includes modern concepts and methods in managing and performing the operations function at the strategic level to achieve competitive priorities, and at the operational level to achieve efficiency in the resources use and their scheduling and effective response to changes in demand and customer needs, the cost is considered one of the production determinants that organizations seek to reduce without affecting the quality of the product [11].

A. Economic Quantity of Order (EOQ) model:
This model aims to determine the optimum order size that makes the costs as least as possible. It volume is called the economic quantity of order and used to determine the optimal level of stock, and when we order the quantity.

The most important of this model for demand without a shortage is the following [10]:

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1- The rate of consumption (demand) is fixed and known.

2- There is only one type of good.

3- There is no shortage in the required quantities.

4-All costs are fixed and independent of the size of the required quantity.

B. Operating costs

The costs are divided into four main types:

- **The preparing cost of order**

The administrative leader determines a set of procedures before decision making to order and determining its size, as following [12]:

A- Determining the materials to be provided and the necessary quantities of them.

B- Research on suppliers.

C- Preparing and sending the order.

D- Receipt of the required items.

E- Material control and inspection.

These administrative procedures have a number of costs, such as the salaries and wages of those in charge of business above.

- **Purchase cost:**

It means the purchasing cost of one unit of the required materials at the price agreed upon with the suppliers when they deliver the goods. Usually, the purchase cost is not fixed and changes relatively with the quantity purchased [13].

- **Holding Cost:**

Holding cost, sometimes called storage cost, represents all costs associated with storing materials until they are used. This cost represents a significant proportion of the total costs of industrial establishments [14].

- **Transportation cost:**

The transportation cost means one unit of the required materials at the price agreed upon when transporting goods from suppliers to warehouses. Usually, the transportation cost is not fixed and changes relatively with the transported quantity [15].

4. Genetic Algorithms

Genetic algorithms are part of evolutionary computing, which is a rapid growth area for artificial intelligence, Genetic Algorithms have been used to search for optimization and appropriate decisions making among a set of available alternatives [2].

Genetic algorithms are an important technique in the search for the optimal solution, and they are a representation of the prevailing belief that human intelligence is created with humans and is largely acquired through heredity.

They are a simulation of the interbreeding process between organisms of the same species. Several terms and adjectives from genetics have been used, like generation, parents, crossing over and mutation, and trying in this way to reach the most appropriate solution to the problem at hand, based

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on the principle of retaining the good features and qualities that exist in the parents 'generation to pass them on to the generation of children with the aim of obtaining strong offspring with the best qualities of the ancestor generation at the very least.

The application of genetic algorithms during described to represent the chromosomes representing the solutions (optimal order quantity) by one of the coding methods. After that, a set of mathematical operations deduced from biological processes such as crossing over, selection and mutation are applied to eventually obtain a set of chromosomes that represent the final generation, and each chromosome is only a member of the generation, and the best chromosome is the optimal solution that we are looking for the issue at hand, where start from a set of solutions and not from one solution or one point [16].

A. Determining the Optimum Order Quantity Using Genetic Algorithms:

Procurement and acquisition of materials and services needed to operate the facility is one of the key roles in the management of various organizations and the goal of the decision maker is to reduce the total cost of materials required to meet customer demands.

The storage level of raw materials is calculated through the following equations [17,18]:

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

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

Where:

L_i^j= the storage level for item i at time j.

Q_i^j=Quantity of demand for item i in time j.

D_i^j=Quantity required to manufacture for item i in time j.

The company's warehouses have a limited capacity for each specific material with a minimum and maximum limit for each period of time. The stock level of materials must be greater than or equal to the quantities required for manufacturing to ensure that there is no shortage in the processing of materials required for manufacturing and therefore no delay in customer requests and this condition is as in the equation the following.

$$V_i^j \geq D_i^j, \forall i \in I, \forall j \in J$$

The purchase price of raw materials decreases with the increase in the quantity of these materials, and the cost of the order purchase is as follows:

$$\text{if } Lower \leq D_i^j < Upper \text{ then } P_i^j = p_i^k Q_i^j \quad ; \quad \forall\, i, j$$

Where:

P_i^j= purchase cost of item i at time j.

p_i^K= number of groups changes the purchase prices of item i and k = { 1,2,3,…..}

Also, the cost of transporting raw materials decreases with the increase in the quantity of these materials, and the cost of transport is as follows:

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

Where: the

T_i^j= transport cost of item i in time j.

