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# Solving multi-objective supply chain management using non-dominated sorting genetic algorithm

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ABSTRACT

Focusing on production processes is the decisive factor in managing an efficient supply chain that leads to the company's success. The objective constraints in the model include all the goals the company seeks to achieve and the level to achieve for each. In addition to clarifying the contribution of each decision variable in achieving the specified levels of the different goals, the conclusions reached are the results that prove the possibility of solving a problem. Applying the mathematical model according to the demand for parts (derived from the demand for the final product) contributed significantly to saving the stock of raw materials, as (100) refers to the quantity that is kept as a regular stock for the first week and varies from one week to another according to the change in demand. As a result of reducing the stock of materials, the costs associated with it will decrease, and the difference can be seen in the total costs of storing raw materials and semi-manufactured parts, which is estimated at (47929.1) Iraqi dinars) for the storage of materials and parts for all weeks, according to the planning periods established by the company. By applying the genetic algorithm, the total storage costs were calculated, and it was (13024.8) Iraqi dinars, which is the most critical indicator of success in improving the supply chain performance.

**Keywords:** Production capacity, Multiple-objective, Supply chain, Genetic algorithms.

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## 1. Introduction

The general company for electrical industries contains many basic operations and various sub-processes. The company focuses on satisfying the consumer by meeting the requirements of the product in a way that increases the company's revenues. For the company to remain in the competition circle, it must be able to improve operations production and work to find the appropriate ways through which its products are manufactured quickly and at the lowest possible cost by using non-dominated sorting genetic algorithms to obtain the optimal solution [1].

Reducing labor costs and the total loading of parts that contain the same manufacturing processes, as similar processing requirements are collected in groups called (part families) and material requirements planning as one batch, and this method has an apparent effect in reducing storage costs and costs of preparation, planning, and implementation [2]. The elements that have similar characteristics from a design point of view (formal) are mixed into a part family, and processing is done for all elements in the family in one batch to take advantage of the similarity of the parts in reducing labor and storage costs. And when compared with the policy in place, schedule the requirements of each element (part) independently of the other [3].

This method can be beneficial through the assistance it provides in designing the manufacturing process and reducing unnecessary diversity that causes duplication in product design, as batch technology can identify product families and parts that can be manufactured in manufacturing cells in one batch [4]. It reduces the preparation time process, reduces waiting time, reduces running stock, and simplifies production planning and control [5]. The part family is formed according to the components in the factory and based on the similarity of the parts in terms of design or manufacturing methods [6].

These parts are scheduled and planned for their needs in each family using a mathematical planning tool represented by the MRP system, which is based on scheduling the primary production to determine the needs of raw materials, essential parts, and sub-assemblies for each (family), where the (MRP) system shows (the types of materials and their quantities to be provided) Taking into account the current stock and waiting times for materials, it also determines the time for issuing orders (purchase or production) to provide the necessary material requirements [7]. This integration would achieve many advantages, the most important of which is achieving economies of scale, reducing the stock of raw materials and finished stocking products, as well as reducing work and organizing the sequence of production operations, which in turn achieves the optimal internal arrangement of the factory and leads to a reduction in production time, which enables the company to meet the requirements of delivery on time [8].

The difficulty that can be faced lies in assembling the requirements for the family of the part, as it is a somewhat complex and multi-dimensional task, that is, many of the similar components, that is, all the requirements of the part family must be selected together. The cost of preparation for the requirements depends on the number of different components in the part family and the proposed scheduled sequence of the resulting batch [9].

### 1.1. Theoretical motivations

Group technology is described as an ideal philosophy for Japanese industries, as it searches for the internal organization of the factory that provides an efficient flow of production based on defining the group of products in the form of families according to two inputs, the first is classification and coding, and the second is represented by the analysis of the flow of production [10]. Classification and coding require the use of advanced techniques in the process of designing and process planning with computer assistance to provide the basis for selecting paths of similar parts and then simplifying and profiling them to increase their efficiency. As for flow analysis of production, it aims to assemble parts in manufacturing cells to achieve high speed in performance and lower costs [11]. And the idea of applying group technology (GT) does not work in isolation from the rest of the other systems, such as the material needs planning system (MRP), because GT applications have a direct relationship and different effects on planning and storage activities. The relationship between the MRP system and group scheduling should work well [12].

Integrating the use of (MRP) and group scheduling provides an effective system for controlling production. This integration aims to reduce labor costs and the total loading of parts that contain the same manufacturing processes. This method is based on the fact that parts with similar processing requirements are grouped into groups called (part families), and their needs are planned as one batch [13]. This method has an apparent effect in reducing storage costs, preparation costs, planning, and implementation, as elements that have similar characteristics from a design point of view (formal) are combined into a part family [14].

All elements in the family are processed in one batch to take advantage of the similarity of parts in reducing labor and storage costs. And when compared with the applicable policy for scheduling the requirements of each item (part) independently of the other, as is usually the case in using the MRP system (in isolation from GT), the computational solutions for scheduling totals save an average of 23% of the costs of preparation and implementation. This method has been developed as an extension of the material requirements planning technique for (part-period) budget [15, 16].

It is possible to take advantage of this method through the assistance it provides in designing the manufacturing process and reducing unnecessary diversity that causes duplication in product design, as aggregate technology can identify product families and parts that can be manufactured in manufacturing cells in one batch, which leads to a reduction in time Preparing for the process, reducing waiting time, reducing stock under operation, and simplifying the process of planning and controlling production [17].

