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SOLVING 4D TRANSPORTATION PROBLEM USING THE PARTICLE SWARM OPTIMIZATION ALGORITHM

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Abstract: This research deals with the problem of four-dimensional transportation in the General Company for Food Stuff Trading because of its great role in managing the transportation process. The transportation problem of the four-dimensional of the different demand centers, the different supply centers, the distribution line, and the various means of transportation was solved using the particle swarm optimization algorithm using the coding formula via the MATLAB program. The goal of choosing a particle swarm optimization algorithm is computationally inexpensive, in addition, it is an effective method for many optimization problems and to find the best solution among a huge number of possible solutions.

Key words: 4D transportation; particle swarm optimization.

2010 AMS Subject Classification: 90C08, 90B06, 68T20.

1. INTRODUCTION

Operations research has achieved great success as it is one of the most important applied sciences in the military and civil fields, as it aims to help decision makers in choosing the right decision,

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and is used in for solving and addressing transportation, production, warehousing and allocation problems in order to reach the optimal decision represented by the greatest profits, least costs and least times [13].

The transportation problem is one of the most important problems that studies all matters related to the transportation of goods, raw materials, people...etc., from their locations to the requesting parties. This process increases transportation costs, so it requires building a mathematical model that reduces transportation costs using special optimal solutions methods. The classical transportation model, called (homogeneous) model, considers only one mode of transportation and homogeneous commodity [8].

In real life, either the transportation process requires a planning study to transfer a group of non-homogeneous products from supply sources to demand stations at variable costs, or the means of transportation are heterogeneous, which may be land, sea or air, and this has increased the complexity of the mathematical model of the transportation problem. The three-dimensional model indicates that the mode of transportation is different or the type of goods transported is different [1].

Usually, road distances between sources and requesting parties are not taken into account in transportation problems, but in reality routes vary between sources and requesting parties, transportation costs per unit and fixed fees are no longer the same. Some paths may be smooth and in good condition while others may be uneven, not all types of vehicles may travel along each path. Therefore, the choice of roads plays a major role in the transportation problem, and therefore if the different paths are considered along with the different means of transportation, the three-dimensional transportation problem is transformed into a four-dimensional transportation problem [4]. There are several criteria for making the best decision to adopt an efficient transportation model that is known for finding realistic solutions to a transportation problem that contains various different resources or requirements to multiple places requesting these requirements by different means of transportation to achieve a number of goals, for example, cost and time ... etc, [2].

The paper is organised as follows: In section 2, a mathematical formulation of the four-dimensional transportation problem will be presented. Section 3 gives a brief description of the Particle Swarm optimization metaheuristic. In section 4 a real case problem will be solved by the PSO metaheuristic. Section 5 concludes the paper and gives some perspectives.

2. Sports Model of the Four-Dimensional Transportation Problem

The formula of the mathematical model is as follows: [Anderson et al. ,1997; Bakhayt, 2016; Bera, et al. 2018, Halder Jana et al. 2019, Sahoo et al. 2020]

$$Min \quad Z = \sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{p}\sum_{q=1}^{d} C_{i,j,k,q} * X_{i,j,k,q} \qquad \ldots\ldots(1-1)$$

As for the restrictions, they include the registration of the various means of transport and the registration of the various supply and demand centers, in addition to the transport of various materials.

$S.t$:

$$\sum_{q=1}^{d}\sum_{j=1}^{n}\sum_{k=1}^{p} X_{i,j,k,q} = a(i) \qquad \forall\ i = 1, \ldots, m \qquad \ldots\ldots(1-2)$$

$$\sum_{i=1}^{m}\sum_{k=1}^{p}\sum_{q=1}^{d} X_{i,j,k,q} = b(j) \qquad \forall\ j = 1, \ldots, n \qquad \ldots\ldots(1-3)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{p} X_{i,j,k,q} = d(q) \qquad \forall\ q = 1, \ldots, d \qquad \ldots\ldots(1-4)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{q=1}^{d} X_{i,j,k,q} = L(k) \qquad \forall\ k = 1, \ldots, p \qquad \ldots\ldots(1-5)$$

$$\sum_{i=1}^{m} a(i) = \sum_{j=1}^{n} b(j) = \sum_{q=1}^{d} d(q) \qquad \ldots\ldots(1-6)$$

$$X_{i,j,k,q} \geq 0 \qquad \ldots\ldots(1-7)$$

knowing that:

m: The number of display sources $(i = 1,2, \ldots, m)$

n: Number of demand centers $(j = 1,2, \ldots, n)$

p: The number of types of materials $(k = 1,2, \ldots, p)$

d: The number of different types and modes of transportation $(q = 1,2, \dots, d)$

$X_{i,j,k,q}$: Quantity of materials transported of commodity of type (k) from source (i) to demand center (j) Transfer of type (q).

