Multiple Objective Optimization of Green Logistics Using Cuckoo Searching Algorithm

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Abstract—Green Logistics becomes critical in Supply Chain Management due to it having less of an impact to the environment. Green Logistics optimization refers to the determination depot quantity, decreasing uncovered demand and CO2 emission reduction. To date, application of Cuckoo searching algorithm has been proven to be very efficient and reliable in solving optimization problems; it is also capable of operating simultaneously with multiple solutions. Basically, Cuckoo searching algorithm imitates the natural evolution of a population with initial solutions. In this paper, a modified Cuckoo searching algorithm is proposed to solve the multiple objective Green Logistics optimization problem. MATLAB software is used to validate and evaluate the proposed model. This work forms the basis for solving many other similar problems that occur in manufacturing and service industries. The final solution to this multiple objective problem is reached by using a set of Pareto solutions.

Keywords—Green Logistics ; Cuckoo searching algorithm; Pareto solutions; multiple objective

1. INTRODUCTION

Since the beginning of time, humans have always tried planning their time, distance, efforts, costs for any activity that is necessary. With globalization, trade is increasingly competitive and demanding; companies must be on time for their customers not just as a matter of convenience as it's a condition that must be satisfied by expectation to retain their loyalty. Cities are always changing, becoming larger, more populated, with more market competition and all these factors can cause more pollution [1]. Improving logistics in business, helps reducing distances, costs and environmental emissions.
Nowadays, a "green or sustainable mindset" is emerging more strongly; and companies want more than ever to reduce costs without affecting the environment. Adopting a sustainable business mindset is key if businesses want to maximize their benefits working with what they have available [2]. Maximizing resources and reducing costs; it is about smart and responsible business, those combinations will maximize economic, social and environmental benefits. Due to the factors above, this thesis arises to solve a transportation and location problem as a multiple objective optimization using a modified genetic algorithm trying to minimize transportation costs and excessive unnecessary depot costs in addition to reducing the uncovered demand not attended for one depot while minimizing the emissions of transportation and depot operations.

Humans have always tried planning their time, distance, efforts, costs for any activity that is necessary. With globalization, trade is increasingly competitive and demanding; companies must be on time with their customers, that's a condition that must be performed as matter of business obligation to retain their loyal customer base. Climate changes are concerning governments leading many enact laws that regulate and encourage the protection of the environment by people and business. Consumers are more socially aware and deeply concerned about the effects of waste, pollution on the ecosystem altering their habits to consume products and utilize services that minimize environmental impact generated by their execution and their processes. Traditional logistics (knowing that their activities also generate negative effects on the environment through energy consumption, use of water, soil and emissions generated mainly by the transport of products and services) have adapted to a new "green" philosophy. "Green" and "sustainable" seem to be buzzwords. As with any social movement, impacting businesses and revenue it spread across all industries including to transportation and logistics operations. In recent years, particularly in 2008, the impact of transportation on the environment became an important factor throughout the whole world, because it was responsible for almost 60% of the fuel consumption according to the Organization of Economic Cooperation and Development countries (OECD) [3]. More and more companies are integrating objectives regarding environmental protection into their operations and promoting their corporate social responsibility. Supply chains within companies are key to achieving these goals as the effects can be displayed in clear, concise measurements.

The motivation to develop this work is based on the existence of an increasing interest in developing new techniques in the area of green logistics (the relationship between business and environment). The main problem is Where to locate new depots to supply demand to other cities and reduce emissions. To develop a new methodology for the solution of a Green Logistics / Green Supply Chain Management problem is the goal of this research, also create a new tool for decision makers and upper level management for the location of depots. Among all the aspects that can be considered when analyzing the role of a company with its environment, the characteristic that is one of the most important is the type of vehicles that are used to move its products or services; in other words, the importance of managing the waste generated by companies in the exercise of their activities, not only processes of sourcing, production and storage generates damage to the environment. Going back several decades, society observed the importance (from an environmental and economic point of view) of the responsible and appropriate management of CO2 and NOx emissions [4]. To comply with governmental regulations and consumer sentiment companies are beginning to consider the use of cleaner processes [5]. If companies take responsibility for their emissions it will not be a serious problem that can affect their results. Business develop their activities in order to achieve certain objectives, this includes obtaining the greatest profit as possible; therefore, activities proposed by them should be cost-effective so that actions can be put into practice. But focusing only on reducing emissions is not the only concern that all the companies have. As it was mentioned before, business are always looking to have profit using as low cost as possible; that's why finding the shortest route for the transportation of their products plays a really important role in order to generate income, not only because costs will decrease, but also because carbon dioxide emissions will be lower. The main objective of this research is to propose a methodology of optimization for a capacitated problem of Green Supply Chain using a modified Cuckoo searching algorithm. This methodology allows us to find the best route design needed to transport products or services, the cost of opening a new depot and where to open it, seeks to minimize the uncovered demand and minimize CO2 emissions generated by transportation.

