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A multi-stages multi-objective assignment for facilities layout design

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ABSTRACT

Al-Ma'amun factory of the General Company for Food Products suffers from inefficient facilities layout of its production departments and warehouses of both types (warehouses of raw materials and warehouses of finished products), which causes a lot of waste of time, resources and effort in the process of transporting raw materials or even individuals, which is leads to an increase in the costs of handling materials and not providing the service in time. Therefore, this study came to solve the problem by constructing a mathematical model based on the method of multi-stage assignment to find the optimal assignment, since the management of the factory has many goals, it was necessary to use an efficient mathematical method which is goal programming. Therefore, a multi-stage multi-objectives assignment method is applied in two stages, the first of which includes the process of transporting raw materials from raw material warehouses to the production departments to carry out the manufacturing process within them, the second stage includes the transfer of finished products from the production department to the final production warehouses. After comparing the results of the proposed layout with the results of the current layout of the factory is achieved an optimum layout of the factory because of it reduced the total traveled distance by (%25) per day, it also reduced the overall time spent by (25.5%) and reduced the total volume of spent fuel by (30.7%) per day for the new layout.

Keywords: Layout Design, Assignment problem, Goal programming, Preemptive method

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1. Introduction

The industrial sector faces continuing and increasing the challenges make large effect on industrial organizations. So, it is essential that these organizations to seek for review the layout planning system to correct the course of the Organization's work. The re-layout of the factory considered one of the most important challenges facing the decision maker by choosing the appropriate alternative among a range of alternatives available. The method of the proposed layout is one of the most important methods used to locate the appropriate sections to ensure the achievement of several objectives, including the choice of the optimal path at the minimum time or distance or fuel consumption or all together, and the process of reaching appropriate decisions with the existence of these goals with the speed and accuracy required require A lot of time and effort by the decision maker or management, so it is necessary to use quantitative methods that deal with the multiple objectives of the company, so the use of a quantitative method as efficient as the goal programming (Goal Programming) helps in the process of allocating the warehouses of raw materials to the production departments in the multiplicity of objectives.

There are many literatures and researches about using multi-objective assignment method for the layout planning.

A multi-objective approach to the problem of the facility re-layout was used with two conflicting objectives, one of which is quantity, which represents the decision maker's desire to reduce the cost of material handling to a minimum, and the other qualitative, namely the desire to increase the proportion of convergence between the internal departments of the establishment, Try to reduce the distance as much as possible and choose the most effective arrangement to make the best use of available resources, it was concluded that the method is simple and can be used easily and quickly [1] .

Adiche and Aïder developed a meta-heuristic algorithm to solve the problem of multi-objective assignment for three or more objectives and compare it with the division algorithm. This algorithm was applied to an applied example of allocating buffers with three objectives [2]. Aiello *et al.* used a new Genetic Algorithms (GA) to solve the facility layout problem. A genetic algorithm proposed to solve the problem of the layout of the factory, taking into account the existence of four conflicting objectives which the decision maker in the factory wishes to reach. The results showing the effectiveness of the algorithm were obtained in achieving an optimal the layout of the factory internal with multiple objectives [3]. Mehlawata and Kumar used a multi-objective linear programming method to re-layout positions of the organization. The decision maker wanted to achieve several objectives, including the process of reducing the distances between the departments of the organization and reducing the total costs, where both objectives are achieved [4]. Matai *et al.* examined a multi-objective allocation problem to finding the optimal allocation that would reduce the total costs of the material handling process between the duty stations, taking into account the reduction of the overall time consumed after all posts are completed. It concluded that the method of goal programming achieved a satisfactory level of objectives selected [5]. Ighravwe and Oke used a bi-objective programming-based facility layout design problem is formulated. They minimize workforce costs and maximize efficiency improvement in a layout. They utilized fuzzy goal programming and big-bang big-crunch algorithm in generating a Pareto solution [6]. The assignment method is presented to determine how the electronic product goods of the Chinese company (W) are distributed efficiently on the sites, by locating the optimal location of the warehouses where the goods are stored, the forklift truck transfers the production from per-warehouses to the permanents. The company has set objectives that it wishes to achieve: increasing convergence to maintain the efficiency of the storage, reduce the distortion, spoilage of the products and their loss in the long term taking into account the reduction in the total operating time [7]. Arabzad *et al.* presented a mathematical model to solve the problem of the facilities layout sites of the Iranian steel production plant in order to design an integrated supply chain, the factory has two objectives, one try to reduce the total costs of the supply chain, reducing the costs of raw materials, transportation costs and plant construction costs, while the other goal involves reducing the overall damage rate. The model solved using the multi-objective integer linear programming method and the results showed that the proposed model could provide a promising outcome for the design of an efficient supply chain [8].

In this study, a multi-stage multi-objectives assignment method was carried out to the Al-Ma'mun factory/General Company for Food Products in two stages, the first of which includes the process of transporting raw materials from raw material warehouses to the production departments to implement the manufacturing process within them, the second stage includes the transfer of finished products from the production department to the final production warehouses as a result of a factory's need to re-layout its work stations.

2. Facility layout

The subject of the facility layout is one of the important topics that have aroused the interest of many because it is an effect on the performance of the company and achieve the flow of processes in the factories or even service companies, and achieve the profits at the level of the establishment. an important part in the design or re-layout of the facility because it determines the best layout of department ,individuals, machinery and flow method of materials and products during the production process, can also play a critical role in the success and profitability of any business or service facility ,where effective planning can reduce delays in material transfer, significantly reduce costs, and maintain flexibility and efficiency in the use of available space and personnel, which in turn improves the overall performance of the establishment. The facility layout can be defined as the arrangement of everything necessary to produce goods or provide services [9, 10].

2.1. Types of facility layout

There are many types of layout that the company can choose in accordance with its available capabilities and ability to develop the work. As the current research is applied in the industry, the focus is on the layout of the industrial establishments.
A number of researchers and writers have pointed out that there are four basic types of internal order [10]:

1. Product Layout.
2. Process Layout.
3. Hybrid layout
4. Fixed –Position Layout

3. Assignment problem

Assignment is a special case of transportation problems, which in turn is considered a special case of linear programming models. It deals with assignment problems in how to assign (n) elements or (jobs) to (n) other elements (machines, tasks ...etc.) for the purpose of reducing the total cost [11].
The assignment process generally focused on the assignment of certain resources to different destination centers, which may be aimed at minimizing distribution costs or maximizing profit.
The methods of solving the assignment problems are based on several basic assumptions [12]:

1. Suppose (m) of the persons (resources) each performs only one task (n) with different efficiency.
2. The model is constructed by assignment (i) resources to (j) tasks this requires time (t_{ij}) of time units or cost of (c_{ij}) to accomplish the task.
3. If the goal function is to reduce cost or time, the goal is to minimize the goal function, but if you make a profit during the completion of the task, the goal is to maximize the goal function.
4. The assignment model must be a square matrix (n × m), that is,(m = n) , ie, the assignment of one effort to one task only.
5. If (m < n) here a Dummy work or effort should be added based on the smallest or largest case between (m, n).