$C_{i,j,k,q}$: The cost of transporting one unit of materials (k) from the source (i) to the demand center (j) with transportation of type (q).

$T_{i,j,k,q}$: Time to transfer one unit of material (k) from source (i) to demand center (j) with transfer type (q).

$a(i)$: The amount of material available in the source (supply) (i).

$b(j)$: Quantity of materials needed by the order center (j).

$d(q)$: The capacity of the transport medium (q) used in the transport process.

$L_{(K)}$: The number of various materials in the supply sources (k).

Equation (1-2) indicates that the sum of the quantities transported from different sources (supply) for each type of different materials is equal to the equipment available in these sources.

Equation (1-3) indicates that the total quantities transferred from different sources (supply) to the different requesting parties must meet the needs of these requests and for each of the different types of materials.

Equation (1-4) indicates that the total quantities transported from different sources (supply) must be transferred to the different requesting parties by means of transport appropriate for the type of different materials.

Equation (1-5) indicates that the sum of the quantities transferred from different sources (supply) to the different requesting parties is equal to the total quantities of all different types of materials.

Equation (1-6) indicates that the quantities of the various commodities received from all the different demand sides are equal to the quantities of commodities supplied from all different sources and the total quantities of the various commodities supplied from all the different sources.

Equation (1-7) indicates a non-negative constraint whose value must be equal to or greater than zero.

This model is difficult to solve exactly in an acceptable time, so we proposed to solve it by an approximate method: the metaheuristic Particle Swarm optimization.

3. The Particle Swarm Optimization (PSO)

An adaptive algorithm, proposed in 1998 by J.Kennedy, adapts a group of individuals by randomly returning to previously successful areas of the search space [9]. The Particle Swarm Optimization Algorithm is a population-based search algorithm based on simulating social behavior of birds. Within the herd, which is the modernization of the society of individuals by applying a type of operator according to the efficiency of the information obtained from the environment it is possible to expect the movement of individuals from the population towards areas of better solutions[10]
Each individual flies in the search space with a speed that is dynamically adjusted according to their own and accompanying flight experience, each individual being a point in the dimensional search space D [6].

In general, it contains three basic aspects, the first represents the individual best, where each individual compares his position to his best position i.e. no information from other particles is used, the second is the convergence problem, either the third is to drive the movement of the particles the location of the best particle of the entire swarm [13].

Pseudo code for PSO Algorithm [13] [4]

Input

m: number of supplier centers

n: number of demand centers

p: number of items

d: number of vehicles

a(q): quantities of items available in the supplier centers q

b(i): demand of items in demand center i

L(k): the amount of diverse items in the supplier centers k

d(j): the capacity of vehicle j

$C_{i,j,q,k}$:cost of transportation $\forall\ q = 1, \dots, m \quad i = 1, \dots, n \quad k = 1, \dots, p \quad j = 1, \dots d$

Output

$V(i|j|q|k)$: best particle for 4transportation

Step1: for each particle:

Initialize particle

Step2: do:

a) for each particle:
   1) insert particle in decoding procedure
   2) calculate fitness value
   3) if the fitness value is better than the best fitness value (pBest) in history
   4) set current value as the new pBest

   End

b) for each particle:
   1) find in the particle neighborhood, the particle with the best fitness
   2) calculate particle velocity according to the velocity
   3) Apply the velocity constriction
   4) Update particle position according to the position
   5) Apply the position constriction

   End

While maximum iterations or minimum

Application of PSO to a real case problem

The data were obtained from the General Company for Food Stuff Trading for the different demand centers (8), the different supply centers (8), the distribution line (2), and the various means of transportation (4).

The use of artificial intelligence algorithms in complex and large-scale problems where it is difficult to model and solve using other methods and given the number of variables in a single-target 4D transport model, we will use artificial intelligence algorithms to solve the problem, but before solving we must find a decoding procedure that helps Algorithms in search of good solutions in record time.

4D TRANSPORTATION PROBLEM

1,1									
suppliers	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8	كميات العرض
supplier 1	831	842	919	929	867	773	739	834	2000
supplier 2	876	723	752	976	704	893	918	812	2000
supplier 3	928	772	985	813	925	712	824	758	2000
supplier 4	739	740	886	846	949	936	719	705	2000
supplier 5	771	806	730	936	832	968	712	813	2000
supplier 6	998	813	939	989	746	966	830	884	2000
supplier 7	745	781	863	982	819	944	714	945	2000
supplier 8	738	821	830	708	763	765	941	816	2000
كميات الطلب	1800	1600	2000	2500	2200	1700	2100	2100	16000

2,1								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	847	763	759	841	961	811	839	807
supplier 2	721	855	732	822	904	927	997	776
supplier 3	794	965	879	721	992	897	819	828
supplier 4	930	705	933	822	761	902	876	944
supplier 5	932	921	783	965	722	739	738	881
supplier 6	731	959	717	750	790	880	706	899
supplier 7	958	862	934	746	911	989	932	838
supplier 8	919	934	751	722	940	935	722	800