2 MULTIPLE-OBJECTIVE OPTIMIZATION BY CUCKOO SEARCHING ALGORITHM

Real-world problems are usually solved by a multi-objective optimization method, although there are problems with just one objective. Most of the optimization problems don't have only one objective to be solved; these problems involve more than one objective to be optimized. Problems where more than one objective is considered are called multi-objective problems and their purpose is to optimize all objectives simultaneously. Most of the time they are in conflict. Optimality refers to finding the optimal solution or at least a good approximation given a set of constraints or restrictions that optimizes the required objectives. Within the multi-objective optimization exits problems where conventional techniques have difficulty finding a good solution, these problems have been treated with meta-heuristic techniques finding feasible solutions to the decision maker [6]. A multi-objective problem usually does not have a unique efficient solution, it has a set of good solutions that cannot be considered different and they're not dominated by another one, i.e. there is no other better solution. This set of solutions, mentioned before, is called Pareto Frontier. One solution is efficient when it is not dominated, i.e. when it is at least as good as the others in all of its objectives and is better in at least one of them [7]. It is difficult to find just one optimal solution for all the objectives. To solve optimization problems two different types of techniques can be used: mathematical methods transform into a one objective problem, linear programming can solve these type of problems; and metaheuristic methods, which don't find an optimal solution, i.e. not only one efficient solution exists, and these solutions are non-dominated solutions in the Pareto Frontier. If it's desired to switch from a dominated solution to a non-dominated one, within the space of the objectives, in order to enhance the value of one of them it is necessary that one or more objectives deteriorate [8].

Cuckoo takes a special reproduction strategy of parasitic brooding. She deposits her eggs in other birds' nests in order to make other birds hatch the next generation for her. To reduce the probability of being discovered, some cuckoos shall make up her eggs like those of the selected birds. When other birds find alien eggs in their nests, they will abandon those eggs or put them in their own nests, or build a new nest in other places. Based on the reproduction strategy of cuckoo, Yang and Deb draw out CS-Algorithm which is based on three ideal rules [9]:

Rule 1. Each cuckoo only produces 1 egg for one time, and randomly chooses one bird nest for storage. Rule 2. The bird nest with the best egg shall be reserved for the next generation. Rule 3. The number of available bird nests are fixed, and the probability of being discovered to be the alien eggs is $P_a \in [0,1]$.

Based on the above three rules, the basic procedure of CS algorithm is as shown in algorithm 1.

Algorithm 1. Cuckoo Search.
Begin
Initialize the population: n host nests X_i(i=1,2,…,n);
Calculate the fitness value: F_i(i=1,2,…,n).
While (doesn't meet the stop condition)
Take the new solutionX_i generated by Lévy flight;
Calculate the fitness value $F_i$of the new solution X_i;
Choose candidate solution X_j;
If($F_i > X_j$)
    Replace candidate solution with the new solution;
End
Discard the bad solutions according to the detection probabilityP_a;
Replace the discarded solution with the new solution generated by preferential random walks
Reserve the best solutions.
End
End

In CS algorithm, one bird nest represent one candidate solution. Firstly, CS algorithm generates a new solution in Lévy flights random walk way based on current solution, evaluates and reserves better solutions; secondly, discard some solutions according to detection probability P_a; Lastly, regenerates a new solution with the same number as that of the discarded solutions by preferential random walks, complete one-iteration after evaluation and reserving the better solutions.

When takes the new solution X_i generated by Lév y flights random walk, execute the operation of formula (1):

$$X_{g+1,i}=X_{g,i}+\alpha \oplus \text{Lévy}(\beta) \tag{1}$$

Thereinto, $X_{g,i}$ represents the i solution of the g generation; α is step message, used for controlling the range of random searching. In order to gain more useful step messages from the current optimal solutions, reference [10] resorts to formula (2) to calculate step message:

$$\alpha=\alpha_0(X_{g,i} - X_{best}) \tag{2}$$

Thereinto, $\alpha_0$is constant ($\alpha_0 = 0.01$), X_{best} represents the current optimal solution.