3.1. Formulation of the assignment model

The assignment model can be formulated using linear programming mathematically as follows [12, 11]:

Min or Max $Z = \sum_{j=1}^{n} \sum_{i=1}^{n} C_{ij} X_{ij}$ (1)

s.t

$\sum_{i=1}^{n} X_{ij} = 1$ $j=1,2,3,...,n$

$\sum_{j=1}^{n} X_{ij} = 1$ $i=1,2,3,\ldots,n$

$X_{ij} = 0$ or 1

Whereas:

C_{ij}: Variable coefficient j in goal function i

X_{ij}: Decision variables are on two types:

($X_{ij} = 1$) if effort i is assigned to task j.

($X_{ij} = 0$) if effort i is not assigned to task j.

4. Goal programming (GP)

Linear programming has treated problems with one goal only. But the decision maker does not always characterized by having only one goal, this section presents two algorithms for solving goal programming. Both methods are based on representing the multiple goals by a single objective function. In the weights method, a single objective function is formed as the weighted sum of the functions representing the goals of the problem. The preemptive method starts by prioritizing the goals in order of importance. The model is then optimized, using one goal at a time such that the optimum value of a higher-priority goal is never degraded by a lower-priority goal. On the basis of the above, it can be said that the goal programming is: A mathematical method that does not aim at maximizing or minimizing a particular goal, but attempts to achieve the values of the goals set in advance [12, 13].

4.1. Methods to solve goal programming

There are two methods to solve the goal programming problems are as follows:

4.1.1. Weighted goal programming

In some cases, all the objectives to be achieved are important for the decision maker's opinion. They are of equal importance. Therefore, it is very difficult to choose between them. Therefore, weight is used for each objective, and it is important from the point of view of the decision maker and Reduce the total number of unwanted deviations [13, 14].
Let us assume that the goal programming model contains (n) of the objectives
G_i: I = 1,2,..., n.
Therefore, the goal function of the weights method will be as follows:

$$\text{Min Z } = \mathrm{W}_1\ \mathrm{G}_1 + \ \mathrm{W}_2\ \mathrm{G}_2 + \cdots + \ \mathrm{W}_n\ \mathrm{G}_n \qquad (2)$$

Where W_i represents positive weights and represents the decision-maker's preferences, indicating the importance of each goal, the total weights must 1.

4.1.2. Preemptive goal programming

It is also called in some literature in the lexicographic method. In the preemptive method, the decision maker must rank the goals of the problem in order of importance. Sometimes the decision maker faces problems with multiple goals. In order to overcome these difficulties, priority is given to each goal. The objectives are arranged according to importance by the decision maker. The optimal solution is obtained by reducing the goal function. The general model for goal programming in a manner priorities can be expressed in the following mathematical model [13, 14]:

a- In case of dependence on the deviation variables, the mathematical model becomes as follows:

$$Minimize\ Z = \sum_{i=1}^{m} A_j(di^- + di^+) \quad i = 1,2,3, \dots.,m \qquad (3)$$

s.t

$$\sum_{j=1}^{n} C_j\, X_j - Si^+ + Si^- = gi \qquad j = 1,2,3, \dots.,n$$

$$\sum_{j=1}^{n} a_{ij}\, X_{ij} = \ b_i$$

$$S_i^+ , S_i^- , X_j \ \geq 0$$

As:
X_j: Decision variables.
C_j: variable coefficient in the goal constraint Xj.
a_{ij}: variable coefficient in model i.
n: Number of constraint.
m; Number of variables.
s_i^+: Positive deviation variable (above achievement) for goal i.
s_i^-: The negative deviation variable (under achievement) of goal i.
g_i: Goal value for constraint i.
C_j: Goal value for model i.

b- In the case of non-reliance on the deviation variables, the mathematical model becomes as follows:

$$Min\ or\ \max\ Z = \sum_{j=1}^{n} \sum_{i=1}^{m} C_{ij} X_{ij} \qquad i = 1,2,3,\dots,n \tag{4}$$

s.t

$$\sum_{j=1}^{n} a_{ij} X_{ij} = b_i$$

$$X_{ij} \geq 0$$

5. A real practical example

Al-Ma'mun factory has (5) production departments, which are fixed duty stations whose locations cannot be changed because they contain giant machines. The factory also contains (25) warehouses, (15) raw materials warehouses and (10) warehouses for the final product, noting that the current layout of the warehouses and department of the plant did not achieve convergence on the basis of the objectives of the decision maker so the company suffers from wasting a lot of time and cost and fuel during the process of transition between warehouses and departments of the plant under a set of objectives obtained As a result of field visits and interviews with the decision maker.

5.1. Formulations of a multi-stage multi objectives assignment

The assignment process was carried out in Al-Mamoun factory in two stages:
The first is to assign the raw materials warehouses to the production departments in the factory in order to reach layout that achieves many of the objectives according to their priorities at the first stage and these priorities are:

1. Goal (1): Assignment based on reduced the time spent (in minutes) to move between raw materials warehouses and the production departments with skilled labor in some of the departments and warehouses
2. Goal (2): Assignment based on the shortest possible distance between them.
3. Goal (3): Assignment based on reducing the volume of fuel consumption to move between them.

The second stage consists of the process to assigning the final products warehouses to the production departments, as a final stage of the assignment to reach layout that achieves many of the objectives according to their priorities at the second stage and these priorities are:

1. Goal (1): Assignment based on the shortest possible distance between the final products warehouses and the production departments.
2. Goal (2): Assignment based on reduced the time spent (in minutes) to move between them.
3. Goal (3): Assignment based on reducing the amount of fuel consumption to move between them.

5.2. The first stage of multi-objective assignment

The following tables represent the data collected from the planning and follow-up and the warehouses management departments in the Al-Ma'mun factory as shown in Tables 1, 2 and 3:

Table 1. The distance (in meters) between warehouses of raw materials and production departments

Production departments / Warehouses	Department of Chlorine production	Department of Liquid detergent production	Department of preparations production	Department of Soap production	Department of cleaning powders production
Warehouse 4	130	65	173	267	423
Warehouse 5	90	199	150	145	455
Warehouse 6	212	342	292	172	537
Warehouse 8	213	344	295	175	539
Warehouse 9	233	369	315	205	558
Warehouse 10	437	442	333	160	314
Warehouse 11	260	415	425	240	380
Warehouse 15	405	505	420	240	245
Warehouse 17	455	590	470	295	310
Warehouse 19	522	537	536	345	380
Warehouse 24	595	679	615	445	341
Warehouse 25	593	677	613	443	329
Warehouse 26	590	676	610	430	326
Warehouse 31	597	684	618	442	335
Warehouse 32	600	687	621	446	337