1,2								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	741	975	999	761	847	749	994	923
supplier 2	945	771	890	847	735	785	744	893
supplier 3	936	997	774	738	736	861	917	979
supplier 4	960	921	861	843	855	827	991	902
supplier 5	896	756	762	721	775	795	891	954
supplier 6	984	904	771	823	974	785	804	850
supplier 7	700	702	937	750	849	961	883	789
supplier 8	783	903	908	977	776	979	844	832

2,2								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	882	965	937	799	906	867	751	808
supplier 2	878	860	916	896	978	716	757	944
supplier 3	999	819	812	718	947	767	823	885
supplier 4	877	899	720	861	811	812	797	934
supplier 5	894	966	889	705	703	979	962	756
supplier 6	867	726	903	817	818	855	978	744
supplier 7	966	983	873	831	901	945	936	833
supplier 8	815	808	886	762	818	874	793	707

1,3								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	992	703	871	853	862	999	822	700
supplier 2	922	916	940	996	714	903	788	777
supplier 3	932	787	821	743	958	920	976	705
supplier 4	873	716	842	806	705	976	953	743
supplier 5	724	834	962	828	976	752	755	863
supplier 6	991	704	946	962	743	745	869	787
supplier 7	766	966	808	744	719	840	808	805
supplier 8	765	714	879	885	906	774	825	921

2,3								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	837	801	852	872	886	855	737	949
supplier 2	875	860	873	824	930	856	869	988
supplier 3	807	811	985	747	990	773	746	761
supplier 4	997	889	848	958	754	821	935	704
supplier 5	875	891	752	867	873	724	701	822
supplier 6	932	975	968	769	933	782	860	738
supplier 7	963	825	701	835	797	962	841	988
supplier 8	723	850	732	703	700	772	937	820

1,4								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	780	840	709	717	832	936	811	748
supplier 2	789	746	895	710	855	855	749	825
supplier 3	878	732	789	770	848	736	846	966
supplier 4	809	983	767	791	719	933	990	960
supplier 5	724	746	890	828	979	725	995	882
supplier 6	775	705	739	921	778	754	901	801
supplier 7	846	922	772	768	828	734	930	907
supplier 8	718	865	734	740	749	853	740	731
2,4								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	914	914	753	981	726	889	787	714
supplier 2	984	883	731	887	865	802	762	975
supplier 3	993	755	946	914	871	822	890	997
supplier 4	736	986	723	869	751	934	900	904
supplier 5	783	778	728	816	846	918	758	859
supplier 6	813	759	736	910	721	966	870	703
supplier 7	898	824	773	915	762	854	735	904
supplier 8	754	934	915	994	793	728	773	721

Table (1-1) data for transportation cost matrices

As for the maximum capacity of the distribution centers and the maximum load of the means of transportation, where we have 4 types of transportation, they are shown below:

L	8000	8000		
d	3900	3800	4200	4100

Table (1-2) data of distribution centers and means of transportation

The aim of this study is to reduce the cost of transportation, and after applying the MATLAB program, we get the following results:

	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(1,1)	0	0	0	0	0	0	0	0
supplier 2		0	0	0	0	2000	0	0	0
supplier 3		0	0	0	0	0	1700	0	0
supplier 4		0	0	0	0	0	0	0	200
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	0	0	0	0	0	0	0
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0
	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(2,1)	0	0	0	0	0	0	0	0
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	0	0	0	0	0
supplier 4		0	0	0	0	0	0	0	0
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	0	0	0	0	0	0	0
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0

	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(1,2)	0	0	0	0	0	0	0	0
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	0	0	0	0	0
supplier 4		0	0	0	0	0	0	0	0
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	0	0	0	0	0	0	0
supplier 7		1800	200	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0

	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(2,2)	0	0	0	0	0	0	0	0
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	300	0	0	0	0
supplier 4		0	0	1500	0	0	0	0	0
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	0	0	0	0	0	0	0
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0

	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(1,3)	0	0	0	0	0	0	0	0
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	0	0	0	0	0
supplier 4		0	0	0	0	0	0	0	0
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	0	0	0	0	0	0	0
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0

	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(2,3)	0	0	0	0	0	0	100	0
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	0	0	0	0	0
supplier 4		0	0	0	0	0	0	0	100
supplier 5		0	0	0	0	0	0	2000	0
supplier 6		0	0	0	0	0	0	0	0
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	1800	200	0	0	0

	K, q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(1,4)	0	0	300	400	0	0	0	0
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	0	0	0	0	0
supplier 4		0	0	0	0	0	0	0	0
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	1400	0	0	0	0	0	0
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0

	K,q	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	(2,4)	0	0	0	0	0	0	0	1200
supplier 2		0	0	0	0	0	0	0	0
supplier 3		0	0	0	0	0	0	0	0
supplier 4		0	0	200	0	0	0	0	0
supplier 5		0	0	0	0	0	0	0	0
supplier 6		0	0	0	0	0	0	0	600
supplier 7		0	0	0	0	0	0	0	0
supplier 8		0	0	0	0	0	0	0	0

Table (1-3) Results of Material Transferred Quantities for Algorithm PSO.