In Formula (1), ⊕ is entry-wise multiplications, Lévy(λ) obey Lévy probability distribution:

$$\text{Lévy}(\beta)\sim u=t^{-1-\beta},\ 0<\beta\leq 2 \tag{3}$$

For easy calculation, reference [9] resorts to formula (4) to calculate Lévy random number:

$$\text{Lévy}(\beta)\sim u\frac{\phi\phi\times u}{|v|^{1/\beta}} \tag{4}$$

Thereinto, u,v obey standard normal distribution, β= 1.5.

$$\phi = \left(\frac{\Gamma(1+\beta)\times\sin(\frac{1}{2}\pi\beta)}{\Gamma((\frac{1+\beta}{2})\times\beta\times 2^{\frac{\beta-1}{2}})}\right)^{\frac{1}{\beta}} \tag{5}$$

Obviously, synthesize formula(1) ~formula(5), in Lévy flights random walk components, CS algorithm takes formula(6) to generate the new solution X_i:

$$X_{g+1,i}=X_{g,i}+\alpha_0\frac{\phi\phi\times u}{|v|^{1/\beta}}(X_{g,i}-X_{g,best}) \tag{6}$$

After discarding some solutions according to a certain probability (detection probability), algorithm takes preferential random walks to regenerate the new solutions with the same number, see formula(7):

$$X_{g+1,i}=X_{g,i}+r(X_{g,j} - X_{g,k}) \tag{7}$$

Thereinto, r is zoom factor, a uniform random number in (0,1) section; $X_{g,j}$and $X_{g,k}$ are two random solutions of the g generation.

3 MODELLING DESIGN

A.Formulations

The mathematical formulations for this multiple-objective optimization problem trying to minimize costs, minimize uncovered demand and minimize environmental emissions are shown and explained below.

a) Minimization of Transportation Costs and Opening a Depot Costs

The first formulation is regarding to find how many depots need to be open and where they need to be located to reduce the transportation cost and the cost of opening a depot [11].

$$\min[\sum_{i\in V_{CD}}\sum_{j\in V_C} c_{ij}x_{ij} + \sum_{i\in V_{CD}} f_i y_i] \tag{8}$$

where
i: Representation of depots
j: Representation of customers
Cij: Transportation costs of attending demand from costumer j to depot i
xij: Equal to 1 if the demand of costumer j is attended by a depot, 0 otherwise
fi: Cost of opening a depot
yi: Equal to 1 if the depot is chosen to operate, 0 otherwise
Vc: Set of costumers {1, 2, 3… j}
Vdc: Set of depots {1, 2, 3… i}

The main goal of this mathematical formula will be to calculate the minimum cost of transportation and the minimum cost of opening a new depot combined for each combination. This results are as important as the other two objectives this work is trying to minimize.

b) Minimization of uncovered demand

This formulation is regarding to minimize the uncovered demand not attended by a depot between capacity and desired demand of the customers.

$$\min\ [\textstyle\sum_j (d_j - \sum_i T_{ij} \cdot x_{ij})] \quad (9)$$

where
i: Representation of depots
j: Representation of customers
dj: Initial demand
Tij: Capacity of each city
xij: Equal to 1 if the depot is chosen to operate, 0 otherwise

The main goal of this mathematical formula will be to calculate the minimum uncovered demand for each combination. This results are as important as the other two objectives this work is trying to minimize.

c) Minimization of CO2 emissions
This formulation intends to minimize the environmental emissions issued by the different transportation types used in this problem.

$$\min \textstyle\sum_i^l \sum_j^l \left(x_{ij} R_{ij} Z_{ij} E_{ij}\right) \cdot [1 + BGd_{ij}] \quad (10)$$

where
i: Representation of depots
j: Representation of customer
xij: Equal to 1 if the depot is chosen to operate, 0 otherwise
Rij: Road factor
Zij: Distance
Eij: Average CO2-emission factor by transport mode (lb)
dj: Initial demand
B: Weight of product per unit in pounds (5 lb)
G: Fuel consumption increased factor (0.1 %)

The main goal of this mathematical formula will be to calculate the total CO2 emissions for each combination. This results are as important as the other two objectives this work is trying to minimize.

B.Transportation data

Transportation types. The table below shows the four different transportation types used in this work. Truck capacity. For this work, each transportation type will have different capacities. Truck CO2-emissions. The following table shows Average CO2-emission factor by transport type (lb/mile) in Table 1. Road type. For this work, three different types of road are used, the following table shows them in Table2.

Table 1: Transportation types, Truck capacity and : CO2 truck emissions

Transportation type	Type of truck	Truck capacity (units)	lb/mile
1	Gasoline light truck	50	0.548
2	Gasoline heavy truck	65	1.266
3	Diesel light truck	55	0.512
4	Diesel heavy truck	70	1.192

Table 2: Road type

Road type	Type of road	Factor
1	Highway	1
2	Urban	1.2
3	Dirt road	1.3

The data shown in tables above are necessary for two of the three mathematical formulas used in this problem. In CO2-emissions formulation, demand is multiplied for B (weight of the product per unit in pounds) to get the total weight, this weight is multiplied by the fuel consumption increased factor, this means, for every pound a truck transport, it will increase the fuel consumption, therefore CO2-emissions will increase too. What this work is trying to do is to minimize those emissions by finding the best possible routes or combinations.