The time required to move between the warehouses of raw materials and the production departments in the factory with the presence of skilled labor in some warehouses and production departments (warehouse 6, warehouse 10, warehouse 15, soap production department, chlorine production department), this time is calculated by computing the time required for the crane to move from the raw material warehouses to the production departments, including the time required for the labor to load and unload as shown in Table 2:

Table 2. Time required (in minutes) to move between warehouses and departments with the presence of skilled labor in some warehouses and production departments

Production departments / Warehouses	Department of Chlorine production	Department of Liquid detergent production	Department of preparations production	Department of Soap production	Department of cleaning powders production
Warehouse 4	12	14	9	24	42
Warehouse 5	10	20	9	24	48
Warehouse 6	10	18	5	20	36
Warehouse 8	14	26	11	16	54
Warehouse 9	16	26	12	20	57
Warehouse 10	10	20	8	20	36
Warehouse 11	18	30	15	20	39
Warehouse 15	10	22	9	48	27

Warehouse 17	26	40	16	28	36
Warehouse 19	30	38	19	32	42
Warehouse 24	34	46	21	36	42
Warehouse 25	34	46	21	36	39
Warehouse 26	34	46	21	36	39
Warehouse 31	24	38	17	36	30
Warehouse 32	24	38	18	40	33

The volume of fuel consumption during the handling of raw materials between the warehouses of raw materials and the production departments as shown in Table 3:

Table 3. Volume of fuel consumed (per liter) to move from the stores of raw materials to the production departments

Production departments / Warehouses	Department of Chlorine production	Department of Liquid detergent production	Department of preparations production	Department of Soap production	Department of cleaning powders production
Warehouse 4	0.5	0.58	0.37	1	1.74
Warehouse 5	0.4	0.82	0.37	1	1.98
Warehouse 6	0.4	1.74	0.2	0.8	2.25
Warehouse 8	0.58	1.9	0.3	0.64	2.25
Warehouse 9	0.66	1.9	0.5	0.8	2.37
Warehouse 10	0.4	0.82	0.33	0.8	1.5
Warehouse 11	0.74	1.24	0.62	0.8	1.62
Warehouse 15	0.4	0.6	0.37	2	1.35
Warehouse 17	1.08	1.6	0.66	1.16	1.5
Warehouse 19	1.62	1.58	0.79	1.32	1.74
Warehouse 24	1.4	1.9	0.87	1.48	1.74
Warehouse 25	1.4	1.9	0.87	1.48	1.62
Warehouse 26	1.4	1.9	0.87	1.48	1.62
Warehouse 31	1	1.95	0.7	1.48	1.62
Warehouse 32	1	1.95	0.75	1.62	1.62

5.2.1. Evaluation of the current layout of the Al-Ma'mun factory for the first stage

After the calculations, the current linear distance between the warehouses of raw materials and the production department is 1361 meters/day. The time required to move between the warehouses of the raw materials and the production department and with skilled labour is 133 minutes/day. The volume of the consumed fuel 5.51 liter/day. For the current order and before the re-layout of the plant. The volume of fuel used to transport between the warehouses of raw materials and production departments is 5.51 liters/day for the current layout and before the re-layout of the Al-Ma'mun factory.

5.2.2. Building a mathematical model of the multi-objectives assignment problem for the first stage:

Before formulating the mathematical model, the decision maker must set priorities among a set of objectives that he aspires to achieve, therefore, the above three objectives can be reached and achieved by using the goal programming, and on this basis will be re layout the warehouses of raw materials and assignment them to productive departments.

Based on the available data, the multi-objective mathematical model of the research problem will be constructed according to equation (4) which consists of (3) objectives, (231) variables and (30) constrains as follows:

Goal (1): Assignment based on least distance between raw materials warehouses and the production departments with skilled labor in some of the departments and warehouses:

$$MinZ_1=12X_{11}+14X_{12}+9X_{13}+24X_{14}+42X_{15}+0X_{16}+0X_{17}+0X_{18}+0X_{19}+0X_{110}+0X_{111}+0X_{112}+0X_{113}+0X_{14}+0X_{115}+10X_{21}+20X_{22}+9X_{23}+24X_{24}+48X_{25}+0X_{26}+0X_{27}+0X_{28}+0X_{29}+0X_{210}+0X_{211}+0X_{212}+0X_{213}+0X_{214}+0X_{215}+10X_{31}+18X_3$$

$$_{2}+5X_{33}+20X_{34}+36X_{35}+0X_{36}+0X_{37}+0X_{38}+0X_{39}+0X_{310}+0X_{311}+0X_{312}+0X_{313}+0X_{314}+0X_{315}+14X_{41}+26X_{42}+11X_{43}+16X_{44}+54X_{45}+0X_{46}+0X_{47}+0X_{48}+0X_{49}+0X_{410}+0X_{411}+0X_{412}+0X_{413}+0X_{414}+0X_{415}+16X_{51}+26X_{52}+12X_{53}+20X_{54}+57X_{55}+0X_{56}+0X_{57}+0X_{58}+0X_{59}+0X_{510}+0X_{511}+0X_{512}+0X_{513}+0X_{514}+0X_{515}+10X_{61}+20X_{62}+8X_{63}+20X_{64}+36X_{65}+0X_{66}+0X_{67}+0X_{68}+0X_{69}+0X_{610}+0X_{611}+0X_{612}+0X_{613}+0X_{614}+0X_{615}+18X_{71}+30X_{72}+15X_{73}+20X_{74}+39X_{75}+0X_{76}+0X_{77}+0X_{78}+0X_{79}+0X7_{710}+0X_{711}+0X_{712}+0X_{713}+0X_{714}+0X_{715}+10X_{81}+22X_{82}+9X_{83}+48X_{84}+27X_{85}+0X_{86}+0X_{87}+0X_{88}+0X_{89}+0X_{810}+0X_{811}+0X_{812}+0X_{813}+0X_{81}+0X_{815}+26X_{91}+40X_{92}+16X_{93}+28X_{94}+36X_{95}+0X_{96}+0X_{97}+0X_{98}+0X_{99}+0X_{910}+0X_{911}+0X_{912}+0X_{913}+0X_{914}+0X_{915}+30X_{101}+38X_{102}+19X_{103}+32X_{104}+42X_{105}+0X_{106}+0X_{107}+0X_{108}+0X_{109}+0X_{1010}+0X_{1011}+0X_{1012}+0X_{1013}+0X_{1014}+0X_{1015}+34X_{111}+46X_{112}+21X_{113}+36X_{114}+42X_{115}+0X_{116}+0X_{117}+0X_{118}+0X_{119}+0X_{1110}+0X_{1111}+0X_{1112}+0X_{1113}+0X_{1114}+0X_{1115}+34X_{121}+46X_{122}+21X_{123}36X_{124}+39X_{125}+0X_{126}+0X_{127}+0X_{128}+0X_{129}+0X_{1210}+0X_{1211}+0X_{1212}+0X_{1213}+0X_{1214}+0X_{1215}+34X_{131}+46X_{132}+21X_{133}+36X_{134}+39X_{135}+0X_{136}+0X_{137}+0X_{138}+0X_{139}+0X_{1310}+0X_{1311}+0X_{1312}+0X_{1313}+0X_{1314}+0X_{1315}+24X_{141}+38X_{142}+17X_{143}+36X_{144}+30X_{145}+0X_{146}+0X_{147}+0X_{148}+0X_{149}+0X_{1410}+0X_{1411}+0X_{1412}+0X_{1413}+0X_{1414}+0X_{1415}+24X_{151}+38X_{152}+18X_{153}+40X_{154}+33X_{155}+0X_{156}+0X_{157}+0X_{158}+0X_{159}+0X_{1510}+0X_{151}+0X_{1512}+0X_{1513}+0X_{1514}+0X_{15150}$$

