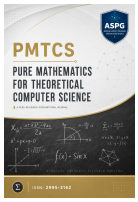
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FULL LENGTH ARTICLE

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 productive organizations, is one of the problems that interests researchers. It is important for organizations seeking global competition, and the integration of their decisions leads to coordination between their departments to determine the optimal order quantity and establish a correct inventory policy that warrants production at the least total cost (transportation, holding, and purchasing costs). This is the objective of any company seeking an adequate inventory level to meet future needs. In this paper, integrated decision making has three stages. The first stage forecasts demand for final products using time series; the second stage determines the quantities of raw materials required to manufacture these products; and the third stage formulates a mathematical model that reduces total cost when transportation and purchase costs vary with the order quantity, whereas demand and purchase costs are fixed in just-in-time or economic-order-quantity models. The aim is to reduce the total cost of raw materials required for manufacturing processes and determine the optimal order quantity using genetic algorithms. The study was applied to the textile factory of Wasit Company for cotton products. The results show that the Holt–Winter method is the best forecasting method because it has the least mean absolute error. Purchasing, transportation, and holding costs constitute 73%, 8%, and 19% of total cost, respectively; cotton accounts for more than 99% of purchasing cost.

Keywords: Order Quantity ▪ Forecasting ▪ Inventory Control ▪ Genetic Algorithm

1. INTRODUCTION

The problem of inventory control appears when physical storage of goods and products is needed to match demand over short, medium, and long periods. Any business project needs to keep inventory to ensure the continuity of its operations. Efficient inventory control must avoid quantities in excess of current or expected warehousing needs because such retention leads to unnecessary costs, and inventory represents a large financial investment [1].

An inventory control system can be defined as a set of scientific operations and procedures that support appropriate decisions about storage quantities in order to face future fluctuations and changes [2]. Genetic algorithms, on the other hand, provide a random search method that uses probability to guide an iterative process toward the optimal decision [3]. They are used in this research to find the optimum order quantity that reduces total cost.

1.1 Research Problem

The main objective of an inventory control system is to achieve a sufficient and appropriate storage level that matches

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future material needs. Keeping stock performs the basic function of addressing short-term fluctuations and seasonal needs.

Inventory is considered an important resource for productive companies, but it can also pose a danger to their financial position and overall activity. Companies face two opposing goals: manufacturers wish to store large quantities to cover demand for raw materials, whereas management wishes to store the least possible quantity because inventory represents tied-up money. It is therefore important to determine the required quantities of raw materials correctly.

1.2 Research Objective

This research studies the integration of decision making in production companies and formulates a mathematical model that attempts to reduce the total cost of raw materials required for manufacturing without failing to provide the needed quantities. It determines the optimal order quantity and controls the inventory level using genetic algorithms. Reducing inventory does not necessarily mean reducing the total cost of materials required in manufacturing.

1.3 Research Importance

The importance of this research lies in using a quantitative method in the decision-making process to determine the optimum order quantity that reduces total cost. The total consists of holding, transportation, purchasing, and ordering costs. Holding and ordering costs are fixed, whereas transportation and purchase costs can be fixed or variable in this research.

2. DECISION-MAKING PROCESS IN PRODUCTIVE ENTERPRISES

Many skills can be acquired through learning, but the ability to make correct decisions quickly is not easily acquired. The decision maker is obligated to make a decision even when some mistakes are possible, because not making a decision may be the worst mistake [1].

Decision making is one of the essential tasks and basic functions of the decision maker. The success achieved by any industrial or service organization depends on the ability and efficiency of its decision makers, their understanding of decisions and decision-making methods, their awareness of the importance of clarity and timing, and their ability to follow up and evaluate implementation [2].

Decision making is intertwined among the departments of an industrial company. When the decision maker performs the planning function, decisions are made at every stage, from developing the plan and setting objectives to drawing policies, preparing programs, determining appropriate resources, and choosing the best operating methods. Decisions are also made in design, manufacturing, marketing, and other stages of industrial activity [2].