C. Data

For this research mock data such as distances, costs, demand, capacity and weight of goods is used. The scale used for distances is miles; for costs, the scale is thousand dollars; the scale used for capacity and demand is goods (units); the weight for each good is 5 lb. CO2-emissions produced by each transportation factor is real data from EPA, United States Environmental Protection Agency [12] and Transport Policy for US [13]. This data will not change during the execution of the methodology.

4 RESULTS AND DISCUSSIONS

To test the performance of this work, a problem with mock data was designed. A routine created in MATLAB was used to solve this optimization problem. This routine was selected to measure the performance of this multiple-objective optimization problem. As it was mentioned before, this codification works together with a cuckoo searching Algorithm and Pareto Front. The program generates matrix yi, likewise generates matrix xij, it starts evaluating the objectives by applying the mathematical formulas previously mentioned. After this evaluation, a ranking is given to the solutions depending of their diversity and their dominance (fitness 1 and fitness 2) creating the Pareto Frontier. The set of solutions obtained are reproduced following Cuckoo searching algorithm parameters; here is when it is applied the cuckoo searching Algorithm.. After this process, a set of final solutions will be obtained, each solution will contain a result for each one of the three objectives: costs, uncovered demand and environmental emissions.

A.Problem mock data

A problem with 12 cities was selected. This 12 cities represent depots and customers. All the data used in this problem are mock values. This proposed methodology might become more mature if real data is implemented. The following tables show all the necessary data to be used for this methodology. Every matrix is necessary for the implementation of the mathematical formulation explained in the front, this mathematical model cannot be used without one of the tables. Every table and information is going to be explained later. Fort this work, these following matrices won't change their values. Data will remind the same for all the possible combinations.

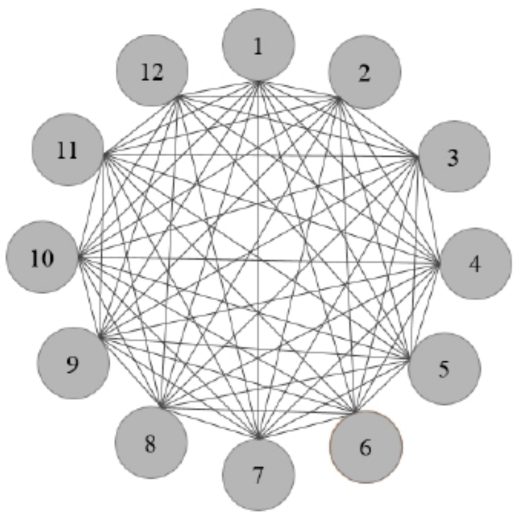

Figure 1: Network with 12 cities fully connected.

Figure 1 shows how the 12 cities used for this work are fully connected between each other. This means, if selected, each city could travel to each one of the other 11 cities. Some assumptions apply to this research, these assumptions will be described later.

Table 3: Cost of transportation between cities.

	City	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**
City	**0**	23	20	18	29	34	36	40	37	31	28	25
City	23	**0**	21	35	29	40	38	27	38	32	22	33
City	20	21	**0**	22	37	28	26	30	26	34	25	26
City	18	35	22	**0**	42	21	40	36	19	33	21	25
City	29	29	37	42	**0**	23	37	26	30	29	21	31
City	34	40	28	21	23	**0**	38	38	25	29	33	24
City	36	38	26	40	37	38	**0**	36	28	21	27	38
City	40	27	30	36	26	38	36	**0**	36	35	29	26
City	37	38	26	19	30	25	28	36	**0**	34	28	21
City	31	32	34	33	29	29	21	35	34	**0**	34	38
City	28	22	25	21	21	33	27	29	28	34	**0**	29
City	25	33	26	25	31	24	38	26	21	38	29	**0**

Table 3 show the cost of transportation between cities. Costs between nodes are assumed. Costs vary between 18 and 42. As it can be seen, going to city one to city two is the same cost as going from city two to city one and so on.

Table 4 shows the cost of opening a depot in each one of the 12 cities used for this problem. Costs vary between 11 and 29 units, this units can be seen as hundreds, thousands or other type of scale. In addition, the initial demand each city has. This values are between 35 and 64 units. As it was mentioned before, each unit weighs 5 pounds each one. For this work, the type of products being demanded are not specified.

Table 4: Cost and Initial demand of opening a depot for each city.