Goal (2): Assignment based on the shortest possible distance between them.

$$\mathrm{Min}Z_2= 130X_{11} + 65X_{12} + 173X_{13} +267 X_{14} +423X_{15} + 0X_{16} + 0X_{17} + 0X_{18} + 0X_{19}+ 0X_{110} + 0X_{111}+ 0X_{112} + 0X_{113} +0X_{114} + 0X_{115} + 90X_{21} + 199X_{22} + 150X_{23} + 145X_{24} + 455X_{25} + 0X_{26} + 0X_{27} + 0X_{28} + 0X_{29} + 0X_{210} + 0X_{211} + 0X_{212} + 0X_{213} + 0X_{214} + 0X_{215} + 212X_{31} +342X_{32} +292X_{33} +172X_{34} + 537X_{35} + 0X_{36} +0X_{37} + 0X_{38} +0X_{39} + 0X_{310} + 0X_{311} + 0X_{312} +0X_{313}+ 0X_{314} + 0X_{315} + 213X_{41} + 344X_{42} + 295X_{43} +175X_{44}+ 539X_{45}+ 0X_{46} + 0X_{47}+ 0X_{48} +0X_{49} + 0X_{410} + 0X_{411} + 0X_{412} + 0X_{413} +0X_{414} +0X_{415} + 233X_{51}+369 X_{52} +315 X_{53} +205 X_{54} + 558X_{55} +0 X_{56} +0 X_{57} + 0X_{58} + 0X_{59} + 0X_{510} + 0X_{511} + 0X_{512} + 0X_{513} + 0X_{514} +0X_{515} +437 X_{61} +442X_{62} + 333_{63} +160 X_{64} +314 X_{65} +0 X_{66} +0 X_{67} + 0X_{68} + 0X_{69} + 0X_{610} + 0X_{611} + 0X_{612} + 0X_{613} + 0X_{614} + 0X_{615} + 260X_{71} +415X_{72} + 425X_{73} + 240X_{74} + 380X_{75} + 0X_{76}+ 0X_{77} + 0X_{78} + 0X_{79} + 0X_{710} + 0X_{711} + 0X_{712} + 0X_{713} + 0X_{714}+ 0X_{715} + 405X_{81} + 505X_{82} + 420X_{83} + 240X_{84} + 245X_{85} + 0X_{86} + 0X_{87} + 0X_{88} + 0X_{89} + 0X_{810} + 0X_{811} + 0X_{812} + 0X_{813} + 0X_{814}+ 0X8_{15} +455X_{91} + 590X_{92} + 470X_{93} + 295X_{94} + 310X_{95} + 0X_{95} +0X_{97} + 0X_{98} + 0X_{99} + 0X_{910} + 0X_{911} + 0X_{912} + 0X_{913} + 0X_{914} + 0X_{915} +522X_{101} + 537X_{102} + 536X_{103} + 345X_{104} + 380X_{105} +0X_{106} + 0X_{107} + 0X_{108} + 0X_{109} + 0X_{1010} + 0X_{1011} + 0X_{1012} +0X_{1013} + 0X_{1014} + 0X_{1015} +595X_{111} + 679X_{112} + 615X_{113} +445X_{114} + 341X_{115} + 0X_{116} + 0X_{117} + 0X_{118} + 0X_{119} + 0X_{1110} + 0X_{1111} + 0X_{1112} + 0X_{1113} + 0X_{1114} + 0X_{1115} + 593X_{121} +677X_{122} +613X_{123} +443X_{124} + 329X_{125} + 0X_{126} + 0X_{127} + 0X_{128} + 0X_{129} + 0X_{1210} + 0X_{1211} + 0X_{1212} + 0X_{1213} + 0X_{1214} 0X_{1215} + 590X_{131} + 676X_{132} + 610X_{133}+ 430X_{134} + 326X_{135} +0X_{136} + 0X_{137} + 0X_{138} + 0X_{139} + 0X_{1310} + 0X_{1211} + 0X_{1312} + 0X_{1313} + 0X_{1314} + 0X_{1315} + 597X_{141} + 684X_{142} + 618X_{143} + 442X_{144} + 335X_{145} + 0X_{146} + 0X_{147} + 0X_{148} + 0X_{149} + 0X_{1410} +0X_{1411} + 0X_{1412} + 0X_{1413} + 0X_{1414} + 0X_{1415} + 600X_{151} + 687X_{152} + 621X_{153} + 446X_{154} + 337X_{155} + 0X_{156} + 0X_{157} + 0X_{158} + 0X_{159} + 0X_{1510} + 0X_{1511} + 0X_{1512} + 0X_{1513} + 0X_{1514} + 0X_{1515}$$

Goal (3): Assignment based on reducing the volume of fuel consumption to move between them