We note that the methods used as the matrix (1,1) (1,4) (2,4) for the quantities of transported materials follow 3 paths because of their appropriate costs, while the rest of the paths were avoided because of their high costs, and the matrix (2,1) (1, 3) All paths were avoided due to their high costs, and the matrix (1,2) (2,2) were avoided because of their high costs, except for two paths that were used because of their appropriate cost, either matrix (2,3) five paths were used because of their cost The rest of the paths equal to zero were avoided.

After substituting in equation (1-1), the cost function is obtained, that is, by multiplying the matrices (1,1) (2,1) (1,2) (2,2) (1,3) (2,3) (1,4) (2,4) The cost of transporting one unit $C_{i,j,k,q}$ from the materials corresponding to the matrices (1,1) (2,1) (1,2) (2,2) (1,3) (2,3) (1,4) (2,4) regarding the amount of different transported materials $X_{i,j,k,q}$.

$Min\ Z_1 =$

Transportation cost matrix (1,1)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	831	842	919	929	867	773	739	834
supplier 2	876	723	752	976	704	893	918	812
supplier 3	928	772	985	813	925	712	824	758
supplier 4	739	740	886	846	949	936	719	705
supplier 5	771	806	730	936	832	968	712	813
supplier 6	998	813	939	989	746	966	830	884
supplier 7	745	781	863	982	819	944	714	945
supplier 8	738	821	830	708	763	765	941	816

*

Matrix of the amount of material transported (1,1)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	0	0	0	0	0	0
0	0	0	0	2000	0	0	0
0	0	0	0	0	1700	0	0
0	0	0	0	0	0	0	200
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	0	0	0	0	0	0	0

+

Transportation cost matrix (2,1)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	847	763	759	841	961	811	839	807
supplier 2	721	855	732	822	904	927	997	776
supplier 3	794	965	879	721	992	897	819	828
supplier 4	930	705	933	822	761	902	876	944
supplier 5	932	921	783	965	722	739	738	881
supplier 6	731	959	717	750	790	880	706	899
supplier 7	958	862	934	746	911	989	932	838
supplier 8	919	934	751	722	940	935	722	800

*

Matrix of the amount of material transported (2,1)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
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	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	0	0	0	0	0	0
0	0	0	0	0	0	0	0

+

Transportation cost matrix (1,2)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	741	975	999	761	847	749	994	923
supplier 2	945	771	890	847	735	785	744	893
supplier 3	936	997	774	738	736	861	917	979
supplier 4	960	921	861	843	855	827	991	902
supplier 5	896	756	762	721	775	795	891	954
supplier 6	984	904	771	823	974	785	804	850
supplier 7	700	702	937	750	849	961	883	789
supplier 8	783	903	908	977	776	979	844	832

*

Matrix of the amount of material transported (1,2)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
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	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
1800	200	0	0	0	0	0	0
0	0	0	0	0	0	0	0

+

Transportation cost matrix (2,2)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	882	965	937	799	906	867	751	808
supplier 2	878	860	916	896	978	716	757	944
supplier 3	999	819	812	718	947	767	823	885
supplier 4	877	899	720	861	811	812	797	934
supplier 5	894	966	889	705	703	979	962	756
supplier 6	867	726	903	817	818	855	978	744
supplier 7	966	983	873	831	901	945	936	833
supplier 8	815	808	886	762	818	874	793	707

*

Matrix of the amount of material transported (2,2)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	300	0	0	0	0
0	0	1500	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	0	0	0	0
0	0	0	0	0	0	0	0

+

Transportation cost matrix (1,3)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	992	703	871	853	862	999	822	700
supplier 2	922	916	940	996	714	903	788	777
supplier 3	932	787	821	743	958	920	976	705
supplier 4	873	716	842	806	705	976	953	743
supplier 5	724	834	962	828	976	752	755	863
supplier 6	991	704	946	962	743	745	869	787
supplier 7	766	966	808	744	719	840	808	805
supplier 8	765	714	879	885	906	774	825	921

*

Matrix of the amount of material transported(1,3)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
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	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	0	0	0	0	0	0
0	0	0	0	0	0	0	0

+

Transportation cost matrix (2,3)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	837	801	852	872	886	855	737	949
supplier 2	875	860	873	824	930	856	869	988
supplier 3	807	811	985	747	990	773	746	761
supplier 4	997	889	848	958	754	821	935	704
supplier 5	875	891	752	867	873	724	701	822
supplier 6	932	975	968	769	933	782	860	738
supplier 7	963	825	701	835	797	962	841	988
supplier 8	723	850	732	703	700	772	937	820