City	**Cost**	**Demand**
City 1	12	65
City 2	23	55
City 3	11	46
City 4	25	60
City 5	18	50
City 6	29	45
City 7	25	35
City 8	16	55
City 9	20	49
City 10	21	57
City 11	15	38
City 12	22	54

Table 5: Transportation type.

	City	City	City	City	City	City	City	City	City	City	City	City
City	0	1	2	3	3	2	4	4	2	3	4	1
City	1	0	2	2	4	2	3	1	4	3	2	2
City	2	2	0	3	3	2	4	1	4	2	1	3
City	3	3	3	0	4	2	4	3	1	2	3	3
City	3	4	3	4	0	2	1	2	3	1	2	4
City	2	2	2	2	2	0	2	2	1	4	3	4
City	4	3	4	4	1	2	0	1	1	2	4	3
City	4	1	1	3	2	2	1	0	2	4	1	2
City	2	4	4	1	3	1	1	2	0	1	3	2
City	3	3	2	2	1	4	2	4	1	0	4	1
City	4	2	1	3	2	3	4	1	3	4	0	1
City	1	2	3	3	4	4	3	2	2	1	1	0

Table 5 shows the transportation type used for each city. This information is necessary so it is possible to know later the capacity for each transportation method and the fuel consumption for each truck used. Table 6 shows the capacity of each truck used by each node in this study. Capacities depend on the transportation used by each city, each transportation method has different capacities: 50, 55, 65 and 70. Table 7 presents distance between cities, this distances do not have and specific unit, i.e. they could be kilometers or miles. Table 8 shows the road type assigned to each city in this research. As it was mentioned before, there are three different types used for this work, each city was assigned randomly with one of the three types of road for this study.

Table 6: Capacity of each truck.

City	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**	**City**
0	50	65	55	55	65	70	70	65	55	70	50
50	0	65	65	70	65	55	50	70	55	65	65
65	65	0	55	55	65	70	50	70	65	50	55
55	55	55	0	70	65	70	55	50	65	55	55
55	70	55	70	0	65	50	65	55	50	65	70
65	65	65	65	65	0	65	65	50	70	55	70
70	55	70	70	50	65	0	50	50	65	70	55
70	50	50	55	65	65	50	0	65	70	50	65
65	70	70	50	55	50	50	65	0	50	55	65
55	55	65	65	50	70	65	70	50	0	70	50
70	65	50	55	65	55	70	50	55	70	0	50
50	65	55	55	70	70	55	65	65	50	50	0

Table 7: Distance between cities.

	City	City	City	City	City	City	City	City	City	City	City	City
City	0	123	250	186	124	179	201	157	149	234	140	189
City	123	0	157	168	189	268	123	235	157	168	187	276
City	250	157	0	167	354	144	257	164	268	214	178	247
City	186	168	167	0	156	154	198	168	249	264	178	132
City	124	189	354	156	0	168	354	264	304	324	125	168
City	179	268	144	154	168	0	324	168	147	154	179	277
City	201	123	257	198	354	324	0	135	124	235	167	179
City	157	235	164	168	264	168	135	0	245	149	199	267
City	149	157	268	249	304	147	124	245	0	139	286	310
City	234	168	214	264	324	154	235	149	139	0	331	246
City	140	187	178	178	125	179	167	199	286	331	0	185
City	189	276	247	132	168	277	179	267	310	246	185	0

The Table 9 presents the type of road each city has to travel one to each other. And the three different types of routes used for this work were described: highway, urban and dirt road. In addition, Table 2 was mentioned the different road factors. Since each city was assigned randomly with one of them, road types were replaced with the actual road factor for each type. Table 10 shows the final outcome for this replacement. For the calculation of the mathematical formulations, other values are necessary. Those values were mentioned. Values B (weight of product per unit in pounds = 5 lb) and G (fuel consumption increased factor = 0.1 %) are necessary for the calculation of the formulas.

Table 8: Road type.

	City	City	City	City	City	City	City	City	City	City	City	City
City	0	3	2	1	2	3	1	1	3	3	2	1
City	1	0	2	1	3	1	2	2	2	3	1	1
City	2	1	0	2	2	3	1	3	1	2	3	2
City	2	2	1	0	3	1	3	3	3	1	2	3
City	3	2	2	2	0	3	2	1	1	1	2	2
City	1	2	2	3	1	0	3	3	2	2	3	1
City	1	1	3	1	1	2	0	1	2	3	1	3
City	3	1	1	2	2	3	1	0	3	1	3	3
City	2	3	1	1	3	1	1	3	0	3	1	2
City	1	2	3	2	3	3	2	2	1	0	2	1
City	3	1	2	3	2	2	3	2	3	2	0	3
City	2	1	3	1	1	2	3	1	2	3	1	0

Table 9 Road type for each city.