$$MinZ_3=0.5X_{11}+0.58X_{12}+0.37X_{13}+X_{14}+1.74X_{15}+0X_{16}+0X_{17}+0X_{18}+0X_{19}+0X_{110}+0X_{111}+0X_{112}+0X_{113}+0X1_{14}+0X_{115}+0.4X_{21}+0.82X_{22}+0.37X_{23}+X_{24}+1.98X_{25}+0X_{26}+0X_{27}+0X_{28}+0X_{29}+0X_{210}+0X_{211}+0X_{212}+0X_{213}+0X_{214}+0X_{215}+0.4X_{31}+1.47X_{32}+0.2X_{33}+0.8X_{34}+2.25X_{35}+0X_{36}+0X_{37}+0X_{38}+0X_{39}+0X_{310}+0X_{311}+0X_{312}+0X_{313}+0X_{314}+0X_{315}+0.58X_{41}+1.9X_{42}+0.3X_{43}+0.64X_{44}+2.25X_{45}+0X_{46}+0X_{47}+0X_{48}+0X_{49}+0X_{410}+0X_{411}+0X_{412}+0X_{413}+0X_{414}+0X_{415}+0.66X_{51}+1.9X_{52}+0.5X_{5}+0.8X_{54}+2.37X_{55}+0X_{56}+0X_{57}+0X_{58}+0X_{59}+0X_{510}+0X_{511}+0X_{512}+0X_{513}+0X_{514}+0X_{515}+0.4X_{61}+0.82X_{62}+0.33X_{63}+0.8X_{64}+1.5X_{65}+0X_{66}+0X_{67}+0X_{68}+0X_{69}+0X_{610}+0X_{611}+0X_{612}+0X_{613}+0X_{614}+0X_{615}+0.74X_{71}+1.24X_{72}+0.62X_{73}+0.8X_{74}+1.62X_{75}+0X_{76}+0X_{77}+0X_{78}+0X_{79}+0X_{710}+0X_{711}+0X_{712}+0X_{713}+0X_{714}+0X_{715}+0.4X_{81}+0.6X_{82}+0.37X_{83}+2X_{84}+1.35X_{85}+0X_{86}+0X_{87}+0X_{88}+0X_{89}+0X_{810}+0X_{811}+0X_{812}+0X_{813}+0X_{814}+0X_{815}+1.08X_{91}+1.6X_{92}+0.66X_{93}+1.16X_{94}+1.5X_{95}+0X_{96}+0X_{97}+0X_{98}+0X_{99}+0X_{910}+0X_{911}+0X_{912}+0X_{913}+0X_{914}+0X_{915}+1.62X_{101}+1.58X_{102}$$

$$+0.79X_{103}+1.32X_{104}+1.74X_{105}+0X_{106}+0X_{107}+0X_{108}+0X_{109}+0X_{1010}+0X_{1011}+0X_{1012}+0X_{1013}+0X_{1014}+0X_{1015}+1.4X_{111}+1.9X_{112}+0.87X_{113}+1.48X_{114}+1.74X_{115}+0X_{116}+0X_{117}+0X_{118}+0X_{119}+0X_{1110}+0X_{1111}+0X_{1112}+0X_{1113}+0X_{1114}+0X_{1115}+1.4X_{121}+1.9X_{122}+0.87X_{123}+1.48X_{124}+1.62X_{125}+0X_{126}+0X_{127}+0X_{128}+0X_{129}+0X_{1210}+0X_{1211}+0X_{1212}+0X_{1213}+0X_{1214}+0X_{1215}+1.4X_{131}+1.9X_{132}+0.87X_{133}+1.48X_{134}+1.62X_{135}+0X_{136}+0X_{137}+0X_{138}+0X_{139}+0X_{1310}+0X_{131}+0X_{1312}+0X_{1313}+0X_{1314}+0X_{1315}+X_{141}+1.95X_{142}+0.7X_{143}+1.48X_{144}+1.62X_{145}+0X_{146}+0X_{147}+0X_{148}+0X_{149}+0X_{1410}+0X_{1411}+0X_{1412}+0X_{1413}+0X_{1414}+0X_{1415}+X_{151}+1.95X_{152}+0.75X_{153}+1.62X_{154}+1.62X_{155}+0X_{156}+0X_{157}+0X_{158}+0X_{159}+0X_{1510}+0X_{1511}+0X_{1512}+0X_{1513}+0X_{1514}+0X_{1515}$$

S.to.

$X_{11}+X_{12}+X_{13}+X_{14}+X_{15}+X_{16}+X_{17}+X_{18}+X_{19}+X_{110}+X_{111}+X_{112}+X_{113}+X_{114}+X_{115}=1$

$X_{21}+X_{22}+X_{23}+X_{24}+X_{25}+X_{26}+X_{27}+X_{28}+X_{29}+X_{210}+X_{211}+X_{212}+X_{213}+X_{214}+X_{215}=1$

$X_{31}+X_{32}+X_{33}+X_{34}+X_{35}+X_{36}+X_{37}+X_{38}+X_{39}+X_{310}+X_{311}+X_{212}+X_{313}+X_{314}+X_{315}=1$

$X_{41}+X_{42}+X_{43}+X_{44}+X_{45}+X_{46}+X_{47}+X_{48}+X_{49}+X_{410}+X_{411}+X_{412}+X_{413}+X_{414}+X_{415}=1$

$X_{51}+X_{52}+X_{53}+X_{54}+X_{55}+X_{56}+X_{57}+X_{58}+X_{59}+X_{510}+X_{511}+X_{512}+X_{513}+X_{514}+X_{515}=1$

$X_{61}+X_{62}+X_{63}+X_{64}+X_{65}+X_{66}+X_{67}+X_{68}+X_{69}+X_{610}+X_{611}+X_{612}+X_{613}+X_{614}+X_{615}=1$

$X_{71}+X_{72}+X_{73}+X_{74}+X_{75}+X_{76}+X_{77}+X_{78}+X_{79}+X_{710}+X_{711}+X_{712}+X_{713}+X_{714}+X_{715}=1$

$X_{81}+X_{82}+X_{83}+X_{84}+X_{85}+X_{86}+X_{87}+X_{88}+X_{89}+X_{810}+X_{811}+X_{812}+X_{813}+X_{814}+X_{815}=1$

$X_{91}+X_{92}+X_{93}+X_{94}+X_{55}+X_{96}+X_{97}+X_{98}+X_{99}+X_{910}+X_{911}+X_{912}+X_{913}+X_{914}+X_{915}=1$

$X_{101}+X_{102}+X_{103}+X_{104}+X_{105}+X_{106}+X_{107}+X_{108}+X_{109}+X_{1010}+X_{1011}+X_{1012}+X_{1013}+X_{1014}+X_{1015}=1$

$X_{111}+X_{112}+X_{113}+X_{114}+X_{115}+X_{116}+X_{117}+X_{118}+X_{119}+X_{1110}+X_{1111}+X_{1112}+X_{1113}+X_{1114}+X_{1115}=1$

$X_{121}+X_{122}+X_{123}+X_{124}+X_{125}+X_{126}+X_{127}+X_{128}+X_{129}+X_{1210}+X_{1211}+X_{1212}+X_{1213}+X_{1214}+X_{1215}=1$

$X_{131}+X_{132}+X_{133}+X_{134}+X_{135}+X_{136}+X_{137}+X_{138}+X_{139}+X_{1310}+X_{1311}+X_{1312}+X_{1313}+X_{1314}+X_{1315}=1$

$X_{141}+X_{142}+X_{143}+X_{144}+X_{145}+X_{146}+X_{147}+X_{148}+X_{149}+X_{1410}+X_{1411}+X_{1412}+X_{1413}+X_{1414}+X_{1415}=1$

$X_{151}+X_{152}+X_{153}+X_{154}+X_{155}+X_{156}+X_{157}+X_{158}+X_{159}+X_{1510}+X_{1511}+X_{1512}+X_{1513}+X_{1514}+X_{1515}=1$