## 2. Modified model

### 2.1. Mathematical model: Multi-objective

The multi-objectives model was built, where the objective constraints in the model include all the goals the company seeks to achieve and the level to achieve for each of them, in addition to clarifying the contribution of each decision variable in achieving the specified levels of the different goals [18, 19].

$$\min TC = \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{i\in G(i)}^{N} C'_{i,j,t}\ X_{i,j,t} + \sum_{t=1}^{T}\sum_{j=1}^{J}(r_{j,t}R_{j,t} + e_{j,t}E_{j,t}) + \sum_{t=1}^{T}\sum_{i=1}^{N} h_{i,t}I_{i,t} \ldots. (1)$$

$$\sum_{j=1}^{J} X_{i,j,t} + I_{i,t-1} = d_{i,t} + I_{i,t} \quad i = 1,2,\ldots,N \ \ t = 1,2,\ldots,T \ \ldots.. (2)$$

$$\sum_{i\in G(i)} a'_{i,j}\ X_{i,j,t} \le R_{j,t} + E_{j,t} \quad j = 1,2,\ldots,J \ \ t = 1,2,\ldots,T \ \ldots. (3)$$

$$R_{j,t} \le M_{j,t}$$

$$E_{j,t} \le Q_{j,t}$$

$$X_{i,j,t}\ , I_{i,t}\, , R_{j,t}\, , E_{j,t} \ge 0 \ \ldots. (4)$$

Where:

t: Period (week)

J: Group

i: Part repeat sequence in technological aggregates

C: part cost

X: The need for the part

r : the group's typical time cost

R: the expected time for the group

e: the cost of additional time for the group

E: group extra time

h : storage cost per part per week

I: stored quantities

d: part demand (weekly)

A: The time it takes to manufacture the part

M: The usual time, greatest

Q: The greatest overtime

The function of the mathematical model refers to the reduction function for the total cost (Min Z), and it consists of three parts, as shown below:

1. Part one:
   $$\sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{i\in G(i)}^{N} C'_{i,j,t}\ X_{i,j,t} \ \ldots..(5)$$

Total (part cost multiplied by the variable (x) that represents (part required, first group, first week).

2. The second part of the equation

$$\sum_{t=1}^{T}\sum_{j=1}^{J}(r_{j,t}R_{j,t} + e_{j,t}E_{j,t})\ldots. (6)$$

The second part includes two aspects. The first refers to reducing the cost of the usual time required to produce the part in the group according to its needs (r_(j,t) R_(j,t)).

While the second aspect refers to reducing the additional time required for some parts, as in (e_(j,t) E_(j,t)), knowing that this part of the model represents the additional time for the totals.

3. The third part

$$\sum_{t=1}^{T}\sum_{i=1}^{N} h_{i,t} I_{i,t} \quad \dots. (7)$$

Refers to the sum (the product of multiplying the cost of storage by the available storage), as the third and final part of the model equation includes reducing the cost associated with calculating storage costs.

### 2.2. Intelligence algorithm

Genetic algorithms are the most powerful algorithms for artificial intelligence techniques in "rapidly developing" biology, and they are genetic algorithms that are indivisible in the field of artificial intelligence.

Genetic Algorithms: As a simple and brief explanation, genetic algorithms are part of evolutionary computing and are the rapid growth of artificial intelligence. The latter is implemented as a computer simulation where evolutionary biology technology is used.

Each system contains a set of laws that are recorded in the organism's genes as codes. Genes are linked in long chains called chromosomes, where each gene represents a specific trait. Any value can be taken from a set of setting modes. Genes are genes, and their settings are the organism's genotype [20].

* In short, we have mentioned that genetic algorithms are a computational method for solving problems by reducing operations, natural use, selection, transformation, and acceptance.

The summary of genetic algorithm steps are:

- start [Start],
- Then the configuration or [Fitness],
- Then childbearing [New population],
- then switch [Replace],
- Then the test [Test],
- Loop [loop].

At the beginning of the solution, the algorithm generates an initial solution (S), either randomly or using another intuitive method, and considers it the current solution with an initialization (T) and setting the iteration rate equal to one (t = 1), and then creates a new solution (S^') from the solution the current one in a certain way from the neighborhood search methods (Neighbor search)

Here are the algorithm steps:

1- Generate an initial solution by the following equation:

$$S_0 = \frac{LB+UB}{2} \quad \dots.. (8)$$

2- Calculate the value of the objective function of the first loop by making

$$S* = S0 \quad f* = f(S0) \dots\dots (9)$$

3- Generate a new solution using the neighborhood search method using the following equation

$S(t) = S0 + (UB - LB) * rand$ ….(10)

4- Calculate the value of the objective function for the new solution if it is the objective function.

$f(s(t)) < f *$

$S *= S(t) \quad f *= f(S(t))$ …..(11)

5-

$p = e^{-\frac{(f(s_{(t)}) - f^*}{T}}$ …… (12)

If p<rand than $S *= S(t) \quad f *= f(S(t))$ ….. (13)

Otherwise, we generate a new solution through step number (3).

6- $C(T, t) = T.\alpha \quad 0 < \alpha < 1 \quad$ step number (2.)

Repeat steps 3-6 until the condition of stopping occurs when the total number of repetitions ends.

- The end

Where:

S: Initial solution

LB: The minimum number of units produced

UB: the upper limit of the units produced

S*: The perfect solution

f*: Optimal solution function

P: Probability

T: Fixed

C: Change the value

t: The frequency of the value.

α: Reduction coefficient, its value ranges from (0-1)

rand: A random variable ranging from (0-1).

## 3. Results and discussion

### 3.1. Required quantities of parts

After solving the mathematical model by genetic algorithm and after programming it using MATLAB language. The results (the output of the system) were represented by the quantities required to be manufactured from the parts to meet the demand for the final products according to the planning periods and as shown in Table 1.