2.1 The Basic Steps for Decision Making

Several approaches are used for decision making, including experience, viewing, trial and error, and the scientific method [4]. Although the steps vary according to the complexity and nature of the problem, the most important scientific-method steps are [5, 6]:

1. Define the problem.
2. Analyze the problem.
3. Determine the alternatives.
4. Evaluate the alternatives.
5. Choose the best alternative.
6. Implement the decision.

2.2 Demand Forecasting Using Time Series

Demand forecasting is an attempt to estimate the market need for a good, service, or mixture of goods during a future period. It is one of the important activities that precede production-capacity and production planning. Available data are analyzed to support correct decisions and achieve production-system objectives. Forecasting results affect aggregate production plans, storage levels, material-requirement planning, master production schedules, manpower planning, and the capital needed to finance production [7].

Several time-series forecasting methods are available [7, 8].

Simple Average Method

This method uses historical data and calculates the average using

$$F_{t+1} = \frac{\sum_{i=1}^{N} Y_t}{N}. \tag{1}$$

Here, N is the number of observations (days, months, or years), t is the time period, Y_t is the observed value at time t, and F_{t+1} is the forecast value for time $t+1$.

Moving Averages Method

This method calculates the average of n values from newly collected time-series data to forecast the next period:

$$\text{Moving average} = \frac{\sum_{r=0}^{n-1} Y_{t-r}}{n}. \tag{2}$$

Old observations are replaced by new observations as they become available. Consequently, the moving average changes whenever new observations are used, while the number of included values remains fixed.

Moving Averages with Trend Method

This method resembles the moving-average method but assumes that the time series has a trend. It uses

$$F_t = \frac{\sum Y_i}{n}, \qquad i = t-n+1, \ldots, t, \tag{3}$$

$$F_t' = F_{t-1}' + \frac{6}{n(n^2-1)} \times \left[(n-1)t + (n+1)(t-n) - 2nF_{t-1}\right], \tag{4}$$

$$F_{t+h} = F_t + F_t' \left[\frac{n-1}{2} + h\right], \tag{5}$$

where h is a future time period.

Single Exponential Smoothing

This method uses recent data and the exponentially smoothed value of the time series in a specific period to predict the next

period. The model is

$$F_{t+1} = \alpha Y_t + (1-\alpha), \tag{6}$$

where α is the smoothing coefficient and $0 \le \alpha \le 1$.

Single Exponential Smoothing with Linear Trend

This method is similar to single exponential smoothing but assumes a specific trend in the time-series data:

$$F_t = \alpha Y_t + (1-\alpha)(F_{t-1} + T_{t-1}), \tag{7}$$
$$T_t = \beta(F_t - T_{t-1}) + (1-\beta)T_{t-1}, \tag{8}$$
$$F_{t+h} = F_t + hT_t, \tag{9}$$

where β is the trend smoothing coefficient, $0 \le \beta \le 1$, $F_0 = y_1$, and $T_0 = 0$.

Holt–Winter Method

This method is based on equations for the level, trend, and seasonal components of a seasonal data model. It resembles Holt's method but includes three constants between zero and one:

$$L_t = \alpha\left(\frac{Y_t}{S_{t-c}}\right) + (1-\alpha)(L_{t-1} + b_{t-1}), \tag{10}$$
$$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}, \tag{11}$$
$$S_t = \gamma\left(\frac{Y_t}{L_t}\right) + (1-\gamma)S_{t-c}, \tag{12}$$
$$F_{t+m} = (L_t + b_t)S_{t+m-c}, \qquad m = 1,2,\ldots,c, \tag{13}$$
$$F_{t+m} = (L_t + mb_t)S_{t+m-2c}, \qquad m = 1,2,\ldots,2c. \tag{14}$$

Here, c is the length of the seasonal cycle, with initial values

$$F_0 = M = \text{average of the first cycle}, \qquad S_t = \frac{Y_t}{m}. \tag{15}$$

2.3 The Importance of Inventory

Economic institutions keep materials that support the uninterrupted continuation of production according to planned programs. Inventory constitutes an important share of trade assets and enables an institution to compete by providing materials, tools, and other requirements according to use rates or demand. Its importance can be summarized as follows [9, 10]:

1. Inventory represents a high percentage of the money invested in an enterprise and may exceed 50% in industrial enterprises.
2. The large share of investment represented by inventory affects the economics of the enterprise because holding costs can be substantial.
3. A scientific storage policy helps the departments of an institution perform their work and improves consistency and integration among them.
4. A clear inventory policy reduces investment in warehouse assets while maintaining enough stock for continuous production and balancing production requirements with actual stores.
5. Inventory management is related to other departments; excessive inventory and holding costs increase total production costs and final-product prices, which can affect customer retention.
6. Inventory is among the least liquid assets, so management errors cannot be treated quickly and, if excessive, may threaten the institution.

2.4 Inventory Control

Inventory control affects both service levels and organizational profitability. This creates a need for effective control and follow-up methods, including the Materials Requirement Planning (MRP) system, a computer-based information system used to prepare purchase orders and schedule inventory [2].

MRP is a logical method for planning and controlling materials used in production. The final product is decomposed into its component parts, and the necessary quantity of each part is calculated from its usage in the preceding part multiplied by the number of required units. Running out of any component obstructs production. Many industrial facilities therefore use scientific methods to plan the storage of materials involved in production [10].

3. PRODUCTION SYSTEM (JUST IN TIME)

Intense competition, rapid development, and changing customer preferences have led organizations to reduce the costs of products and services while maintaining and continuously improving quality. This creates a need for the Just-in-Time (JIT) production system.

JIT is a philosophy that includes modern concepts and methods for managing and performing operations. At the strategic level it supports competitive priorities, and at the operational level it supports efficient resource use, effective scheduling, and rapid response to changes in demand and customer needs. Cost is one of the production determinants that organizations seek to reduce without affecting product quality [11].

3.1 Economic Quantity of Order (EOQ) Model

The EOQ model determines the order size that makes costs as low as possible. This volume is called the economic order quantity and is used to determine the optimal stock level and when to place an order. For demand without shortages, the principal assumptions are [10]:

1. The consumption (demand) rate is fixed and known.
2. There is only one type of good.
3. No shortage occurs in the required quantities.
4. All costs are fixed and independent of the order size.

3.2 Operating Costs

Operating costs are divided into four main types.

The Preparing Cost of an Order

Before ordering and determining order size, administrative procedures include determining the materials and required quantities, researching suppliers, preparing and sending the order, receiving the required items, and controlling and inspecting materials [12]. These activities incur administrative costs such as staff salaries and wages.

Purchase Cost

Purchase cost is the price of one unit of required material agreed with the supplier. It is usually not fixed and changes with the purchased quantity [13].

Holding Cost

Holding or storage cost represents all costs associated with storing materials until they are used. It constitutes a significant proportion of the total costs of industrial establishments [14].

Transportation Cost

Transportation cost is the cost of moving one unit of the required material from the supplier to the warehouse. It is usually not fixed and changes with the transported quantity [15].

4. GENETIC ALGORITHMS

Genetic algorithms are part of evolutionary computing, a rapidly growing area of artificial intelligence. They have been used to search for optimal decisions among a set of available alternatives [2]. They simulate the interbreeding process among organisms of the same species and use concepts such as generations, parents, crossover, and mutation.

The solutions (optimal order quantities) are represented as chromosomes using a coding method. Mathematical operations derived from biological processes, including crossover, selection, and mutation, are then applied to obtain a final generation of chromosomes. Each chromosome is a member of the generation, and the best chromosome represents the optimal solution. The search therefore begins from a set of solutions rather than one solution or one point [16].

4.1 Determining the Optimum Order Quantity Using Genetic Algorithms

The procurement and acquisition of materials and services needed to operate a facility are key management roles. The decision maker seeks to reduce the total cost of the materials required to meet customer demand.