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r_i^m= The number of groups changes prices for item i and that m = { 1,2,3,….}.

The holding cost of maintaining the storage per one unit of the raw material, which is denoted by the symbol (hi) ,and the total cost is in the following formula:

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

The objective function is to reduce the cost of holding, purchasing and transporting, and it is as follows:

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

5. Case Study

The spinning and weaving industry is one of the important industries in Iraq, and the Wasit state company for textile industries is one of the main important companies affiliated to the Ministry of Industry and Minerals and specialized in the field of textile industries in Iraq, if it was established under the Soviet-Agreement on 16/3/1959 and the actual production began in 1/10/1966.

The company consists of two main factories, the spinning and weaving factory and the knitting factory. The research was applied in the spinning and weaving factory, which produces five products (Baza, Sada, poplin, printed poplin and Al-Naba weaving).

A. Integrated Decisions Making to Determine the Optimal Quantity Order

The spinning and weaving factory uses cotton as a raw material in addition to some chemicals and color, and the factory's products are requested by many institutions and customers with different quantities of each product. The level of storage that reduces the total cost will be determined through three stages shown in Figure (1).

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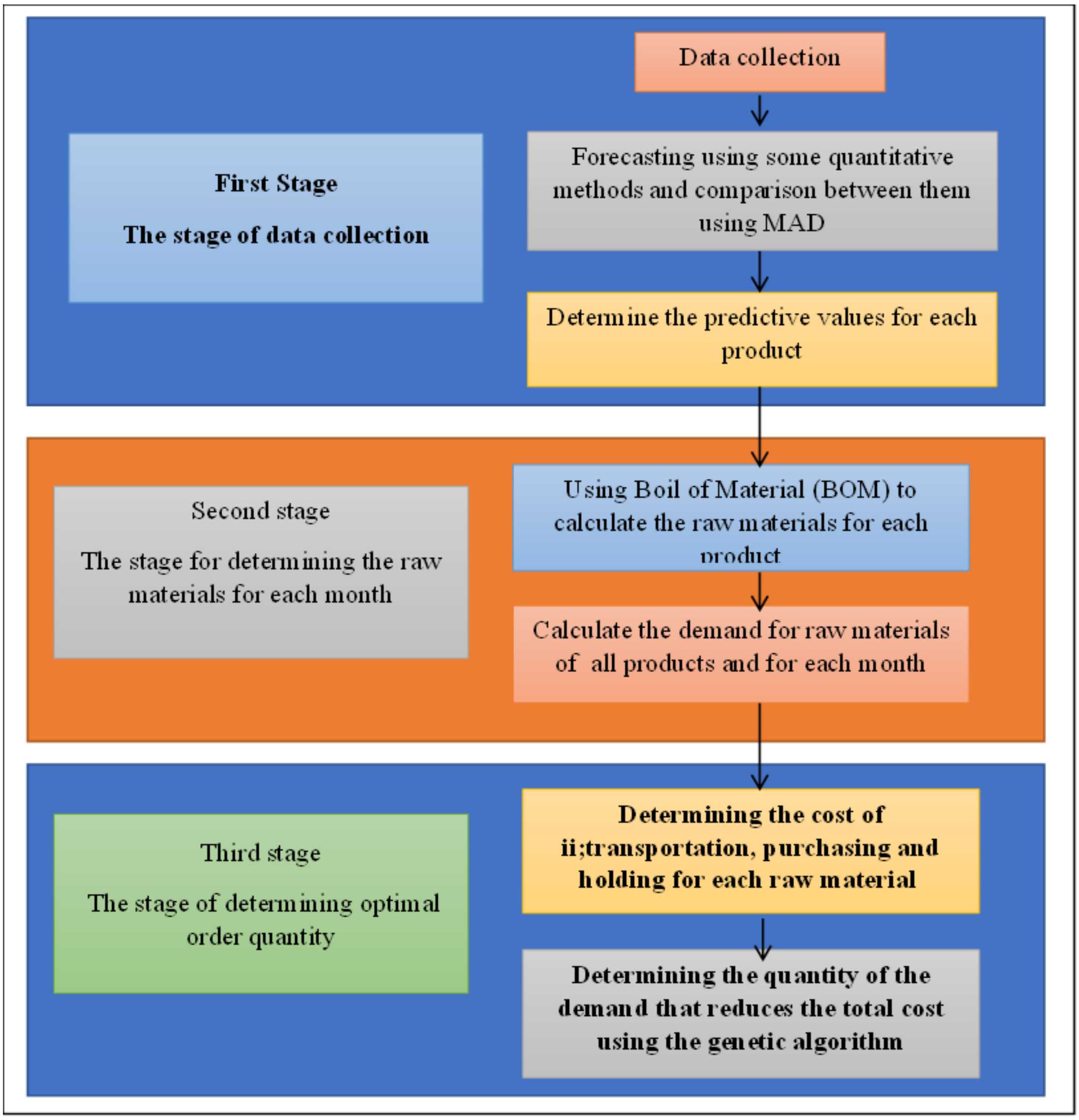