Table 1. The outputs of the system characterized by the quantities required to be manufactured from the parts to meet the demand for the final products according to the planning periods

| | | | The required quantities of parts according to the planning periods | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| number part | Part name | Part code | week 1 | week 2 | week 3 | week 4 | week 5 | week 6 | week 7 | weejk 8 | week9 | week10 | week 11 | week 12 | Costs for each part according to the planning periods |
| 1 | Motor | M. | 1856 | 1800 | 1796 | 1776 | 1680 | 1560 | 1332 | 1308 | 1160 | 1100 | 1064 | 1060 | 361180 |
| 2 | End shild | ES. | 1392 | 1350 | 1347 | 1332 | 1260 | 1170 | 999 | 981 | 870 | 825 | 798 | 795 | 342050 |
| 3 | Mositure proot la | MPL | 1902 | 1860 | 1848 | 1732 | 1636 | 1534 | 1380 | 1374 | 1230 | 1126 | 1082 | 1080 | 287910 |
| 4 | Rotor Assy | R.ASS. | 2320 | 2250 | 2245 | 2220 | 2100 | 1950 | 1665 | 1635 | 1450 | 1375 | 1330 | 1325 | 4242972 |
| 5 | Hex.Nut.M5 | H.N.M5 | 2760 | 2580 | 2440 | 2460 | 2320 | 2132 | 2120 | 2100 | 1988 | 1952 | 1904 | 1820 | 814440 |
| 6 | Cover | CO. | 2760 | 2580 | 2440 | 2460 | 2320 | 2132 | 2120 | 2100 | 1988 | 1952 | 1904 | 1820 | 761516 |
| 7 | BUSH | BU | 2760 | 2580 | 2440 | 2460 | 2320 | 2132 | 2120 | 2100 | 1988 | 1952 | 1904 | 1820 | 871840 |
| 8 | Screw M5 X8 | SC.M5X8 | 1948 | 1920 | 1900 | 1688 | 1592 | 1508 | 1428 | 1440 | 1300 | 1152 | 1100 | 1100 | 486746 |
| 9 | Lable name plate | L.N.P | 928 | 900 | 898 | 888 | 840 | 780 | 666 | 654 | 580 | 550 | 532 | 530 | 716000 |
| 10 | Base | B . | 464 | 450 | 449 | 444 | 420 | 390 | 333 | 327 | 290 | 275 | 266 | 265 | 314275 |
| 11 | Stator Assy | St.ASS. | 2830 | 2760 | 2746 | 2620 | 2476 | 2314 | 2046 | 2028 | 1810 | 1676 | 1614 | 1610 | 2589225 |
| 12 | Terminal | Te. | 2308 | 2190 | 2118 | 2118 | 2000 | 1846 | 1726 | 1704 | 1574 | 1526 | 1484 | 1440 | 1329960 |
| 13 | Wound roter | W.r. | 2760 | 2580 | 2440 | 2460 | 2320 | 2132 | 2120 | 2100 | 1988 | 1952 | 1904 | 1820 | 1067360 |
| 14 | Capacitor | Ca. | 1380 | 1290 | 1220 | 1230 | 1160 | 1066 | 1060 | 1050 | 994 | 976 | 952 | 910 | 468020 |
| 15 | Clamp MTG Assy | Cla.MTG | 2760 | 2580 | 2440 | 2460 | 2320 | 2132 | 2120 | 2100 | 1988 | 1952 | 1904 | 1820 | 1201320 |
| 16 | Spring Washer | S.Wa | 974 | 960 | 950 | 844 | 796 | 754 | 714 | 720 | 650 | 576 | 550 | 550 | 4749680 |
| 17 | Shaft | Sh. | 928 | 900 | 898 | 888 | 840 | 780 | 666 | 654 | 580 | 550 | 532 | 530 | 3090500 |
| 18 | Sleeve | SL. | 690 | 645 | 610 | 615 | 580 | 533 | 530 | 525 | 497 | 488 | 476 | 455 | 1096050 |
| 19 | Ball Bearn | Ba.Be | 1664 | 1605 | 1560 | 1459 | 1376 | 1287 | 1244 | 1245 | 1147 | 1064 | 1026 | 1005 | 400450 |
| 20 | Core Rottor | C.R | 1380 | 1290 | 1220 | 1230 | 1160 | 1066 | 1060 | 1050 | 994 | 976 | 952 | 910 | 919620 |
| 21 | Governor sleeve | Go.sl. | 1641 | 1575 | 1534 | 1481 | 1398 | 1300 | 1220 | 1212 | 1112 | 1051 | 1017 | 995 | 3092120 |
| 22 | Rotor lamtnatior | Ro.la | 1641 | 1575 | 1534 | 1481 | 1398 | 1300 | 1220 | 1212 | 1112 | 1051 | 1017 | 995 | 4747200 |
| 23 | Winding specf | Wi.Sp | 464 | 450 | 449 | 444 | 420 | 390 | 333 | 327 | 290 | 275 | 266 | 265 | 12635260 |
| 24 | Frame | Fr. | 1177 | 1125 | 1085 | 1037 | 978 | 910 | 887 | 885 | 822 | 776 | 751 | 730 | 5541150 |
| 25 | Connctor | Con. | 487 | 480 | 475 | 422 | 398 | 377 | 357 | 360 | 325 | 288 | 275 | 275 | 15152745 |
| 26 | Slcore Assy | SL.ASS | 487 | 480 | 475 | 422 | 398 | 377 | 357 | 360 | 325 | 288 | 275 | 275 | 4096670 |
| 27 | Lead wire | Le.wi | 1177 | 1125 | 1085 | 1037 | 978 | 910 | 887 | 885 | 822 | 776 | 751 | 730 | 4406025 |
| 28 | Statur laminatior | St.la | 1380 | 1290 | 1220 | 1230 | 1160 | 1066 | 1060 | 1050 | 994 | 976 | 952 | 910 | 9179010 |
| 29 | Inis matl Assy | In.Ass. | 974 | 960 | 950 | 844 | 796 | 754 | 714 | 720 | 650 | 576 | 550 | 550 | 24668400 |
| 30 | Nut | N. | 487 | 480 | 475 | 422 | 398 | 377 | 357 | 360 | 325 | 288 | 275 | 275 | 5056700 |
| 31 | SCR | SC. | 464 | 450 | 449 | 444 | 420 | 390 | 333 | 327 | 290 | 275 | 266 | 265 | 3479250 |
| 32 | Cleant | Cl. | 1641 | 1575 | 1534 | 1481 | 1398 | 1300 | 1220 | 1212 | 1112 | 1051 | 1017 | 995 | 4122690 |
| 33 | Lamination | La. | 928 | 900 | 898 | 888 | 840 | 780 | 666 | 654 | 580 | 550 | 532 | 530 | 688344 |
| 34 | Wedge | We. | 928 | 900 | 898 | 888 | 840 | 780 | 666 | 654 | 580 | 550 | 532 | 530 | 3868620 |
| 35 | Insulator | In | 1641 | 1575 | 1534 | 1481 | 1398 | 1300 | 1220 | 1212 | 1112 | 1051 | 1017 | 995 | 2737300 |
| | total | | 52281 | 50010 | 48600 | 47386 | 44734 | 41509 | 38946 | 38625 | 35517 | 33817 | 32771 | 31980 | 129582598 |

Table 1 indicates the required quantities (produced or purchased) of parts according to the planning periods for each group and each week. It represents (1856) the number of required units (which were planned according to the need of the part in each product) from the first part in the first group in the first week, and (1800) the number of units required from the first part in the first group in the second week. So on for the rest of the parts, for all groups. The table also indicates the total costs associated with the parts.