*

Matrix of the amount of material transported (2,3)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	0	0	0	0	100	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	100
0	0	0	0	0	0	2000	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	1800	200	0	0	0

+

Transportation cost matrix (1,4)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	780	840	709	717	832	936	811	748
supplier 2	789	746	895	710	855	855	749	825
supplier 3	878	732	789	770	848	736	846	966
supplier 4	809	983	767	791	719	933	990	960
supplier 5	724	746	890	828	979	725	995	882
supplier 6	775	705	739	921	778	754	901	801
supplier 7	846	922	772	768	828	734	930	907
supplier 8	718	865	734	740	749	853	740	731

*

Matrix of the amount of material transported (1,4)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	300	400	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	0	0	0
0	0	0	0	0	0	0	0
0	1400	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

+

Transportation cost matrix (2,4)

	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	914	914	753	981	726	889	787	714
supplier 2	984	883	731	887	865	802	762	975
supplier 3	993	755	946	914	871	822	890	997
supplier 4	736	986	723	869	751	934	900	904
supplier 5	783	778	728	816	846	918	758	859
supplier 6	813	759	736	910	721	966	870	703
supplier 7	898	824	773	915	762	854	735	904
supplier 8	754	934	915	994	793	728	773	721

*

Matrix of the amount of material transported(2,4)

demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	0	0	0	0	0	1200
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	200	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	600
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Cost function=11316400

S.T.

As for the restrictions on the quantities of materials available in the supply centers, according to equation (1-2), we have 8 restrictions.

(1,1)	supplier 1	0	0	0	0	0	0	0	0	+	(2,1)	supplier 1	0	0	0	0	0	0	0	0	
(1,2)	supplier 1	0	0	0	0	0	0	0	0	+	(2,2)	supplier 1	0	0	0	0	0	0	0	0	+
(1,3)	supplier 1	0	0	0	0	0	0	0	0	+	(2,3)	supplier 1	0	0	0	0	0	0	100	0	+ +
(1,4)	supplier 1	0	0	300	400	0	0	0	0	+	(2,4)	supplier 1	0	0	0	0	0	0	0	1200	=2000

This means the center of the first offer is equal to the available quantities

(1,1)	supplier 2	0	0	0	0	2000	0	0	0	+	(2,1)	supplier 2	0	0	0	0	0	0	0	0	
(1,2)	supplier 2	0	0	0	0	0	0	0	0	+	(2,2)	supplier 2	0	0	0	0	0	0	0	0	+
(1,3)	supplier 2	0	0	0	0	0	0	0	0	+	(2,3)	supplier 2	0	0	0	0	0	0	0	0	+
(1,4)	supplier 2	0	0	0	0	0	0	0	0	+	(2,4)	supplier 2	0	0	0	0	0	0	0	0	+

=2000

The second offer center is equal to the available quantities

(1,1)	supplier 3	0	0	0	0	0	1700	0	0	+	(2,1)	supplier 3	0	0	0	0	0	0	0	0	
(1,2)	supplier 3	0	0	0	0	0	0	0	0	+	(2,2)	supplier 3	0	0	0	300	0	0	0	0	+
(1,3)	supplier 3	0	0	0	0	0	0	0	0	+	(2,3)	supplier 3	0	0	0	0	0	0	0	0	+
(1,4)	supplier 3	0	0	0	0	0	0	0	0	+	(2,4)	supplier 3	0	0	0	0	0	0	0	0	+

=2000

The third display center is also equal to the available quantities

				(1,1)											(2,1)				
supplier 4	0	0	0	0	0	0	0	200	+	**supplier 4**	0	0	0	0	0	0	0	0	+
				(1,2)											(2,2)				
supplier 4	0	0	0	0	0	0	0	0	+	**supplier 4**	0	0	1500	0	0	0	0	0	+
				(1,3)											(2,3)				
supplier 4	0	0	0	0	0	0	0	0	+	**supplier 4**	0	0	0	0	0	0	0	100	+
				(1,4)											(2,4)				
supplier 4	0	0	0	0	0	0	0	0	+	**supplier 4**	0	0	200	0	0	0	0	0	

=2000

The fourth offer center is equal to the available quantities

				(1,1)											(2,1)				
supplier 5	0	0	0	0	0	0	0	0	+	**supplier 5**	0	0	0	0	0	0	0	0	+
				(1,2)											(2,2)				
supplier 5	0	0	0	0	0	0	0	0	+	**supplier 5**	0	0	0	0	0	0	0	0	+
				(1,3)											(2,3)				
supplier 5	0	0	0	0	0	0	0	0	+	**supplier 5**	0	0	0	0	0	0	2000	0	+
				(1,4)											(2,4)				
supplier 5	0	0	0	0	0	0	0	0	+	**supplier 5**	0	0	0	0	0	0	0	0	