	City	City	City	City	City	City	City	City	City	City	City	City
City	0	1.3	1.2	1	1.2	1.3	1	1	1.3	1.3	1.2	1
City	1	0	1.2	1	1.3	1	1.2	1.2	1.2	1.3	1	1
City	1.2	1	0	1.2	1.2	1.3	1	1.3	1	1.2	1.3	1.2
City	1.2	1.2	1	0	1.3	1	1.3	1.3	1.3	1	1.2	1.3
City	1.3	1.2	1.2	1.2	0	1.3	1.2	1	1	1	1.2	1.2
City	1	1.2	1.2	1.3	1	0	1.3	1.3	1.2	1.2	1.3	1
City	1	1	1.3	1	1	1.2	0	1	1.2	1.3	1	1.3
City	1.3	1	1	1.2	1.2	1.3	1	0	1.3	1	1.3	1.3
City	1.2	1.3	1	1	1.3	1	1	1.3	0	1.3	1	1.2
City	1	1.2	1.3	1.2	1.3	1.3	1.2	1.2	1	0	1.2	1
City	1.3	1	1.2	1.3	1.2	1.2	1.3	1.2	1.3	1.2	0	1.3
City	1.2	1	1.3	1	1	1.2	1.3	1	1.2	1.3	1	0

Table 10: Transportation factor.

	City 1	City 2	City 3	City 4	City 5	City 6	City 7	City 8	City 9	City 10	City 11	City 12
City 1	0	0.548	1.266	0.512	0.512	1.266	1.192	1.192	1.266	0.512	1.192	0.548
City 2	0.548	0	1.266	1.266	1.192	1.266	0.512	0.548	1.192	0.512	1.266	1.266
City 3	1.266	1.266	0	0.512	0.512	1.266	1.192	0.548	1.192	1.266	0.548	0.512
City 4	0.512	0.512	0.512	0	1.192	1.266	1.192	0.512	0.548	1.266	0.512	0.512
City 5	0.512	1.192	0.512	1.192	0	1.266	0.548	1.266	0.512	0.548	1.266	1.192
City 6	1.266	1.266	1.266	1.266	1.266	0	1.266	1.266	0.548	1.192	0.512	1.192
City 7	1.192	0.512	1.192	1.192	0.548	1.266	0	0.548	0.548	1.266	1.192	0.512
City 8	1.192	0.548	0.548	0.512	1.266	1.266	0.548	0	1.266	1.192	0.548	1.266
City 9	1.266	1.192	1.192	0.548	0.512	0.548	0.548	1.266	0	0.548	0.512	1.266
City 10	0.512	0.512	1.266	1.266	0.548	1.192	1.266	1.192	0.548	0	1.192	0.548
City 11	1.192	1.266	0.548	0.512	1.266	0.512	1.192	0.548	0.512	1.192	0	0.548
City 12	0.548	1.266	0.512	0.512	1.192	1.192	0.512	1.266	1.266	0.548	0.548	0

B.Codification

For this work, assumptions are taken into account: Transportation cost and cost of opening a depot are given in US dollars. Costs are thousand dollars. For this research, costs are in scale. Opening a depot costs are capital costs. Fuel consumption takes into account if the transportation type is stopped. For the codification of the algorithm, MATLAB software was used. This codification consists initially of a binary matrix of 12x1. In this matrix, the MATLAB code choose randomly four cities to become a depot following the assumptions for this work, this matrix is called yi matrix. After matrix yi is generated, matrix xij is created; this is a 12x12 matrix, here, in the MATLAB codification, the cities that became depots will supply the demand for the remaining cities. Below, matrix yi and matrix xij are shown, this matrices show one of the multiple possible combinations.

Table 11: Matrix yi.

City 1	1
City 2	0
City 3	0
City 4	0
City 5	1
City 6	0
City 7	1
City 8	0
City 9	0
City 10	0
City 11	0
City 12	1

Cities 1, 5, 7 and 12 were chosen to operate as a depots to supply demand for the remaining cities.

Table 12: Matrix xij.

	City	City	City	City	City	City	City	City	City	City	City	City
City	0	1	0	0	0	0	1	0	0	0	1	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	0	0	0	1	0	0	0	1	0	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	1	0	0	0	0	1	0	0	0	1
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	0	0	0	0	0	0	0	0	0	0	0	0
City	1	0	0	1	1	0	0	0	1	0	0	0

In Table 12 it can be seen that cities that were chosen to operate as a depot will supply demand to themselves and to the remaining cities. In this codification, the three objectives are calculated separate but at the end they will conform a single solution due to the use of Pareto Front (using both fitness: diversity and dominance). This process was run iteratively.