The storage level of raw materials is calculated through [17, 18]

$$L_i^j = L_i^{j-1} + Q_i^j - D_i^{j-1}, \qquad \forall j \in J \setminus \{0\}, \tag{16}$$

$$Q_i^j \geq 0, \qquad Q_i^0 = 0, \qquad \forall i \in I. \tag{17}$$

Here, L_i^j is the storage level of item i at time j, Q_i^j is the demanded quantity of item i at time j, and D_i^j is the quantity required for manufacturing item i at time j.

Company warehouses have limited capacities for each material, with minimum and maximum limits for every period. The stock level must be at least the quantity required for manufacturing in order to prevent shortages and delays:

$$V_i^j \geq D_i^j, \qquad \forall i \in I, \forall j \in J. \tag{18}$$

The purchase price decreases as the quantity increases. The purchase cost is

$$\text{if Lower} \leq D_i^j < \text{Upper}, \quad P_i^j = p_i^k Q_i^j, \qquad \forall i, j, \tag{19}$$

where P_i^j is the purchase cost of item i at time j, and p_i^k denotes a purchase-price group, $k \in \{1,2,3,\ldots\}$.

Transportation cost also decreases as quantity increases:

$$\text{if Lower} \leq D_i^j < \text{Upper}, \quad T_i^j = r_i^m Q_i^j, \qquad \forall i, j, \tag{20}$$

where T_i^j is the transportation cost of item i at time j, and r_i^m denotes a transportation-price group, $m \in \{1,2,3,\ldots\}$.

If h_i denotes the holding cost per unit of raw material, the holding cost is

$$H(Q_i^j) = h_i V_i^j, \qquad \forall i, j. \tag{21}$$

The objective function minimizes holding, purchasing, and transportation costs:

$$\min Z = C(q_i^j) = \sum_{i \in I} \sum_{j \in J} \left(P(Q_i^j) + H(Q_i^j) + R(Q_i^j) \right). \tag{22}$$

5. CASE STUDY

The spinning and weaving industry is one of the important industries in Iraq. Wasit State Company for Textile Industries is one of the principal companies affiliated with the Ministry of Industry and Minerals and specializes in textile industries. It was established under the Soviet Agreement on March 16, 1959, and actual production began on October 1, 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.

5.1 Integrated Decision Making to Determine the Optimal Order Quantity

The spinning and weaving factory uses cotton as a raw material in addition to chemicals and color. Its products are requested by institutions and customers in different quantities. The storage level that reduces total cost is determined through the three stages shown in Figure 1.

5.2 First Stage: Data Collection and Demand Forecasting for Each Product

This stage is divided into data collection, comparison of quantitative forecasting methods, and determination of predictive values.

Data Collection

Sales data for the textile factory's five products (Baza, Sada, poplin, Al-Naba weaving, and printed poplin) were collected from 2019 to 2023, as shown in Tables 1–5.