Figure 1: The stages of integrated decision making to determine the optimal quantity of the demand.

B. First Stage: data collection and demand forecasting for each product

This stage was divided into several steps:

- **Data collection**

  Data were collected for sales of textile factory products, which are (Baza, Sada, Poplin, , Al-Nabaa weaving, and printed poplin), from 2019 to 2023 as shown in Tables (1), (2), (3), (4) and (5), respectively.

Table 1: Baza fabric data (2019-2023).

Month	9201	2020	2120	2220	3202
January	33690	89360	100010	90520	87480
February	52560	75620	94940	70270	69720
March	50190	51990	44180	41240	42010
April	55870	99690	111780	92870	93690
May	47270	57870	65560	65740	63245
June	54250	60000	52920	53530	52686
July	53140	41430	53980	30500	31450
August	10330	15660	73960	61450	62540

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September	52450	62880	68020	58140	58240
October	41680	69700	76700	87610	86500
November	34580	71040	88020	82770	82540
December	40000	36660	37850	48800	47500

Table 2: Poplin fabric data (2019-2023).

Month	9201	2020	2120	2220	3202
January	22500	25920	57190	39570	39509
February	45200	50280	65745	23490	23314
March	40400	46440	81540	30835	30633
April	44400	46200	55080	48555	48527
May	40500	37500	86680	94840	94899
June	39500	32490	57510	83850	83976
July	31150	32400	41880	52570	52628
August	24700	37410	52225	69420	69504
September	42000	52010	52890	57635	57540
October	43320	43320	97330	94840	94855
November	32100	33480	64798	36975	36869
December	31000	33060	60630	32520	32410

Table 3: Sada fabric data (2019-2023).

Month	9201	2020	2120	2220	3202
January	111500	189340	255600	209640	211960
February	188000	202500	346170	336363	345860
March	165700	278920	364510	335800	338740
April	190400	182900	162440	110505	111110
May	160500	186720	232200	241265	243840
June	144440	156420	206820	221030	223650
July	663500	78810	81560	99145	100070
August	895400	102149	186946	221775	224540
September	46312	72312	93380	103480	103970
October	150400	160470	182080	187820	176760
November	195680	180180	165560	156955	163590
December	180030	190530	158550	160500	156600

Table 4: Naba fabric data (2019-2023).

Month	9201	2020	2120	2220	3202
January	39400	9600	10670	12140	12938
February	18220	17820	9720	8600	6339
March	11440	12960	0	0	0
April	38730	37740	0	0	0
May	28640	32940	35160	38000	39574
June	6000	7100	12970	15600	17923
July	0	0	0	0	0
August	0	0	0	0	0
September	0	0	0	0	0
October	31680	18680	14760	12700	11034

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November	20010	18600	17450	16600	16024
December	0	0	0	0	0

Table 5: Printed poplin fabric data (2019-2023).

Month	9201	2020	2120	2220	3202
January	0	0	1460	660	670
February	0	0	0	0	0
March	0	0	0	0	0
April	4440	5640	3400	4770	4922
May	1800	2310	1500	330	402
June	2500	3660	0	2660	2712
July	380	155	0	0	0
August	0	0	0	0	0
September	0	0	0	0	0
October	0	0	2100	270	287
November	0	0	0	0	0
December	0	0	0	0	0

- **Forecasting using some quantitative methods**

The moving average method with linear trend, exponential smoothing method with trend, Holt Winter method, and the comparison between these methods using Mean Absolute Error (MAE), which is the average difference between the observation values and the predictive values for the same period, is calculated from through the following formula:

$$MAE = \frac{\sum_{t=1}^{N} |Y_i - F_t|}{N}$$

The better the method is least the value of (MAE), It was used as a criterion for compare between different methods for each product, as shown in Table (6) and using the computer program (Win QSB).