The total costs of manufacturing the part for all weeks were obtained as a final output after applying the model in the MATLAB program based on the cost of manufacturing one unit and the number of required units.

### 1.1. Stock quantities of parts

As the units' needs were planned for the parts that must be kept as storage, and for each part of the products, based on the demand for products, previous storage, and safe storage and according to the planning periods for the next Period, as shown in Table 2.

Table 2. Stock quantities of parts

| Table 2 | | | Stock quantities of parts | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| number part | Part name | Part code | week 1 | week 2 | week 3 | week 4 | week 5 | week 6 | week 7 | weejk 8 | week9 | week10 | week 11 | week 12 | Costs for each part according to the planning periods |
| 1 | Motor | M. | 613 | 100 | 142 | 186 | 236 | 286 | 336 | 372 | 422 | 463 | 513 | 563 | 52053.6 |
| 2 | End shild | ES. | 150 | 372 | 463 | 565 | 751 | 886 | 985 | 1072 | 1152 | 1245 | 1425 | 1504 | 111748.8 |
| 3 | Mositure | MPL | 765 | 121 | 182 | 242 | 303 | 364 | 425 | 472 | 533 | 594 | 655 | 704 | 13400 |
| 4 | Rotor Ass | R.ASS. | 628 | 90 | 146 | 191 | 247 | 285 | 332 | 388 | 436 | 492 | 541 | 572 | 55219.6 |
| 5 | Hex.Nut.N | H.N.M5 | 677 | 103 | 159 | 200 | 254 | 309 | 365 | 421 | 468 | 523 | 579 | 621 | 56148 |
| 6 | Cover | CO. | 732 | 115 | 178 | 223 | 277 | 309 | 372 | 420 | 483 | 543 | 606 | 669 | 65036.4 |
| 7 | BUSH | BU | 705 | 120 | 180 | 225 | 285 | 322 | 354 | 414 | 467 | 527 | 587 | 647 | 62829 |
| 8 | Screw M5 | SC.M5X8 | 221 | 34 | 51 | 68 | 85 | 102 | 119 | 136 | 153 | 170 | 187 | 204 | 13464 |
| 9 | Lable nam | L.N.P | 502 | 80 | 120 | 160 | 200 | 234 | 264 | 304 | 344 | 384 | 424 | 464 | 56376 |
| 10 | Base | B . | 800 | 132 | 205 | 274 | 348 | 398 | 473 | 538 | 571 | 601 | 650 | 725 | 111442.5 |
| 11 | Stator Ass | St.ASS. | 143 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 | 9108 |
| 12 | Terminal | Te. | 117 | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 108 | 7938 |
| 13 | Wound ro | W.r. | 91 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 5229 |
| 14 | Capacitor | Ca. | 130 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 7110 |
| 15 | Clamp MT | Cla.MTG | 104 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 6840 |
| 16 | Spring Wa | S.Wa | 91 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 9072 |
| 17 | Shaft | Sh. | 737 | 139 | 196 | 252 | 291 | 330 | 404 | 442 | 486 | 554 | 618 | 672 | 65036.7 |
| 18 | Sleeve | SL. | 364 | 56 | 84 | 112 | 140 | 168 | 196 | 224 | 252 | 280 | 308 | 336 | 24444 |
| 19 | Ball Bearn | Ba.Be | 182 | 28 | 42 | 56 | 70 | 84 | 98 | 112 | 126 | 140 | 154 | 168 | 19026 |
| 20 | Core Rott | C.R | 169 | 26 | 39 | 52 | 65 | 78 | 91 | 104 | 117 | 130 | 143 | 156 | 10296 |
| 21 | Governor | Go.sl. | 312 | 48 | 72 | 96 | 120 | 144 | 168 | 192 | 216 | 240 | 264 | 288 | 16848 |
| 22 | Rotor lam | Ro.la | 498 | 80 | 120 | 146 | 186 | 225 | 265 | 305 | 345 | 381 | 421 | 458 | 31899 |
| 23 | Winding s | Wi.Sp | 143 | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 | 7920 |
| 24 | Frame | Fr. | 390 | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 24030 |
| 25 | Connctor | Con. | 91 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 10521 |
| 26 | Slcore Ass | SL.ASS | 70 | 12 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 9342 |
| 27 | Lead wire | Le.wi | 494 | 76 | 114 | 152 | 190 | 228 | 266 | 304 | 342 | 380 | 418 | 456 | 54378 |
| 28 | Statur lam | St.la | 208 | 32 | 48 | 64 | 80 | 96 | 112 | 128 | 144 | 160 | 176 | 192 | 28512 |
| 29 | Inis matl A | In.Ass. | 169 | 26 | 39 | 52 | 65 | 78 | 91 | 104 | 117 | 130 | 143 | 156 | 29367 |
| 30 | Nut | N. | 130 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 8820 |
| 31 | SCR | SC. | 65 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 5445 |
| 32 | Cleant | Cl. | 512 | 80 | 120 | 160 | 200 | 235 | 275 | 315 | 352 | 392 | 432 | 472 | 49275.5 |
| 33 | Laminatio | La. | 505 | 80 | 110 | 145 | 185 | 225 | 265 | 305 | 345 | 385 | 425 | 465 | 30272 |
| 34 | Wedge | We. | 91 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 7560 |
| 35 | Insulator | In | 312 | 48 | 72 | 96 | 120 | 144 | 168 | 192 | 216 | 240 | 264 | 288 | 45792 |
| | total | | 11911 | 2242 | 3266 | 4229 | 5338 | 6298 | 7320 | 8288 | 9239 | 10234 | 11341 | 12316 | 1121799.1 |

Table 2 indicates the stock quantities of parts according to the planning periods for each part, in each group, and for each week. As it represents (613) the number of stored units (which were planned according to the need of the part in each product) from the first part in the first group in the first week, It represents (150) the number of units stored from the second part in the first group in the first week, representing (730) the number of units stored from the third part in the first group in the first week. Thus, it is planned to store the other parts in the totals for the first week and calculate the total costs of storing the parts for all weeks according to the mathematical model based on the cost of storing one unit of the part and the number of units stored.