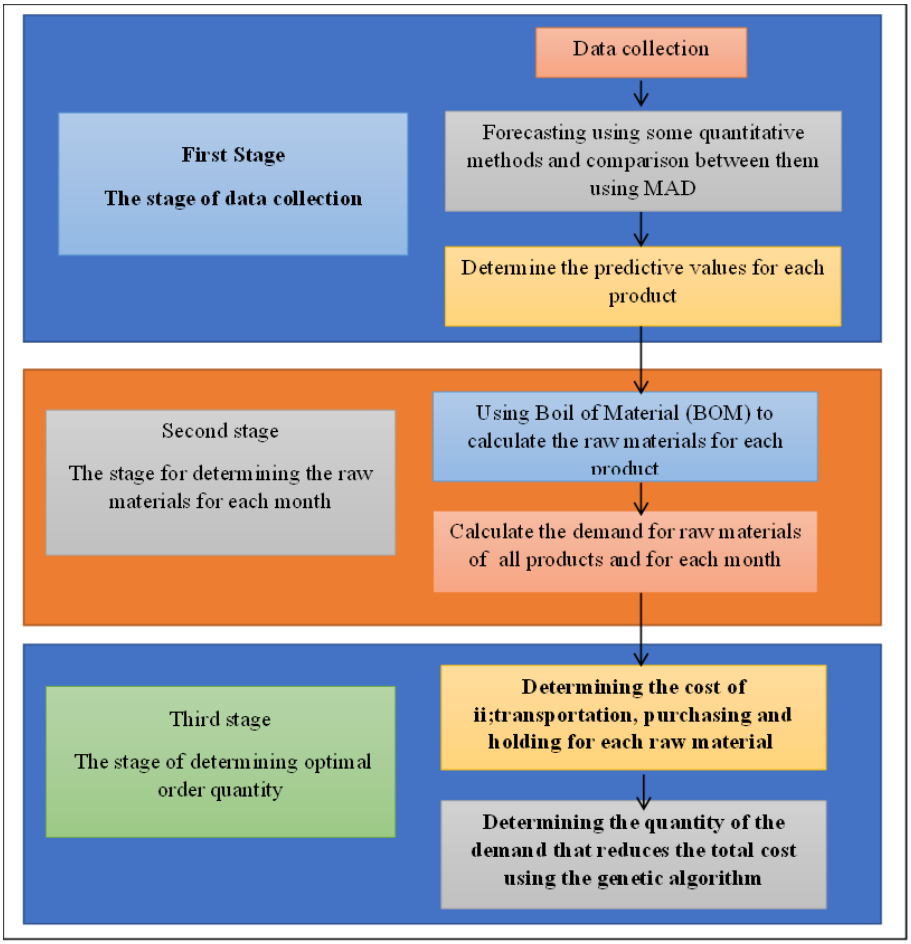


Figure 1. The stages of integrated decision making to determine the optimal quantity of demand.

Table 1. Baza fabric data (2019–2023).

Month	2019	2020	2021	2022	2023
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
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	2019	2020	2021	2022	2023
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

Forecasting Using Quantitative Methods

Moving averages with linear trend, exponential smoothing with trend, and Holt–Winter forecasting were compared using the Mean Absolute Error (MAE), the average absolute difference between observed and predicted values for the same period:

$$\text{MAE} = \frac{\sum_{t=1}^{N} |Y_t - F_t|}{N}. \tag{23}$$

The method with the lowest MAE is considered better. The WinQSB program was used to perform the comparisons shown in Table 6.

Determining the Predictive Values for Each Product

After identifying the method with the least MAE for each product, predictive values for 2024 were determined, as shown in Table 7.

Table 3. Sada fabric data (2019–2023).

Month	2019	2020	2021	2022	2023
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	2019	2020	2021	2022	2023
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
November	20010	18600	17450	16600	16024
December	0	0	0	0	0

Table 5. Printed poplin fabric data (2019–2023).

Month	2019	2020	2021	2022	2023
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

Table 6. Choosing the best forecasting method using MAE.

No.	Product	Method	MAE	Least-MAE method	Criterion
1	Baza fabric	Moving average with linear trend	2486.377		$C = 12$
		Exponential smoothing with trend	1773.603		$\alpha = 0.06$
		Holt–Winter	1061.574	Holt–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–Winter	1153.863	Holt–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–Winter	5329.174	Holt–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–Winter	303.5792	Holt–Winter	$\beta = 0,\ \gamma = 1$
5	Printed poplin fabric	Moving average with linear trend	143.9774		$C = 12$
		Exponential smoothing with trend	79.70847		$\alpha = 0$
		Holt–Winter	35.18692	Holt–Winter	$\beta = 0,\ \gamma = 0.13$

Table 7. Forecasting values of all products for 2024.

Month	Printed Poplin	Naba	Sada Poplin	Baza
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

5.3 Second Stage: Defining the Raw Materials for Each Month

This stage consists of using the Bill of Materials (BOM) to calculate raw-material requirements and then calculating the monthly raw-material order.

Using the BOM to Calculate Raw Materials

The BOM for each product is illustrated in Figure 2. Each product consists of cotton as a basic material in addition to color.