$X_{11}+X_{21}+X_{31}+X_{41}+X_{51}+X_{61}+X_{71}+X_{81}+X_{91}+X_{101}+X_{111}+X_{121}+X_{311}+X_{141}+X_{151}=1$

$X_{12}+X_{22}+X_{32}+X_{42}+X_{52}+X_{62}+X_{72}+X_{82}+X_{92}+X_{102}+X_{112}+X_{122}+X_{312}+X_{142}+X_{152}=1$

$X_{13}+X_{23}+X_{33}+X_{43}+X_{53}+X_{63}+X_{73}+X_{83}+X_{93}+X_{103}+X_{113}+X_{123}+X_{313}+X_{143}+X_{153}=1$

$X_{14}+X_{24}+X_{34}+X_{44}+X_{54}+X_{64}+X_{74}+X_{84}+X_{94}+X_{104}+X_{114}+X_{124}+X_{134}+X_{144}+X_{154}=1$

$X_{15}+X_{25}+X_{35}+X_{45}+X_{55}+X_{65}+X_{75}+X_{85}+X_{95}+X_{105}+X_{115}+X_{125}+X_{315}+X_{145}+X_{155}=1$

$X_{16}+X_{26}+X_{36}+X_{46}+X_{56}+X_{66}+X_{76}+X_{86}+X_{96}+X_{106}+X_{116}+X_{126}+X_{316}+X_{146}+X_{156}=1$

$X_{17}+X_{27}+X_{37}+X_{47}+X_{57}+X_{67}+X_{77}+X_{87}+X_{97}+X_{107}+X_{117}+X_{127}+X_{317}+X_{147}+X_{157}=1$

$X_{18}+X_{28}+X_{38}+X_{48}+X_{58}+X_{68}+X_{78}+X_{88}+X_{98}+X_{108}+X_{118}+X_{128}+X_{318}+X_{148}+X_{158}=1$

$X_{19}+X_{29}+X_{39}+X_{49}+X_{59}+X_{69}+X_{79}+X_{89}+X_{99}+X_{109}+X_{119}+X_{129}+X_{319}+X_{149}+X_{159}=1$

$X_{110}+X_{210}+X_{310}+X_{410}+X_{510}+X_{610}+X_{710}+X_{810}+X_{910}+X_{1010}+X_{1110}+X_{1210}+X_{3110}+X_{1410}+X_{1510}=1$

$X_{111}+X_{211}+X_{311}+X_{411}+X_{511}+X_{611}+X_{711}+X_{811}+X_{911}+X_{1011}+X_{1111}+X_{1211}+X_{3111}+X_{1411}+X_{1511}=1$

$X_{112}+X_{212}+X_{312}+X_{412}+X_{512}+X_{612}+X_{712}+X_{812}+X_{912}+X_{1012}+X_{1112}+X_{1212}+X_{3112}+X_{1412}+X_{1512}=1$

$X_{113}+X_{213}+X_{313}+X_{413}+X_{513}+X_{613}+X_{713}+X_{813}+X_{913}+X_{1013}+X_{1113}+X_{1213}+X_{3113}+X_{1413}+X_{1513}=1$

$X_{114}+X_{214}+X_{314}+X_{414}+X_{514}+X_{614}+X_{714}+X_{814}+X_{914}+X_{1014}+X_{1114}+X_{1214}+X_{3114}+X_{1414}+X_{1514}=1$

$X_{115}+X_{215}+X_{315}+X_{415}+X_{515}+X_{615}+X_{715}+X_{815}+X_{915}+X_{1015}+X_{1115}+X_{1215}+X_{3115}+X_{1415}+X_{1515}=1$

X_{ij}= 0 or 1

5.2.3. Solving the mathematical model using the goal programming method

After the mathematical model was built for first stage of the assignment and model data was entered into the (WinQ.S.B.2) program, the results of the solution to the values of the objective functions and the basic variables were obtained (see Table 1 in Annex 1) as well as the results of the constraints of the mathematical model and as shown in Tables 4 and 5:

After the mathematical model was built for the first phase of the assignment, the mathematical model data were entered into the (Win.Q.S.B.2) and then solved it and obtained the results of the values of goal functions, the basic variables as well as the left hand side and right hand side constraints. The detailed results are shown in Tables 4 and 5:

Table 4. the values of goal functions in the first stage

Type of goal	Goals	Value
Reduce time	Min Goal (1)	72
Reduce the distance	Min Goal (2)	867
Reduce the volume of fuel consumption	Min Goal (3)	2.19

Table 5. Results of the optimal assignment in the first stage

Decision Variable	Solution Value
$X_{1,2}$	1
$X_{2,1}$	1
$X_{3,3}$	1
$X_{4,4}$	1
$X_{8,5}$	1

5.2.4. Discussion of the results of the first stage:

After the mathematical model data was entered into the (TORA), we obtained the value of the first objective function that can be achieved by the institution, which is 72 minutes/day and represents the total time spent to move between warehouses of raw materials and production departments with skilled labor In some warehouses (6),(10) and (15) and production departments (soap production department and chlorine production department), we note that some warehouses were selected and allocated to the production departments despite the length of distance between them compared to the distance between warehouses and other production departments and the reason that they contain skilled labour was able to complete the loading and unloading accurately and skill and speed, which led to the reduction of time which the institution wants to reach it. The value of second objective function is 867 meters /day, it represents the shortest total distance from the warehouses of raw materials to the production departments. While the third objective function which represents the desire of the institution to reduce the amount of fuel consumed during the transfer the crane from the warehouses of raw materials to the production departments where the objective value is 2.19 liters/day.

Accordingly, the assignment is based on the following:

- Assignment of the first warehouse (warehouse 4) to the second department (liquid detergent department).
- Assignment of the second warehouse (warehouse 5) to the first production department (chlorine production department).
- Assignment the third warehouse (warehouse 6) to the third department (production department of preparations).
- Assignment the fourth warehouse (warehouse 8) to the fourth production department (soap production department).
- Assignment the eighth warehouse (warehouse 15) to the fifth production department (detergents production department).

5.2.5. Comparison between the current layout of the Al-Ma'mun factory and the proposed new layout

After a change in the assignment of workplaces (warehouses), it was found that the time spent to move from the warehouses of raw material to the production departments of the new layout is equal to 72 minutes/day.

Since the time to handle the materials for the current layout is 133 (minutes/day) indicates that the new layout after the re-assignment process saves time of 61 minutes/day. As well as the distance between warehouses of raw materials and production departments was 1361 meters/day for the current layout. After the re-assignment process, it became 867 meters/day and this means reducing the distance between warehouses of raw materials and production departments by 494 meters/day.

The volume of fuel consumed during the process of handling materials from the warehouses of raw materials to the production departments of the new order is equal to 2.19 liters/day, while it was equal to 5.51 liters/day of the current layout, this indicates that the new layout has decreased in the volume of fuel consumed by 3.32 liters/day.