### 1.2. Improving supply chain performance

After obtaining the necessary data for the completion of the research from the researched company and compared with the system outputs, it was found that the company maintains large quantities of stocks of raw materials, semi-manufactured parts, and the finished product. This leads to them incurring additional storage costs, which leads to an increase in the cost of producing one unit. This is different from essential supply chain management by reducing costs and delivering on time. The reality of the company's condition is its inability to deliver its orders on time due to the increase in the time required for weekly planned production and their need for additional time .After solving the mathematical model by the fairy algorithm, the stock of raw materials and semi-finished parts became based on planning for the need for parts, and this contributed significantly to reducing the stock to its lowest levels, which led to a reduction in storage costs, which in turn is reflected in a reduction in the total costs, and this leads to a reduction in the unit cost from the final product.

The system achieves one of the essential objectives of supply chain performance represented by reducing unit costs without compromising product quality or at the expense of other criteria (delivery, flexibility). The improvement can be seen in the cost dimension through the difference between the quantities and the associated costs, as shown in Table 3.

Table 3. Improving based on supply chain performance

| | | | The improvement | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| number part | Part name | Part code | week 1 | week 2 | week 3 | week 4 | week 5 | week 6 | week 7 | weejk 8 | week9 | week10 | week 11 | week 12 | Costs for each part according to the planning periods |
| 1 | Motor | M. | 1544 | 1345 | 1346 | 1355 | 1370 | 407 | 413 | 470 | 500 | 524 | 529 | 530 | 361180 |
| 2 | End shild | ES. | 2980 | 1760 | 1764 | 1826 | 1960 | 2178 | 2196 | 2464 | 2626 | 2770 | 2896 | 2910 | 342050 |
| 3 | Mositure proot la | MPL | 2329.4 | 1461.4 | 1505.4 | 1547.4 | 1595.4 | 1725.4 | 1747.4 | 1867.4 | 2021.4 | 2139.4 | 2139.4 | 2211.4 | 287910 |
| 4 | Rotor Assy | R.ASS. | 2777 | 1837 | 1921 | 1969 | 2005 | 2117 | 2137 | 2149 | 2337 | 2477 | 2457 | 2597 | 4242972 |
| 5 | Hex.Nut.M5 | H.N.M5 | 1393.6 | 923.6 | 965.6 | 989.6 | 1007.6 | 1063.6 | 1073.6 | 1079.6 | 1173.6 | 1243.6 | 1233.6 | 1303.6 | 814440 |
| 6 | Cover | CO. | 2778.8 | 1838.8 | 1922.8 | 1970.8 | 2006.8 | 2118.8 | 2138.8 | 2150.8 | 2338.8 | 2478.8 | 2458.8 | 2598.8 | 761516 |
| 7 | BUSH | BU | 988.8 | 564.8 | 564.8 | 590.8 | 664.8 | 734.8 | 728.8 | 768.8 | 810.8 | 858.8 | 964.8 | 974.8 | 871840 |
| 8 | Screw M5 X8 | SC.M5X8 | 941.6 | 543.6 | 545.6 | 563.6 | 593.6 | 667.6 | 679.6 | 793.6 | 853.6 | 901.6 | 911.6 | 913.6 | 486746 |
| 9 | Lable name plate | L.N.P | 836.4 | 601.4 | 622.4 | 634.4 | 643.4 | 671.4 | 676.4 | 679.4 | 726.4 | 761.4 | 756.4 | 791.4 | 716000 |
| 10 | Base | B . | 1719.6 | 1060.6 | 1081.6 | 1119.6 | 1202.6 | 1300.6 | 1299.6 | 1342.6 | 1431.6 | 1514.6 | 1615.6 | 1660.6 | 314275 |
| 11 | Stator Assy | St.ASS. | 716.2 | 481.2 | 502.2 | 514.2 | 523.2 | 551.2 | 556.2 | 559.2 | 606.2 | 641.2 | 636.2 | 671.2 | 2589225 |
| 12 | Terminal | Te. | 1405 | 935 | 977 | 1001 | 1019 | 1075 | 1085 | 1091 | 1185 | 1255 | 1245 | 1315 | 1329960 |
| 13 | Wound roter | W.r. | 1687.4 | 1041.4 | 1063.4 | 1097.4 | 1158.4 | 1258.4 | 1266.4 | 1346.4 | 1444.4 | 1527.4 | 1580.4 | 1621.4 | 1067360 |
| 14 | Capacitor | Ca. | 1720.6 | 1074.6 | 1096.6 | 1130.6 | 1191.6 | 1291.6 | 1299.6 | 1379.6 | 1477.6 | 1560.6 | 1613.6 | 1654.6 | 468020 |
| 15 | Clamp MTG Assy | Cla.MTG | 486 | 287 | 288 | 297 | 312 | 349 | 355 | 412 | 442 | 466 | 471 | 472 | 1201320 |
| 16 | Spring Washer | S.Wa | 1236 | 789 | 810 | 835 | 881 | 944 | 946 | 969 | 1037 | 1096 | 1144 | 1184 | 4749680 |