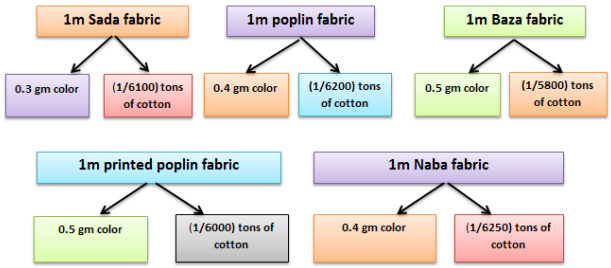


Figure 2. Bill of Materials for textile factory products.

Calculation of Raw-Material Orders for Each Month

The raw-material quantities (cotton and color) were calculated using the BOM and the predictive product quantities, as shown in Tables 8 and 9.

5.4 Third Stage: Determining the Optimal Order Quantity

This stage first determines transportation, purchase, and holding costs and then uses the genetic algorithm to determine the optimum order quantity.

Transportation, Purchase, and Holding Costs

The costs of transportation, purchase, and holding, as well as the initial storage levels of cotton and color, are shown in Tables 10–12.

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

Item	Tier 1	Tier 2	Tier 3	Tier 4
	1–∞			
Cotton	2,500,000	–	–	–
	1–250	250–500	500–1,000	1,000–∞
Color	3,500	3,250	3,000	2,750

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

Item	0–100	100–250	250–5,000
Cotton	300,000	275,000	250,000
Color	500	400	300

Table 12. Holding cost and initial storage level for raw materials.

Item	h_i (dinar)	L_i^0
Cotton	500,000	100 tons
Color	5,000	150 kg

Determining the Optimum Order Quantity Using the Genetic Algorithm

The optimum order quantity for the textile factory is shown in Table 13. The MATLAB program generated 100 solutions, as illustrated in Figure 3; each solution produces a different total cost depending on the specified order quantities.

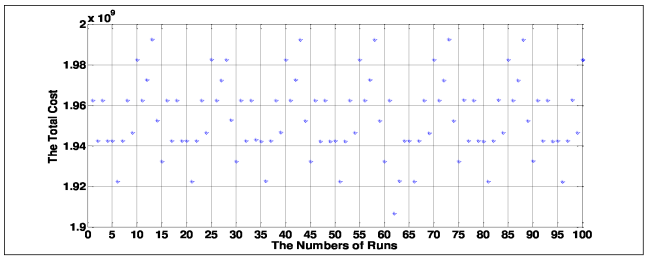


Figure 3. Comparison of the set of solutions using the MATLAB program.

Table 13. Optimal order quantity.

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	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 the solutions and chooses the optimum order quantities that reduce total cost as much as possible. The reported total cost was 1,906,701,000 dinars in solution No. 62. The resulting inventory levels and holding, purchasing, and transportation costs are shown in Tables 14–17.

Table 8. Required quantities of cotton material (tons) for 2024.

Month	Printed Poplin	Naba	Sada	Poplin	Baza	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. Required quantities of color (liters) for 2024.

Month	Printed Poplin	Naba	Sada	Poplin	Baza	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

Table 14. Optimal inventory level.

i	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}
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

Table 15. Purchasing cost (thousands of dinars).

i	1	2	3	4	5	6	7	8	9	10	11	12	Holding costs
1	3,650	33,500	50,000	36,500	31,000	14,500	28,000	16,500	48,000	23,000	18,000	0	352,650
2	1,350	675	510	1,280	695	355	650	440	720	570	445	20	8,460
												Total holding cost (thousand dinars)	**361,110**

Table 16. Purchasing cost (thousands of dinars).

i	1	2	3	4	5	6	7	8	9	10	11	12	Purchasing costs
1	80,000	167,500	250,000	40,000	155,000	75,000	145,000	90,000	250,000	27,500	100,000	0	1,380,000
2	812.5	56	357	825.5	150.5	234.5	441	294	490	385	304.5	0	4,350.5
												Total purchasing cost (thousand dinars)	**361,110**

Table 17. Transportation cost (thousands of dinars).

i	1	2	3	4	5	6	7	8	9	10	11	12	Transportation costs
1	9,600	20,100	27,500	4,800	18,600	9,000	17,400	10,800	27,500	3,300	12,000	0	160,600
2	125	8	51	127	21.5	33.5	63	42	70	55	43.5	0	639.5
												Total transportation cost (thousand dinars)	**361,110**

6. CONCLUSION

The integrated decision-making model was used to determine the optimal order quantity. The Holt–Winter method was better than moving averages with linear trend and exponential smoothing with trend for forecasting the data of the five textile-factory products because it produced the lowest MAE.