C.Results

After running the MATLAB code for initial population size of 50, 100, 150 and 200 cuckoo to search the bird nests, with the codification and the parameters previously explained, these results were obtained:

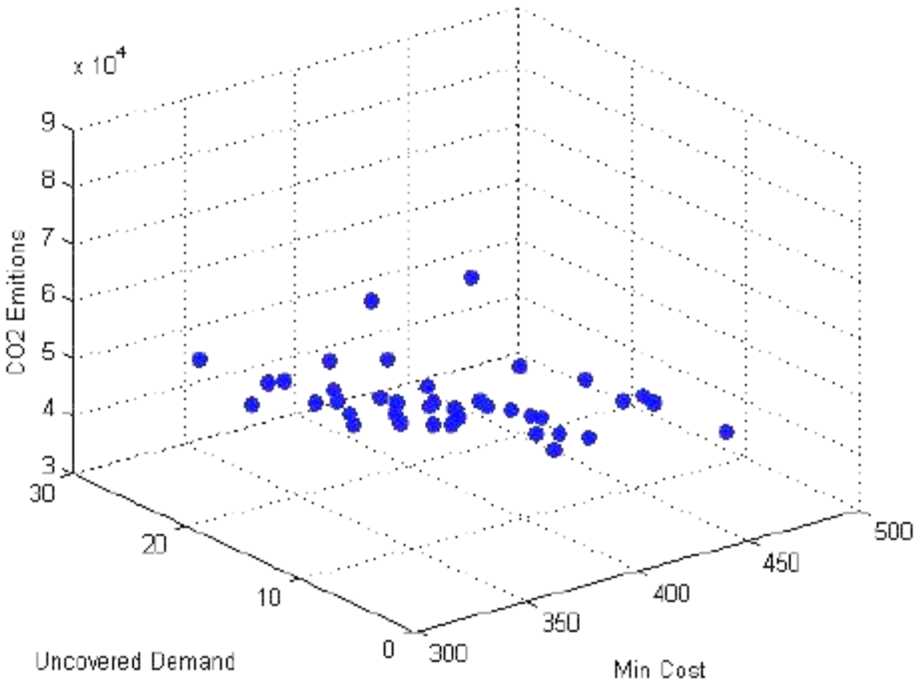

Fig 2: Pareto Front for an initial population of 50.

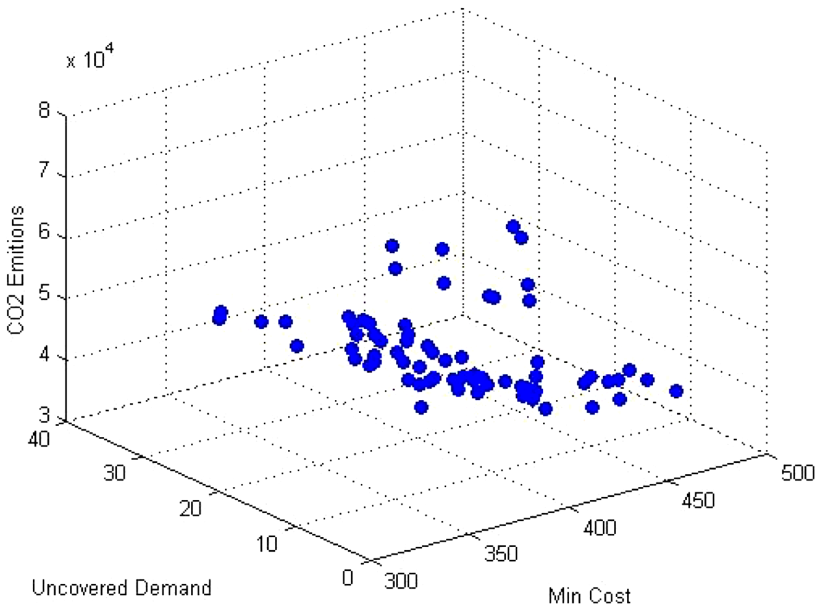

Fig 3: Pareto Front for an initial population of 100.