| 17 | Shaft | Sh. | 500.8 | 288.8 | 288.8 | 301.8 | 338.8 | 373.8 | 370.8 | 390.8 | 411.8 | 435.8 | 488.8 | 493.8 | 408730 |
| 18 | Sleeve | SL. | 487 | 275 | 275 | 288 | 325 | 360 | 357 | 377 | 398 | 422 | 475 | 480 | 400450 |
| 19 | Ball Bearn | Ba.Be | 1252.4 | 805.4 | 826.4 | 851.4 | 897.4 | 960.4 | 962.4 | 985.4 | 1053.4 | 1112.4 | 1160.4 | 1200.4 | 939384 |
| 20 | Core Rottor | C.R | 1410.4 | 940.4 | 982.4 | 1006.4 | 1024.4 | 1080.4 | 1090.4 | 1096.4 | 1190.4 | 1260.4 | 1250.4 | 1320.4 | 919620 |
| 21 | Governor sleeve | Go.sl. | 1000 | 576 | 576 | 602 | 676 | 746 | 740 | 780 | 822 | 870 | 976 | 986 | 3125240 |
| 22 | Rotor lamtnation | Ro.la | 505.6 | 293.6 | 293.6 | 306.6 | 343.6 | 378.6 | 375.6 | 395.6 | 416.6 | 440.6 | 493.6 | 498.6 | 3092120 |
| 23 | Winding specf | Wi.Sp | 473.2 | 274.2 | 275.2 | 284.2 | 299.2 | 336.2 | 342.2 | 399.2 | 429.2 | 453.2 | 458.2 | 459.2 | 4827840 |
| 24 | Frame | Fr. | 1719.6 | 1073.6 | 1095.6 | 1129.6 | 1190.6 | 1290.6 | 1298.6 | 1378.6 | 1476.6 | 1559.6 | 1612.6 | 1653.6 | 336345 |
| 25 | Connctor | Con. | 1008 | 610 | 612 | 630 | 660 | 734 | 746 | 860 | 920 | 968 | 978 | 980 | 332475 |
| 26 | Slcore Assy | SL.ASS | 941 | 543 | 545 | 563 | 593 | 667 | 679 | 793 | 853 | 901 | 911 | 913 | 225507.8 |
| 27 | Lead wire | Le.wi | 1687.6 | 1041.6 | 1063.6 | 1097.6 | 1158.6 | 1258.6 | 1266.6 | 1346.6 | 1444.6 | 1527.6 | 1580.6 | 1621.6 | 2201570 |
| 28 | Statur lamination | St.la | 473.3 | 274.3 | 275.3 | 284.3 | 299.3 | 336.3 | 342.3 | 399.3 | 429.3 | 453.3 | 458.3 | 459.3 | 5541150 |
| 29 | Inis matl Assy | In.Ass. | 483.1 | 284.1 | 285.1 | 294.1 | 309.1 | 346.1 | 352.1 | 409.1 | 439.1 | 463.1 | 468.1 | 469.1 | 15610365 |
| 30 | Nut | N. | 1717.6 | 1071.6 | 1093.6 | 1127.6 | 1188.6 | 1288.6 | 1296.6 | 1376.6 | 1474.6 | 1557.6 | 1610.6 | 1651.6 | 15152745 |
| 31 | SCR | SC. | 3360.2 | 2068.2 | 2112.2 | 2180.2 | 2302.2 | 2502.2 | 2518.2 | 2678.2 | 2874.2 | 3040.2 | 3146.2 | 3228.2 | 4169294 |
| 32 | Cleant | Cl. | 1697.8 | 1051.8 | 1073.8 | 1107.8 | 1168.8 | 1268.8 | 1276.8 | 1356.8 | 1454.8 | 1537.8 | 1590.8 | 1631.8 | 4096670 |
| 33 | Lamination | La. | 944 | 546 | 548 | 566 | 596 | 670 | 682 | 796 | 856 | 904 | 914 | 916 | 4406025 |
| 34 | Wedge | We. | 943.6 | 545.6 | 547.6 | 565.6 | 595.6 | 669.6 | 681.6 | 795.6 | 855.6 | 903.6 | 913.6 | 915.6 | 4406025 |
| 35 | Insulator | In | 940 | 542 | 544 | 562 | 592 | 666 | 678 | 792 | 852 | 900 | 910 | 912 | 9533562 |
| | total | | 47085.6 | 29649.6 | 30289.6 | 31189.6 | 32692.6 | 34386.6 | 34654.6 | 36928.6 | 39662.6 | 41925.6 | 43048.6 | 44199.6 | 100329611.8 |

It is possible to note the difference between the reality of the state of the researched company (before) and (.after), which refers to planning needs after applying an algorithm. As in the proposed mathematical model and its most crucial constraint, the produced quantities cover the demand for the final product while maintaining a safety stock at a certain percentage. It is not feasible to produce large quantities that exceed demand, and safety stocks lead to additional production costs and storage costs for each of the final products and their parts, which raises the cost of one unit. The difference in production quantities (before and after) can be seen in the first part, for example. The company used to produce (1856) units, while the demand for this part (which is derived from the demand for the final product) and after applying the algorithm based on the (MRP) system, the quantities required for production, which contain safety stocks within its planning, became 1544 units, and this is reflected on Production costs directly, as the difference in the total costs of the first part (before and after) the application of the system can be seen decreased from (129582598) Cost before applying the system to (100329611.8)

### 1.3. Storage costs for raw materials

The difference between the reality of the researched company and the application of the proposed system concerning storage and costs for raw materials is in Table 4.