Table 6: Choosing the best method for forecasting using (MAE)

NS	Product	Product	MAE	Method that least MAE	ia of method that least MAE
1	Baza fabric	moving average with linear trend	2486.377		$C = 12$
		exponential smoothing with trend	1773.603		$\alpha = 0.06$
		Holt and Winter	1061.574	Holt and Winter	$\beta = 0, \gamma = 1$
2	poplin fabric	moving average with linear trend	2132.114		$C = 12$
		exponential smoothing with trend	1539.732		$\alpha = 0.06$
		Holt and Winter	1153.863	Holt and Winter	$\beta = 0.16, \gamma = 0.96$
3	Sada fabric	moving average with linear trend	8328.96		$C = 12$
		exponential smoothing with trend	7713.507		$\alpha = 0$
		Holt and Winter	5329.174	Holt and Winter	$\beta = 0, \gamma = 0.94$
4	Naba fabric	moving average with linear trend	1180.716		$C = 12$
		exponential smoothing with trend	1090.912		$\alpha = 0$
		Holt and Winter	303.5792	Holt and Winter	$\beta = 0, \gamma = 1$
5		moving average with linear	143.9774		$C = 12$

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	printed poplin fabric	trend			
		exponential smoothing with trend	79.70847		$\alpha = 0$
		Holt and Winter	35.18692	Holt and Winter	$\beta = 0, \gamma = 0.13$

- **Determining the predictive values for each product**

After determining the method with least (MAE) in the previous step for each product, the predictive values for 2024 and for each product are determined as shown in Table (7).

Table 7: Forecasting values of all products for the year (2024).

Month	Printed Poplin Fabric	Naba Fabric	Sada Fabric	Poplin Fabric	Baza Fabric
January	90287	39056	211971	12938	305
February	69926	23053	345294	6339	0
March	40886	30740	338647	0	0
April	92577	48777	111265	0	4540
May	65316	95238	243643	39574	1466
June	53081	84231	223431	17923	2399
July	30215	52880	99959	0	231
August	61351	69597	224241	0	0
September	58171	57539	103899	0	0
October	87636	94703	177398	11034	274
November	82843	36782	163226	16024	0
December	48800	32411	156834	0	0

C. The second stage: The stage of defining the raw materials for each month:

This stage is divided into two steps:

- **Using (BOM) to calculate the raw materials for each product**

Bill Of Material (BOM) for each product can be illustrated in Figure (2). Each product consists of cotton as a basic material in addition color.