Also, a reduction in the distance between the warehouses of the raw materials and the productive department, the distance of the current layout before the re-assignment was 1361 meters/day. After the process of assignment become 867 meters/day, the distance between warehouses of raw materials and production department will be reduced by 494 meters/day.

5.3. The second stage of multi-objective assignment

The second stage consists of the process of assigning 10 warehouses of finished products to the production departments, as a final stage of the assignment. Tables 6-8 stand for the data which include distance, volume of fuel consumption and time spent between the production departments and the final production warehouses in the factory for the second stage.

Table 6. The distance (in meters) between the production departments and the final production warehouses

Warehouse # / Production departments	2	7	13	14	16	18	20	21	22A	22B
Department of Chlorine production	125	250	400	450	450	580	500	588	520	529
department of Liquid production	90	330	540	500	500	750	550	600	570	590
Department of preparations Production	210	300	500	550	550	650	600	530	620	640
Department of soap production	132	230	220	250	250	380	300	332	200	230
Department of cleaning powders production	425	850	225	235	235	400	220	255	260	212

Table 7. The total time spent (in minutes) to move between the production departments and the final production warehouses

Warehouse # / Production departments	2	7	13	14	16	18	20	21	22A	22B
Department of Chlorine production	36	44	56	64	64	88	76	88	80	88
department of Liquid production	40	60	105	95	95	150	115	120	115	120
Department of preparations Production	20	22	38	42	42	52	48	50	50	52
Department of soap production	90	100	100	120	120	130	120	130	90	100
Department of cleaning powders production	182	520	117	130	130	182	130	143	156	117

Table 8: The amount of fuel consumed (per liter) during the transfer of the finished product between the production departments and the final production warehouses

Warehouses / Production departments	2	7	13	14	16	18	20	21	22A	22B
Department of Chlorine production	1.5	1.83	2.33	2.66	2.66	3.66	3.166	3.66	3.33	3.66
department of Liquid production	1.66	2.5	4.37	3.95	3.95	6.25	6.66	5	4.79	5
Department of preparations Production	0.33	0.45	0.79	0.87	0.87	1.08	1	1.04	1.04	1.08
Department of soap production	3.75	4.16	4.16	5	5	5.41	5	5.41	3.75	4.16
Department of cleaning powders production	5.58	21.16	4.87	4.41	5.41	7.58	5.41	5.95	6.5	4.87

5.3.1. Evaluation of the current layout of the Al-Ma'mun factory for the second stage

After the calculations, the current linear distance between the production departments and the final production warehouses is 1400 meters/day. The time spent to move between the production departments and the final production warehouses is 416 minutes/day. The amount of fuel consumed to transport between the production departments and the final production warehouses is (42.76) (liters/day) for the current layout and before the re-layout of the Al-Ma'mun factory.

5.3.2. Building a mathematical model of the multi-objectives assignment problem for the second stage:

Before formulating the mathematical model, the decision maker must set priorities among a set of objectives that he aspires to achieve, therefore, the above three objectives and on this basis will be re-layout the final production warehouses and assignment them to productive departments. The multi-objective mathematical model of the research problem will be constructed according to equation (4) which consists of (3) objectives, (100) variables and (20) constrains as follows:

Goal (1): Assignment based on the shortest possible distance between the final products warehouses and the production departments

$MinZ_1=125X_{11}+250X_{12}+400X_{13}+450X_{14}+450X_{15}+580X_{16}+500X_{17}+588X_{18}+520X_{19}+529X_{110}+90X_{21}+330X_{22}+540X_{23}+500X_{24}+500X_{25}+750X_{26}+550X_{27}+600X_{28}+570X_{29}+590X_{210}+210X_{31}+300X_{32}+500X_{33}+550X_{34}+550X_{35}+650X_{36}+600X_{37}+530X_{38}+620X_{39}+640X_{310}+132X_{41}+230X_{42}+220X_{43}+250X_{44}+250X_{45}+380X_{46}+300X_{47}+332X_{48}+200X_{49}+230X_{410}+425X_{51}+850X_{52}+225X_{53}+235X_{54}+235X_{55}+400X_{56}+220X_{57}+255X_{58}+260X_{59}+212X_{510}+0X_{61}+0X_{62}+0X_{63}+...+0X_{1010}$

Goal (2): Assignment based on reduced the time spent (in minutes) to move between them

$MinZ_2=36X_{11}+44X_{12}+56X_{13}+64X_{14}+64X_{15}+88X_{16}+76X_{17}+88X_{18}+80X_{19}+88X_{110}+40X_{21}+60X_{22}+105X_{23}+95X_{24}+95X_{25}+150X_{26}+115X_{27}+120X_{28}+115X_{29}+120X_{210}+20X_{31}+22X_{32}+38X_{33}+42X_{34}+42X_{35}+52X_{36}+48X_{37}+50X_{38}+50X_{39}+52X_{310}+90X_{41}+100X_{42}+100X_{43}+120X_{44}+120X_{45}+130X_{46}+120X_{47}+130X_{48}+90X_{49}+100X_{410}+182X_{51}+520X_{52}+117X_{53}+130X_{54}+130X_{55}+182X_{56}+130X_{57}+143X_{58}+156X_{59}+117X_{510}+0X_{61}+0X_{62}+0X_{63}+...+0X_{1010}$

Goal (3): Assignment based on reducing the amount of fuel consumption to move between them

$MinZ_3=1.5X_{11}+1.83X_{12}+2.33X_{13}+2.66X_{14}+2.66X_{15}+3.66X_{16}+3.16X_{17}+3.66X_{18}+3.3X_{19}+3.66X_{110}+1.66X_{21}+2.5X_{22}+4.37X_{23}+3.95X_{24}+3.95X_{25}+6.25X_{26}+6.66X_{27}+5X_{28}+4.79X_{29}+5X_{210}+0.33X_{31}+0.45X_{32}+0.75X_{33}+0.87X_{34}+0.87X_{35}+1.08X_{36}+X_{37}+1.04X_{38}+1.04X_{39}+1.08X_{310}+3.75X_{41}+4.16X_{42}+4.16X_{43}+5X_{44}+5X_{45}+5.41X_{46}+5X_{47}+5.4$

$1X_{48}+3.75X_{49}+4.16X_{410}+5.58X_{51}+21.6X_{52}+4.87X_{53}+5.41X_{54}+4.41X_{55}+7.58X_{56}+5.41X_{57}+5.95X_{58}+65X_{59}+4.87X_{510}+0X_{61}+0X_{62}+0X_{63}+... +0X_{1010}$

S.to.