The genetic algorithm is an advanced quantitative method for determining the optimum order quantity because it accommodates fixed or variable costs associated with the required quantity. Purchase cost accounts for the largest share of total cost (73%), followed by holding cost (19%) and transportation cost (8%). Cotton accounts for more than 99% of purchase cost.

Decision makers in factories and companies are therefore encouraged to rely on quantitative methods for integrated decision making.

REFERENCES

[1] S. Axs"ater, *Inventory Control*, ser. International Series in Operations Research and Management Science, vol. 225. Springer, 2015.

[2] A. F. A.-R. H. Mahmoud, "The use of dynamic programming and neural network to find the optimal stockpiling stores general company for vegetable oil," Master's thesis, College of Administration and Economics, University of Baghdad, 2010.

[3] S. Marrouchi and S. Ben Saber, "A comparative study of fuzzy logic, genetic algorithm, and gradient-genetic algorithm optimization methods for solving the unit commitment problem," *Mathematical Problems in Engineering*, vol. 2014, 2014.

[4] C. H. Kepner and B. B. Tregoe, *The Rational Manager: A Systematic Approach to Problem Solving and Decision Making*. Princeton Research Press, 1995.

[5] E. Niman, "A multi-criteria optimization model for a four-stage multi-product supply chain," 2010.

[6] W. H. Laith, "A study of multi-objective decision making to select the best drawing die in ur company," Master's thesis, Industrial Engineering Department, University of Technology, 2007.

[7] I. A. Almosabbeh and M. A. Almoree, "The relationship between manufacturing production and economic growth in the kingdom of saudi arabia," *Journal of Economic Studies*, vol. 45, pp. 674–690, 2018.

[8] H. A. Taha, *Operations Research: An Introduction*. Pearson Prentice Hall, 2007.

[9] F. Munier, "Firm size, technological intensity of sector and relational competencies to innovate: Evidence from french industrial innovating firms," *Economics of Innovation and New Technology*, vol. 15, pp. 493–505, 2006.

[10] D. Blumenfeld, *Introduction to Operations Research Calculations Handbook*, 2nd ed. USA: Taylor & Francis Group, 2009.

[11] A. Battersby, *A Guide to Stock Control*. London: Pitman Publishing Limited, 2006.

[12] G. Ghiani, G. Laporte, and R. Musmanno, *Introduction to Logistics Systems Planning and Control*. John Wiley & Sons, 2004.

[13] F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*. McGraw-Hill Education, 2015.

[14] F. Burger, "The impact of warehousing and transportation optimization on supply chain effectiveness," Ph.D. dissertation, University of Johannesburg, 2003.

[15] M. Eker and F. Pala, "The effect of competition, just in time production and total quality management on the use of multiple performance measures: An empirical study," *Journal of Economic and Social Research*, vol. 10, pp. 35–72, 2008.

[16] V. V. Raghavan and B. Agarwal, "Optimal determination of user-oriented clusters: An application for the reproductive plan," in *Proceedings of the Second International Conference on Genetic Algorithms*, Cambridge, MA, 1987.

[17] W. H. Laith, S. S. A. Ali, and M. A. Mahmoud, "Integrated decision making in production department inside internal supply chain," *American Journal of Industrial Engineering*, vol. 4, pp. 21–28, 2017.

[18] W. H. Laith, S. S. Al-Zubaidy, and M. A. Mahmoud, "Determination optimum inventory level for material using genetic algorithm," *Journal of Engineering*, vol. 24, pp. 218–230, 2018.