The fifth display center is equal to the available quantities =2000

				(1,1)											(2,1)				
supplier 6	0	0	0	0	0	0	0	0	+	**supplier 6**	0	0	0	0	0	0	0	0	+
				(1,2)											(2,2)				
supplier 6	0	0	0	0	0	0	0	0	+	**supplier 6**	0	0	0	0	0	0	0	0	+
				(1,3)											(2,3)				
supplier 6	0	0	0	0	0	0	0	0	+	**supplier 6**	0	0	0	0	0	0	0	0	+
				(1,4)											(2,4)				
supplier 6	0	1400	0	0	0	0	0	0	+	**supplier 6**	0	0	0	0	0	0	0	600	

The sixth offer center is equal to the available quantities =2000

				(1,1)											(2,1)				
supplier 7	0	0	0	0	0	0	0	0	+	**supplier 7**	0	0	0	0	0	0	0	0	+
				(1,2)											(2,2)				
supplier 7	1800	200	0	0	0	0	0	0	+	**supplier 7**	0	0	0	0	0	0	0	0	+
				(1,3)											(2,3)				
supplier 7	0	0	0	0	0	0	0	0	+	**supplier 7**	0	0	0	0	0	0	0	0	+
				(1,4)											(2,4)				
supplier 7	0	0	0	0	0	0	0	0	+	**supplier 7**	0	0	0	0	0	0	0	0	

The seventh show center is equal to the available quantities =2000

					(1,1)									(2,1)					
supplier 8	0	0	0	0	0	0	0	0	+	**supplier 8**	0	0	0	0	0	0	0	0	
					(1,2)									(2,2)					+
supplier 8	0	0	0	0	0	0	0	0	+	**supplier 8**	0	0	0	0	0	0	0	0	
					(1,3)									(2,3)					+
supplier 8	0	0	0	0	0	0	0	0	+	**supplier 8**	0	0	0	1800	200	0	0	0	
					(1,4)									(2,4)					+
supplier 8	0	0	0	0	0	0	0	0	+	**supplier 8**	0	0	0	0	0	0	0	0	

The eighth display center is equal to the available quantities =2000

And the restrictions for the different demand centers, we have 8 restrictions, according to (1-3) equation

(1,1) demand node 1		(2,1) demand node 1		(1,2) demand node 1		(2,2) demand node 1		(1,3) demand node 1		(2,3) demand node 1		(1,4) demand node 1		(2,4) demand node 1
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		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		1800		0		0		0		0		0
0		0		0		0		0		0		0		0

=1800

This means that the first order center is identical to the transported quantities and does not need a transfer process from another center

(1,1) demand node 2		(2,1) demand node 2		(1,2) demand node 2		(2,2) demand node 2		(1,3) demand node 2		(2,3) demand node 2		(1,4) demand node 2		(2,4) demand node 2
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		0		0		0		0		0		0		0
0		0		0		0		0		0		0		0
0		0		0		0		0		0		1400		0
0		0		200		0		0		0		0		0
0		0		0		0		0		0		0		0

=1600

The second order center is also identical to the transported quantities and does not need a transfer process from another center

(1,1) demand node 3		(2,1) demand node 3		(1,2) demand node 3		(2,2) demand node 3		(1,3) demand node 3		(2,3) demand node 3		(1,4) demand node 3		(2,4) demand node 3
0		0		0		0		0		0		300		0
0		0		0		0		0		0		0		0
0	+	0	+	0	+	0	+	0	+	0	+	0	+	0
0		0		0		1500		0		0		0		200
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		0		0		0		0		0		0		0

=2000

The third order center is identical to the transported quantities and does not need a transfer process from another center

(1,1)		(2,1)		(1,2)		(2,2)		(1,3)		(2,3)		(1,4)		(2,4)
demand node 4		demand node 4		demand node 4		demand node 4		demand node 4		demand node 4		demand node 4		demand node 4
0		0		0		0		0		0		400		0
0		0		0		0		0		0		0		0
0	+	0	+	0	+	300	+	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		0		0		0
0		0		0		0		0		0		0		0
0		0		0		0		0		1800		0		0

=2500

The fourth order center is identical to the transported quantities and does not need a transfer process from another center

(1,1)		(2,1)		(1,2)		(2,2)		(1,3)		(2,3)		(1,4)		(2,4)
demand node 5		demand node 5		demand node 5		demand node 5		demand node 5		demand node 5		demand node 5		demand node 5
0		0		0		0		0		0		0		0
2000		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		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		0		0		200		0		0

=2200

The fifth order center is identical to the transported quantities and does not need a transfer process from another center