Table 4. Storage costs for raw materials

| | Warehousing and storage costs | | | | | | | | | | | | Costs for each part according to the planning periods |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| part number | planning periods | | | | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| 1. Before | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 52380.9 |
| 1 after. | 100 | 150 | 200 | 249 | 288 | 338 | 380 | 430 | 476 | 526 | 575 | 617 | 73800 |
| 2. | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 52053.6 |
| | 100 | 142 | 186 | 236 | 286 | 336 | 372 | 422 | 463 | 513 | 563 | 613 | 207241.2 |
| 3. | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 1857 | 111748.8 |
| | 372 | 463 | 565 | 751 | 886 | 985 | 1072 | 1152 | 1245 | 1425 | 1504 | 1596 | 18300 |
| 4. | 610 | 610 | 610 | 610 | 610 | 610 | 610 | 610 | 610 | 610 | 610 | 610 | 13400 |
| | 121 | 182 | 242 | 303 | 364 | 425 | 472 | 533 | 594 | 655 | 704 | 765 | 85344 |
| 5. | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 55219.6 |
| | 90 | 146 | 191 | 247 | 285 | 332 | 388 | 436 | 492 | 541 | 572 | 628 | 80640 |
| 6. | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 560 | 500 | 56148 |
| | 103 | 159 | 200 | 254 | 309 | 365 | 421 | 468 | 523 | 579 | 621 | 677 | 99792 |
| 7. | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 630 | 65036.4 |
| | 115 | 178 | 223 | 277 | 309 | 372 | 420 | 483 | 543 | 606 | 669 | 732 | 93600 |
| 8. | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 62829 |
| | 120 | 180 | 225 | 285 | 322 | 354 | 414 | 467 | 527 | 587 | 647 | 705 | 17952 |
| 9. | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 13464 |
| | 34 | 51 | 68 | 85 | 102 | 119 | 136 | 153 | 170 | 187 | 204 | 221 | 77760 |
| 10. | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 56376 |
| | 80 | 120 | 160 | 200 | 234 | 264 | 304 | 344 | 384 | 424 | 464 | 502 | 175500 |
| 11. | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 750 | 111442.5 |
| | 132 | 205 | 274 | 348 | 398 | 473 | 538 | 571 | 601 | 650 | 725 | 800 | 11812.8 |
| 12. | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 9108 |
| | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 | 143 | 9996 |
| 13. | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 7938 |
| | 18 | 27 | 36 | 45 | 54 | 63 | 72 | 81 | 90 | 99 | 108 | 117 | 6772.8 |
| 14. | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 5229 |
| | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 8911.2 |
| 15. | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 94 | 7110 |
| | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 8436 |
| 16. | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 6840 |
| | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 | 88 | 96 | 104 | 11750.4 |
| 17. | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 68 | 9072 |
| | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 111556.8 |
| 18. | 732 | 732 | 732 | 732 | 732 | 732 | 732 | 732 | 732 | 732 | 732 | 732 | 65036.7 |
| | 139 | 196 | 252 | 291 | 330 | 404 | 442 | 486 | 554 | 618 | 672 | 737 | 32359.2 |
| 19. | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 24444 |
| | 56 | 84 | 112 | 140 | 168 | 196 | 224 | 252 | 280 | 308 | 336 | 364 | 23737.2 |
| 20. | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 131 | 19026 |
| | 28 | 42 | 56 | 70 | 84 | 98 | 112 | 126 | 140 | 154 | 168 | 182 | 13200 |
| 21. | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 10296 |
| | 26 | 39 | 52 | 65 | 78 | 91 | 104 | 117 | 130 | 143 | 156 | 169 | 21715.2 |
| 22. | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 232 | 16848 |
| | 48 | 72 | 96 | 120 | 144 | 168 | 192 | 216 | 240 | 264 | 288 | 312 | 44416.8 |
| 23. | 398 | 398 | 398 | 398 | 398 | 398 | 398 | 398 | 398 | 398 | 398 | 398 | 31899 |
| | 80 | 120 | 146 | 186 | 225 | 265 | 305 | 345 | 381 | 421 | 458 | 498 | 10560 |
| 24. | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 7920 |
| | 22 | 33 | 44 | 55 | 66 | 77 | 88 | 99 | 110 | 121 | 132 | 143 | 31506 |
| 25. | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 295 | 24030 |
| | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 390 | 13827.6 |
| 26. | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 69 | 10521 |
| | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 0 |
| 27. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71931.6 |
| 28. | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 377 | 54378 |
| | 76 | 114 | 152 | 190 | 228 | 266 | 304 | 342 | 380 | 418 | 456 | 494 | 36115.2 |
| 29. | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 152 | 28512 |
| | 32 | 48 | 64 | 80 | 96 | 112 | 128 | 144 | 160 | 176 | 192 | 208 | 39156 |
| 30. | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 29367 |
| | 26 | 39 | 52 | 65 | 78 | 91 | 104 | 117 | 130 | 143 | 156 | 169 | 10936.8 |
| 31. | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 93 | 8820 |
| | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 6679.2 |
| 32. | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 46 | 5445 |
| | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 65552.4 |
| 33. | 393 | 393 | 393 | 393 | 393 | 393 | 393 | 393 | 393 | 393 | 393 | 393 | 49275.5 |
| | 80 | 120 | 160 | 200 | 235 | 275 | 315 | 352 | 392 | 432 | 472 | 512 | 42240 |
| 34. | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 30272 |
| | 80 | 110 | 145 | 185 | 225 | 265 | 305 | 345 | 385 | 425 | 465 | 505 | 9360 |
| 35. | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 7560 |
| | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 5000 |
| | | | | | | | | | | | | | 47929.1 |
| | | | | | | | | | | | | | 13024.8 |

The above table shows the difference between material storage and associated costs between (1. before) and (1. after) applying the system to the proposed mathematical model and using the genetic algorithm. In the first part, for example, (500) refers to the quantity that is kept as regular storage for the first week and at a constant pace for all weeks, and this leads to accumulation in storage (demand is not constant), which in turn negatively affects the increase in storage costs. But after applying the mathematical model based on the (MRP) system, the storage was planned and controlled according to the demand for parts (derived from the demand for the final product), which significantly contributed to saving the storage of raw materials. This refers (100) to the quantity kept as regular storage for the first week and varies from week to week according to the change in demand. As a result of reducing the stock of materials, the associated costs will decrease. The difference can be seen in the total costs of stocking raw materials and semi-manufactured parts due to the reality of the researched company, estimated at (47929.1). Iraqi dinars for storing materials and parts for all weeks, according to the planning periods determined by the company. After applying the proposed system, the total storage costs were calculated, and it was (13024.8) Iraqi dinars, which is the most critical indicator of success in improving the performance of the supply chain, In addition to improving the cost.