$X_{11}+X_{12}+X_{13}+X_{14}+X_{15}+X_{16}+X_{17}+X_{18}+X_{19}+X_{110} =1$
$X_{21}+X_{22}+X_{23}+X_{24}+X_{25}+X_{26}+X_{27}+X_{28}+X_{29}+X_{210} =1$
$X_{31}+X_{32}+X_{33}+X_{34}+X_{35}+X_{36}+X_{37}+X_{38}+X_{39}+X_{310} =1$
$X_{41}+X_{42}+X_{43}+X_{44}+X_{45}+X_{46}+X_{47}+X_{48}+X_{49}+X_{410} =1$
$X_{51}+X_{52}+X_{53}+X_{54}+X_{55}+X_{56}+X_{57}+X_{58}+X_{59}+X_{510} =1$
$X_{61}+X_{62}+X_{63}+X_{64}+X_{65}+X_{66}+X_{67}+X_{68}+X_{69}+X_{610} =1$
$X_{71}+X_{72}+X_{73}+X_{74}+X_{75}+X_{76}+X_{77}+X_{78}+X_{79}+X_{710} =1$
$X_{81}+X_{82}+X_{83}+X_{84}+X_{85}+X_{86}+X_{87}+X_{88}+X_{89}+X_{810} =1$
$X_{91}+X_{92}+X_{93}+X_{94}+X_{55}+X_{96}+X_{97}+X_{98}+X_{99}+X_{910} =1$
$X_{101}+X_{102}+X_{103}+X_{104}+X_{105}+X_{106}+X_{107}+X_{108}+X_{109}+X_{1010} =1$
$X_{11}+X_{21}+X_{31}+X_{41}+X_{51}+X_{61}+X_{71}+X_{81}+X_{91}+X_{101} =1$
$X_{12}+X_{22}+X_{32}+X_{42}+X_{52}+X_{62}+X_{72}+X_{82}+X_{92}+X_{102} =1$
$X_{13}+X_{23}+X_{33}+X_{43}+X_{53}+X_{63}+X_{73}+X_{83}+X_{93}+X_{103} =1$
$X_{14}+X_{24}+X_{34}+X_{44}+X_{54}+X_{64}+X_{74}+X_{84}+X_{94}+X_{104} =1$
$X_{15}+X_{25}+X_{35}+X_{45}+X_{55}+X_{65}+X_{75}+X_{85}+X_{95}+X_{105} =1$
$X_{16}+X_{26}+X_{36}+X_{46}+X_{56}+X_{66}+X_{76}+X_{86}+X_{96}+X_{106} =1$
$X_{17}+X_{27}+X_{37}+X_{47}+X_{57}+X_{67}+X_{77}+X_{87}+X_{97}+X_{107} =1$
$X_{18}+X_{28}+X_{38}+X_{48}+X_{58}+X_{68}+X_{78}+X_{88}+X_{98}+X_{108}+ =1$
$X_{19}+X_{29}+X_{39}+X_{49}+X_{59}+X_{69}+X_{79}+X_{89}+X_{99}+X_{109} =1$
$X_{110}+X_{210}+X_{310}+X_{410}+X_{510}+X_{610}+X_{710}+X_{810}+X_{910}+X_{1010} =1$
$X_{ij}= 0 \text{ or } 1$

5.3.3. Solving the mathematical model using the goal programming method

After the mathematical model was built for second stage of the assignment and model data was entered into the (TORA) program, the results of the solution to the values of the objective functions and the basic variables were obtained as well as the results of the constraints of the mathematical model and as shown in Tables (9 and 10):

Table 9: The values of goal functions in the second stage

Type of goal	Goals	Value
Reduce the distance	Min Goal (1)	1202.00
Reduce the time	Min Goal (2)	325.00
Reduce the amount of fuel	Min Goal (3)	13.06

Table 10: Results of the optimal assignment in the second stage

Decision Variable	Solution Value
$X_{1,3}$	1
$X_{2,1}$	1
$X_{3,2}$	1
$X_{4,9}$	1
$X_{5,10}$	1

5.3.4. Discussion of the results of the second stage:

After the mathematical model data was entered into the (TORA), we obtained the value of the first objective function that can be achieved by the institution, which is value of first objective function is 1202 meters /day and represents the shortest total distance from the production departments to the final production warehouses. The second objective function which is 325 minutes/day. It represents the total time spent to move between production departments to the final production warehouses. While the third objective function which represents the desire of the institution to reduce the amount of fuel consumed during the transfer the crane from the production departments to the final production warehouses where the objective value is 13.06 liters/day.

So, the assignment is based on the following:

- Assignment of the third warehouse (warehouse 13) to the first department (Chlorine production department).
- Assignment of the first warehouse (warehouse 2) to the second production department (liquid detergent production department).
- Assignment the second warehouse (warehouse 7) to the third department (preparations production department).
- Assignment the ninth warehouse (warehouse 22A) to the fourth production department (soap production department).
- Assignment the tenth warehouse (warehouse 22B) to the fifth production department (cleaning powder production department).

5.3.5. Comparison between the current layout of the Al-Ma'mun factory and the proposed new layout in the second stage

After a change in assignment of workplaces (warehouses), it was found that the distance between production departments to the final production warehouses is 1400 meters/day for the current layout then after re-assignment process, it became 1202 meters/day and this means reducing the distance by 198 meters/day. The time spent for the current layout to move from production departments to the final production warehouses is 416 minutes/day. After the re-assignment process, it became 325 minutes/day and this means reducing the distance by 91 meters/day. An amount of fuel consumed to handle materials between them of the new layout is 13.06 liter/day, while it was equal to 16.85 liters /day of the current layout, this indicates that the new layout has decreased in amount of fuel consumed by 3.79 liters /day.

6. Conclusions

1. The inefficiency of the current layout results in wasting a lot of time and effort for the cranes and for the labourers who are handling the materials, which leads to the deterioration of the production process.
2. Using the multi-objective assignment model in the process of designing the layout of the Al-Ma'amun factory, it helps the decision-maker in the process of selecting the best sites with the multiple objectives.
3. Assignment models deal with large numbers and types of the problems with high efficiency, giving accurate results.
4. The Al-Ma'amoon factory does not depend on scientific and mathematical methods such as assignment models, rather it depends on personal experience and some simple mathematical methods.
5. After the comparison between the current layout of the plant and the proposed layout obtained from the application of the multi-objective assignment method for two stages, the proposed layout showed that Al-Ma'amoon factory reduced the distance of (692) (meters/day) from the linear distance between the raw materials warehouses and the production departments for the first stage. The total linear distance of the two stages to the current layout was (2761) (meters/day), as for the proposed layout the total linear distance (2069) (meters/day). Reduction of spent time was achieved by (152) (minutes/day) for the two stages, as the spent time of the two stages of the current layout is (549) (minutes/day), the spent time for the two stages of the proposed layout became (397) (minutes/day). Finally, a reduction of (6.77)

(liters/day) was achieved from the amount of fuel consumed for the two stages. The total fuel volume for the current layout of the two stages was (22.02) (liters/day), while the total fuel volume for the proposed internal order was (15.25) (liters/day).

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