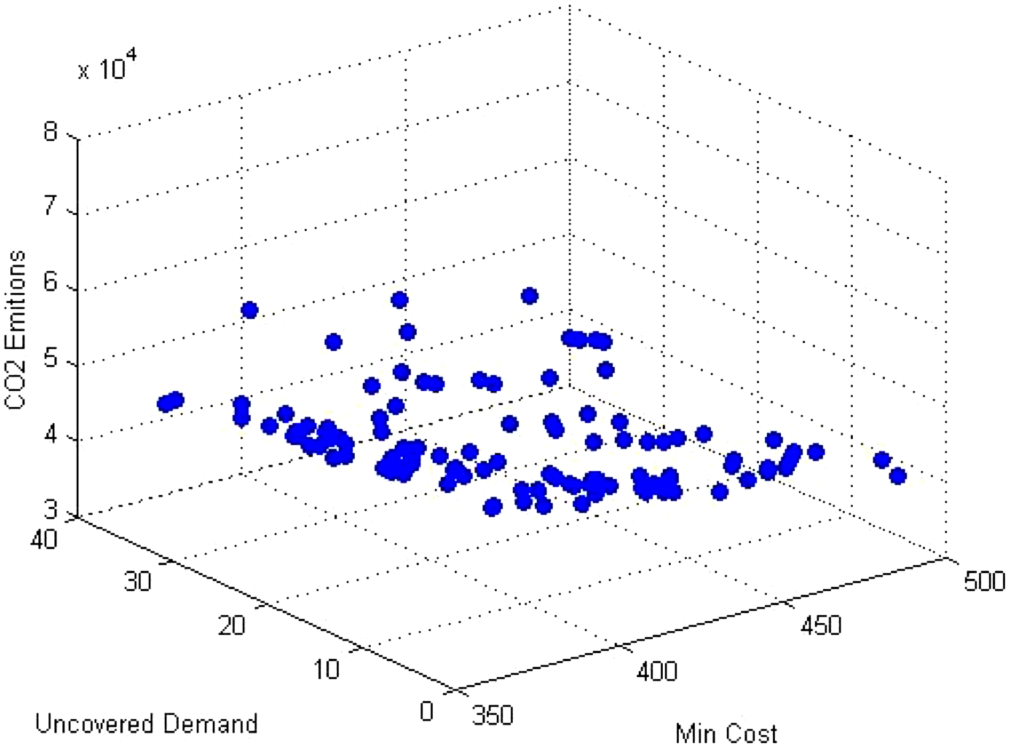

Fig 4: Pareto Front for an initial population of 150.

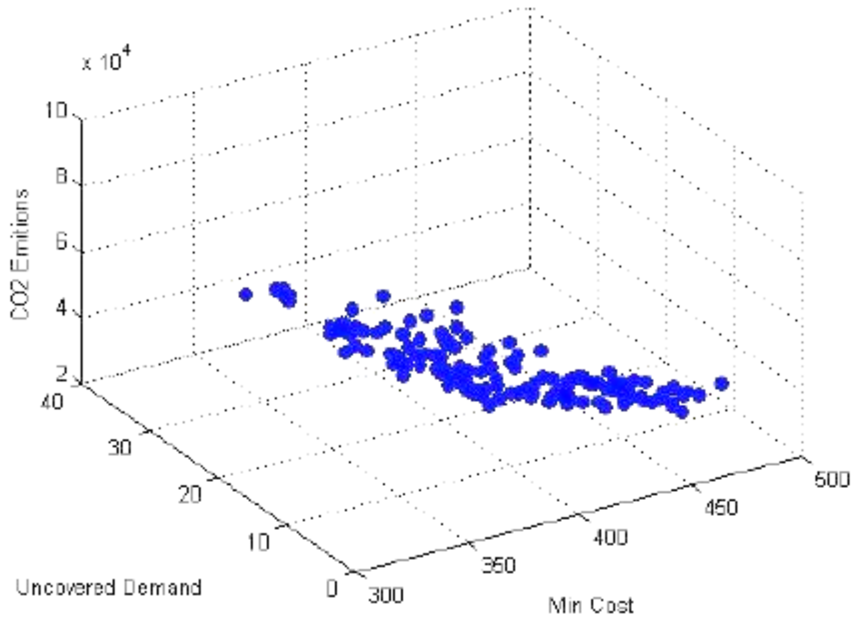

Fig 5: Pareto Front for an initial population of 200.

With a size of 200 cuckoo, the number of results was bigger in a short period of time.This solution was chosen to know the combination and configuration of matrix yi and xij. This solution was selected because apparently it was the one closest to point (0, 0).

5 CONCLUSION

A new method was proposed to find a set of good solutions. A numerical example was introduced in order to show how this modified Cuckoo searching Algorithm works. This research presented a different algorithm to solve a Multiple Objective Optimization Problem considering objectives as minimization of transportation cost and opening a new depot cost, minimization of uncovered demand and minimization of CO2 emissions to be optimize simultaneously. Since this work is a multiple-objective optimization problems, these three objectives are in conflict making optimization complicated. The new MOEA presented is "friendly" enough to be applied to these three objectives, but since this work is a heuristic method, it is impossible to guarantee an optimal solution, but a set of good solutions was obtained. This algorithm generated a set of non-dominated solutions, these results are good enough to be consider "optimal". The obtained solutions conform the Pareto Optimal set, but since they are in conflict a Post-Pareto analysis should be done.

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