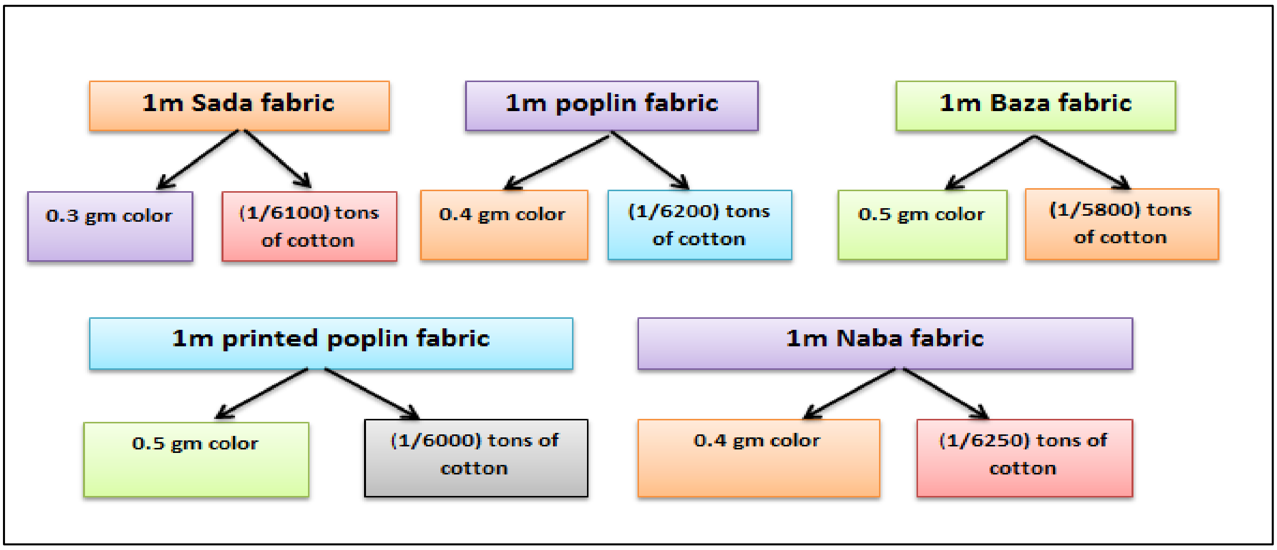

Figure 2: Bill of Material for textile factory products.

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- **Calculation of order for raw materials and all products for each month**

The raw materials (cotton and color) calculated through bill of materials and using the predictive values for the quantity of products as shown in tables (8) and (9).

Table 8: The required quantities of cotton material (tons) for the year (2024)

Month	Printed Poplin Fabric	Naba Fabric	Sada Fabric	Poplin Fabric	Baza Fabric	Total
January	15.56672	6.402623	34.18887	2.03748	0.050833	59
February	12.05621	3.77918	55.69258	0.998268	0	73
March	7.04931	5.039344	54.62048	0	0	67
April	159.6171	79.96361	17.94597	0	0.756667	43
May	11.26138	15.61279	39.29726	6.232126	0.244333	73
June	9.151897	13.80836	36.03726	2.82252	0.399833	62
July	5.209483	8.668852	16.12242	0	0.0385	30
August	10.57776	11.40934	36.1679	0	0	58
September	10.02948	9.432623	16.7579	0	0	36
October	15.10966	15.52508	28.61258	1.737638	0.045667	61
November	14.28328	6.029836	26.32677	2.523465	0	50
December	8.413793	5.313279	25.29581	0	0	40

Table 9: The required quantities of color (in liters) for the year (2024)

Month	Printed Poplin Fabric	Naba Fabric	Sada Fabric	Poplin Fabric	Baza Fabric	Total
January	45.1435	15.6224	63.5913	5.1752	0.1525	130
February	34.963	9.2212	103.5882	2.5356	0	151
March	20.443	12.296	101.5941	0	0	135
April	46.2885	19.5108	33.3795	0	2.27	102
May	32.658	38.0952	73.0929	15.8296	0.733	161
June	26.5405	33.6924	67.0293	7.1692	1.1995	136
July	15.1075	21.152	29.9877	0	0.1155	67
August	30.6755	27.8388	67.2723	0	0	126
September	29.0855	23.0156	31.1697	0	0	84
October	43.818	37.8812	53.2194	4.4136	0.137	140
November	41.4215	14.7128	48.9678	6.4096	0	112
December	24.4	12.9644	47.0502	0	0	85

D. The Third stage: determining optimal order quantity

This phase divided into two steps:

- **Determine cost of transportation, purchase and holding**

The cost of transportation, purchase and holding of raw materials, as well as the level of primary storage of cotton and color in this factory, as shown in tables (10), (11) and (12), respectively.

Table 10: Purchase cost (in thousands of dinars) for raw materials

Item $i \in I$	Price Costs			
	1	2	3	4
	1-∞			

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Cotton	2500000			
Color	1-250	250-500	500-1000	1000-∞
	3500	3250	3000	2750

Table 11: Transportation cost (in thousands of dinars) for raw materials

Item $i \in I$	r_i^{m-1} - r_i^m			
	0-100	100-250	250-5000	
Cotton	300000	275000	250000	
Color	500	400	300	

Table 12: Holding for raw materials and the level of primary storage

Item $i \in I$	h_i (Dinar)	L_i^0
Cotton	500000	100 (ton)
Color	5000	150 (KG)

- **Determining the optimum order quantity using the genetic algorithm**

The optimal order quantity for the textile factory can be clarified in Table (13) after performing 100 solutions using Matlab program as in Figure (3), and that each solution gives a different total cost depending on the level of the specific order quantity each time.

Table 13: Optimal order quantity.

		$j \in J$											
		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}
$i \in I$	1	32	100	10	100	35	30	58	36	100	11	40	0
	2	131	135	102	277	20	67	126	84	250	2	85	0

The program compares these solutions and then chooses the optimum order quantity that reduces the total cost to the least possible, as the total cost was (1906701000) dinars in solution No. 62, the level of inventory and the cost of transportation, purchase and holding is shown in Tables (14), (15), (16) and (17) respectively.