(1,1)		(2,1)		(1,2)		(2,2)		(1,3)		(2,3)		(1,4)		(2,4)
demand node 6		demand node 6		demand node 6		demand node 6		demand node 6		demand node 6		demand node 6		demand node 6
0		0		0		0		0		0		0		0
0		0		0		0		0		0		0		0
1700	+	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		0		0		0		0		0		0
0		0		0		0		0		0		0		0
0		0		0		0		0		0		0		0

=1700

The sixth application center is identical to the transported quantities and does not require a transfer process from another center

(1,1)		(2,1)		(1,2)		(2,2)		(1,3)		(2,3)		(1,4)		(2,4)
demand node 7		demand node 7		demand node 7		demand node 7		demand node 7		demand node 7		demand node 7		demand node 7
0		0		0		0		0		100		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		0
0		0		0		0		0		2000		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		0

=2100

The seventh order center is also identical to the transported quantities, which means that it does not need a transfer process from another center

(1,1) demand node 8		(2,1) demand node 8		(1,2) demand node 8		(2,2) demand node 8		(1,3) demand node 8		(2,3) demand node 8		(1,4) demand node 8		(2,4) demand node 8
0		0		0		0		0		0		0		1200
0		0		0		0		0		0		0		0
0	+	0	+	0	+	0	+	0	+	0	+	0	+	0
200		0		0		0		0		100		0		0
0		0		0		0		0		0		0		0
0		0		0		0		0		0		0		600
0		0		0		0		0		0		0		0
0		0		0		0		0		0		0		0

=2100

The eighth order center is identical to the transported quantities and does not need a transfer process from another center

The constraints of the distribution centers, we have two constraints, according to equation(1-5)

the first entry is the result of the matrix (1,4) To make sure that each distribution center has the quantities entering it equal to 8000. In this case, summation of the quantities (1,1) (1,2) (1,3)

1,1	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	0	0
supplier 2	0	0	0	0	2000	0	0	0
supplier 3	0	0	0	0	0	1700	0	0
supplier 4	0	0	0	0	0	0	0	200
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

+

1,2	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
	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	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	1800	200	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

+

1,3	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	0	0
supplier 2	0	0	0	0	0	0	0	0
supplier 3	0	0	0	0	0	0	0	0
supplier 4	0	0	0	0	0	0	0	0
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

+

1,4	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
	0	0	300	400	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	0	0	0
	0	0	0	0	0	0	0	0
	0	1400	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

= 8000

The second constraint results from the matrix summation of the quantities (2,1) (2,2) (2,3(2,4)

2,1	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	0	0
supplier 2	0	0	0	0	0	0	0	0
supplier 3	0	0	0	0	0	0	0	0
supplier 4	0	0	0	0	0	0	0	0
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

+

2,2	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	300	0	0	0	0
	0	0	1500	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	0	0	0	0
	0	0	0	0	0	0	0	0

+

2,3	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	100	0
supplier 2	0	0	0	0	0	0	0	0
supplier 3	0	0	0	0	0	0	0	0
supplier 4	0	0	0	0	0	0	0	100
supplier 5	0	0	0	0	0	0	2000	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	1800	200	0	0	0

+

2,4	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
	0	0	0	0	0	0	0	1200
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	200	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	600
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

=8000

The restrictions related to the means of transportation, we have 4 restrictions, according to equation(1-4)

The first entry we add both the matrix (1,1) and (2,1) to get $d_1 = 3900$ as shown below:

1,1	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	0	0
supplier 2	0	0	0	0	2000	0	0	0
supplier 3	0	0	0	0	0	1700	0	0
supplier 4	0	0	0	0	0	0	0	200
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

+

2,1	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
	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	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	0	0	0	0	0	0
	0	0	0	0	0	0	0	0

=3900

The second entry we add each of the matrix (1,2) (2,2) to get $d_2 = 3800$ as shown below:

1,2	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	0	0
supplier 2	0	0	0	0	0	0	0	0
supplier 3	0	0	0	0	0	0	0	0
supplier 4	0	0	0	0	0	0	0	0
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	1800	200	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

+

2,2	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	300	0	0	0	0
	0	0	1500	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	0	0	0	0
	0	0	0	0	0	0	0	0

=3800

The third constraint we add all of the matrix (1,3) (2,3) to get d_3=4200 as shown below:

1,3								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	0	0	0	0	0	0
supplier 2	0	0	0	0	0	0	0	0
supplier 3	0	0	0	0	0	0	0	0
supplier 4	0	0	0	0	0	0	0	0
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	0	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

\+

2,3							
demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	0	0	0	0	100	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	100
0	0	0	0	0	0	2000	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	1800	200	0	0	0

=4200

As for the fourth entry, we add each of the matrix (1,4) (2,4) until we get $d_4 = 4100$ as shown below:

1,4								
	demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
supplier 1	0	0	300	400	0	0	0	0
supplier 2	0	0	0	0	0	0	0	0
supplier 3	0	0	0	0	0	0	0	0
supplier 4	0	0	0	0	0	0	0	0
supplier 5	0	0	0	0	0	0	0	0
supplier 6	0	1400	0	0	0	0	0	0
supplier 7	0	0	0	0	0	0	0	0
supplier 8	0	0	0	0	0	0	0	0

\+

2,4							
demand node 1	demand node 2	demand node 3	demand node 4	demand node 5	demand node 6	demand node 7	demand node 8
0	0	0	0	0	0	0	1200
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	200	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	600
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

=4100

Best solution using PSO

decoding	13	20	4	14	18	5	11	19	8	1	6	16	3	22	15	12	9	7	21	17	10	2

The best solution was obtained through the process of combining eight supply centers with eight demand centers, two distribution lines and four means of transportation.