## 4. Conclusions

- The mathematical model focused on a criterion no less important than the other criteria, which is reducing manufacturing costs and delivering on time, as the system followed by the company is not based on the principle. Group technology in parts manufacturing needs to consider the storage and surplus production that causes a waste of time and an increase in cost. The work is not divided into parts according to groups according to the principle of similarity in engineering design or manufacturing characteristics.
- The cost is considered an actual sacrifice, and organizations work to reduce that sacrifice to maximize profits. To compete based on cost, the supply chain must be managed through attention to materials, damage, and costs to design a system that works to reduce the cost of one unit of the product.
- In improving the performance of the supply chain in industrial companies. It provides a generally suitable environment to develop its performance by integrating manufacturing processes and systems.
- Integrating the use of (MRP) and group scheduling provides an effective system for controlling production.
- To enable the organization to meet the requirements of delivery on time. The difficulty that can be faced lies in assembling the requirements for the family of the part, as it is a somewhat complex and multi-dimensional task. The reason for this is that looking for the needs of a single part will turn into the needs of (the family of the part), that is, many of the similar components. That is, all the requirements of the part family must be selected together. The cost of preparation for the requirements depends on the number of different components in the part family and the proposed scheduled sequence of the resulting batch.

### Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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### References

[1] D. Barnes, *Operations Management: An International Perspective*, 1st ed. London, England: Red Globe Press, 2020.

[2] Y. Liu and Y. Yang, “A probabilistic linguistic opinion dynamics method based on the DeGroot model for emergency decision-making in response to COVID-19,” *Comput. Ind. Eng.*, vol. 173, no. 108677, p. 108677, 2022.

[3] F. Jacobs and R. Chase, “Operations and supply chain management”,” *15TH ED., McGraw-Hill Education, New York,* 2018.

[4] J. &. 4- Heizer, &. Barry, and C. Munson, *Operations Management Sustainability and Supply Chain Management*. Pearson Education, USA, 2017.

[5] A. Brandon-Jones, *Operations and Management", Principles and Practice for Strategic Impact, 5TH ED*. Slovakia: Pearson Education Limited, 2018.

[6] L. V. Lerman, G. B. Benitez, J. M. Müller, P. R. de Sousa, and A. G. Frank, "Smart green supply chain management: a configurational approach to enhance green performance through digital transformation," *Supply Chain Manage.: Int. J.*, vol. 27, no. 7, pp. 147–176, 2022.

[7] K. Salçuk and C. Şahin, "A novel multi-objective optimization model for sustainable supply chain network design problem in closed-loop supply chains," *Neural Comput. Appl.*, vol. 34, no. 24, pp. 22157–22175, 2022.

[8] T. Allehashemi, S. Hassanzadeh Amin, and S. Zolfaghari, "A proposed multi-objective model for cellphone closed-loop supply chain optimization based on fuzzy QFD," *Expert Systems with Applications*, vol. 210, 2022.

[9] N. Y. A. Alrda, B. A. Khalaf, and H. W. A. Alrahman, "The role of the flexibility of processes in measurement the relation between the supply chain & development of a product Applied research: Al Doawra refinery," *Period. Eng. Nat. Sci. (PEN)*, vol. 8, no. 4, pp. 2274–2289, 2020.

[10] M. A. M. Salih, A. H. Mahmoud, and B. A. Khalaf, "The application of six sigma - supported expert system in construction projects," *IOP Conf. Series: Materials Science and Engineering*, vol. 881, 2020.

[11] X. Chen, W. Zhang, X. Xu, and W. Cao, "Managing group confidence and consensus in intuitionistic fuzzy large group decision-making based on social media data mining," *Group Decis. Negot.*, vol. 31, no. 5, pp. 995–1023, 2022.

[12] K. Atanassov, "Type-1 fuzzy sets and intuitionistic fuzzy sets," *Algorithms*, vol. 10, no. 3, p. 106, 2017.

[13] R. D. Sharma, M. Raut, B. E. Hajiaghaei-Keshteli, R. Narkhede, and P. Gokhale, "Mediating effect of industry 4.0 technologies on the supply chain management practices and supply chain performance," *Journal of Environmental Management*, vol. 322, 2022.

[14] M. S. Bhatia, R. K. Srivastava, S. Kumar Jakhar, and S. Kumar, "What's critical for closed-loop supply chain operations? - Findings from the Indian small and medium manufacturing enterprises," *Journal of Cleaner Production*, vol. 372, 2022.

[15] A. Kumar and G. Dixit, "A novel hybrid MCDM framework for WEEE recycling partner evaluation on the basis of green competencies," *Journal of Cleaner Production*, 2019.

[16] W. S. Khalaf, B. A. Khalaf, and N. O. Abid, "A plan for transportation and distribution the products based on multi-objective traveling salesman problem in fuzzy environmental," *Period. Eng. Nat. Sci. (PEN)*, vol. 9, no. 4, p. 5, 2021.

[17] B. A. Khalaf, W. S. Khalaf, and H. K. Mansor, "An integrated model for solving production planning and production capacity problems using an improved fuzzy model for multiple linear programming according to Angelov's method," *Period. Eng. Nat. Sci. (PEN)*, vol. 9, no. 3, p. 715, 2021.

[18] M. A. H. Ashour, A. A. Ahmed, and A. S. Ahmed, "Optimization algorithms for transportation problems with stochastic demand," *Period. Eng. Nat. Sci. (PEN)*, vol. 10, no. 3, p. 172, 2022.

[19] T. Harrer, O. M. Lehner, and C. Weber, "A multi-level understanding of trust development in contexts of blurred organizational boundaries: the case of crowdfunding," *Scand. J. Manag.*, vol. 39, no. 1, p. 101247, 2023.

[20] G. Qi, J. Li, B. Kang, and B. Yang, "The aggregation of Z-numbers based on overlap functions and grouping functions and its application on group decision-making," *Inf. Sci. (Ny)*, vol. 623, pp. 857–899, 2023.