Table 14: Optimal inventory level.

`		$j \in J$												
		L_i^0	L_i^1	L_i^2	L_i^3	L_i^4	L_i^5	L_i^6	L_i^7	L_i^8	L_i^9	L_i^{10}	L_i^{11}	L_i^{12}
$i \in I$	1	100	73	67	100	73	62	29	56	33	96	39	36	0
	2	150	270	135	102	256	139	71	130	88	144	114	89	4

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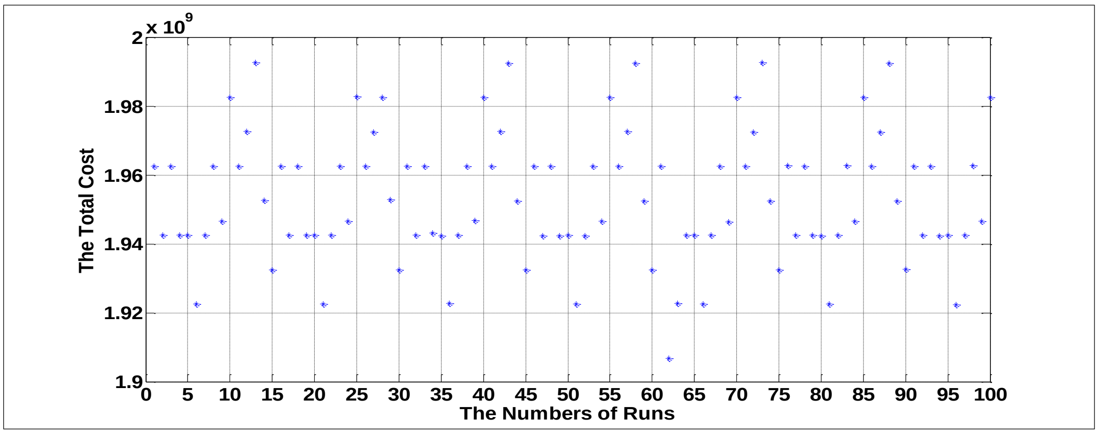

Figure 3: Comparison of the set of solutions using the program MATLAB

Table 15: Purchasing cost (thousands dinars).

`		$j \in J$												Holding Costs
		1	2	3	4	5	6	7	8	9	10	11	12	
$i \in I$	1	3650	33500	50000	36500	31000	14500	28000	16500	48000	23000	18000	0	352650
	2	1350	675	510	1280	695	355	650	440	720	570	445	20	8460
Total holding cost (thousand dinars)														361110

Table 16: Purchasing cost (thousands dinars).

		$j \in J$												purchasing Costs
		1	2	3	4	5	6	7	8	9	10	11	12	
$i \in I$	1	80000	167500	250000	40000	155000	75000	145000	90000	250000	27500	100000	0	1380000
	2	812.5	56	357	825.5	150.5	234.5	441	294	490	385	304.5	0	4350.5
Total purchasing cost (thousand dinars)														361110

Table 17: Transportation cost (thousands dinars).

`		$j \in J$												Transportation Costs
		1	2	3	4	5	6	7	8	9	10	11	12	
$i \in I$	1	9600	20100	27500	4800	18600	9000	17400	10800	27500	3300	12000	0	160600
	2	125	8	51	127	21.5	33.5	63	42	70	55	43.5	0	639.5
Total transportation cost (thousand dinars)														361110

6. Conclusions

The integrated decision-making model has been used to determine the optimal order quantity. Also, we can conclude that the Holt Winter method is a better method than the two methods of moving

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average with linear trend and exponential smoothing with trend in forecasting the data of the five products of the textile factory in Wasit Company for being less (MAE).

Genetic algorithm method is a one of the advanced quantitative methods for determining the optimum order quantity, as it deals with fixed or variable costs with the required quantity. The percentage of the purchase cost is greater than the cost of holding and transportation, which is 73%, followed by the cost of holding, which is 19%, and finally the cost of transportation, which is 8%, and the percentage of purchasing cotton is more than 99% of the purchase cost.

Moreover, we recommend directing the attention of decision makers in factories and companies in general to relying on quantitative methods in integrated decisions making.

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