RESULTS

The results are obtained by MATLAB program.

By solving the four-dimensions transportation model, the lowest cost was obtained (11316,400) dollars through the different distribution lines for the different means of transportation from the different supply centers to the different demand center.

5. CONCLUSIONS AND PERSPECTIVES

Different results were achieved using the proposed algorithm of the four-dimensional transportation model with one goal for the data obtained from the Iraqi Ministry of Trade by taking different samples (8 supply centers, 8 demand centers, 2 distribution lines, 4 different means of transportation) through the results obtained It is done by MATLAB program and choosing the best solution, among those multiple optimum solutions obtained by means of the decoding procedure.

Generalizing the four-dimensional transportation model to all companies that require decisions to reduce transportation costs, whether the different means of transportation through the different distribution line in addition to the different supply and demand centers.

We note that the solution of the four-dimensional transport model with a single goal provides optimal solutions in determining the quantities of homogeneous and heterogeneous materials that will be transported by different means of transport from different sources to different requesting parties at the lowest total cost Generalizing the multi-objective four-dimensional transportation model to all companies that require decisions to reduce transportation costs, times and distance together, whether the different transportation means across the different distribution line in addition to homogeneous or heterogeneous materials.

We recommend the use of the multi-objective four-dimensional transport model by the Iraqi Ministry of Trade when importing homogeneous and heterogeneous materials according to the actual need of the country and the planned quantities of transport using artificial intelligence algorithms.

The future work will be to solve the multi-objective four-dimensional transportation model and generalize it's use to all companies that require decisions to reduce transportation costs, times and distance together, whether the different transportation means across the different distribution line in addition to homogeneous or heterogeneous materials. We also propose to compare several different metaheuristics for solving the problem.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

REFERENCES

[1] A.J. Bakhit, A. Khader, S. Faisal, Solving the three-dimensional transfer problem using fuzzy multi-objective programming, City Sci. Univ. Coll. J. 10 (2018), 137-158.

[2] M.M. Ahmed, A.R. Khan, M.S. Uddin, et al. A new approach to solve transportation problems, Open J. Optim. 5 (2016), 22-30.

[3] E.W. Anderson, C. Fornell, R.T. Rust, Customer satisfaction, productivity, and profitability: Differences between goods and services, Market. Sci. 16 (1997), 129-145.

[4] A.G.K. Bakhayt, Solving bi-objective 4-dimensional transportation problem by using PSO, Sci. Int. 28 (2016), 2403-2410.

[5] S. Bera, P.K. Giri, D.K. Jana, et al. Multi-item 4D-TPs under budget constraint using rough interval, Appl. Soft Comput. 71 (2018), 364-385.

[6] A.P. Engelbrecht, Computational intelligence: an introduction, John Wiley & Sons, (2007).

[7] S. Halder Jana, B. Jana, B. Das, et al. Constrained FC 4D MITPs for damageable substitutable and complementary items in rough environments, Mathematics, 7 (2019), 281.

[8] A.A. Hamada, The role of operations research in solving the problem of fuzzy transport (an empirical study), J. Phys.: Conf. Ser. 1530 (2020), 012079.

[9] J. Kennedy, The behavior of particles. In International conference on evolutionary programming, Springer, Berlin, Heidelberg, (1998), 579-589.

[10] J. Kennedy, R. Eberhart, Particle swarm optimization, in: Proceedings of ICNN'95 - International Conference on Neural Networks, IEEE, Perth, WA, Australia, 1995: pp. 1942–1948.

[11] P. Sahoo, D.K. Jana, S. Pramanik, G. Panigrahi, Uncertain four-dimensional multi-objective multi-item transportation models via GP technique, Soft Comput. 24 (2020), 17291–17307.

[12] H.A. Taha, Operations research: An introduction, 10th Edition, Pearson, 2017.

[13] P.K. Tripathi, S. Bandyopadhyay, S.K. Pal, Multi-objective particle swarm optimization with time variant inertia and acceleration coefficients, Inform. Sci. 177 (2007), 5033-5049.

[14] D. Wang, D. Tan, L. Liu, Particle swarm optimization algorithm: an overview, Soft Comput. 22 (2018), 387-408.