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Investigating Modeling and Solving a Hybrid Problem Considering the Simultaneous Loading and Delivery of the Vehicle and the Locating of Facilities for Storing and Recycling in a Three-Level Green Supply Chain

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Abstract
Today, In this research, we intend to study the modeling and solving a hybrid problem considering the simultaneous loading and delivery of the vehicle and the locating of facilities for storing and recycling in a three-level green supply chain. This issue is known as 3-level mapping routing issue in the subject literature. With the goal of presenting a mathematical model for the vehicle routing problem and locating the storage facilities and recycling facilities in a green supply chain network, an efficient algorithm is developed to optimize the problem and compare the performance of the algorithm with known algorithms such as genetics. Also one of the other purposes is to find a combination of truck and facility paths so that results in minimum transfer costs in a direct and reverse manner. By reviewing the recent articles and discovering the existing research gap, we will develop a problem model with a specific application, and eventually we will overwrite the problem in the framework of the language of the meta-innovative algorithms to solve the problem by the meta-innovative method. To compare the efficiency of the meta-innovative algorithm developed in this research and its validation, we will compare the results with a precise method using GAMS software for small issues. Also, one of the genetic algorithms can be used to test the performance of the algorithm. This research is considered within the framework of applied research regarding the orientation, because using the results of this study, some suggestions can be made to solve specific problems in the organization. In addition, this research is a descriptive method in which mathematical and modeling tools are used.
Keywords: Logistic Network, Green Supply Chain, Locating and Routing Problem, Combined or Hybrid Meta-Innovative Algorithm

1. Introduction

One The intensification of the global competition in an ever-changing environment has made the need for appropriate responses from organizations and manufacturing companies to be doubled and insists on their flexibility with the unreliable foreign environment and today's organizations in the national and global arena are to obtain and maintain a suitable place need to use a suitable model such as supply chain management in order to realize the competitive advantage and expectations of customers. Customers in today's organizations are working along with the members of the organization in the production of goods and services, processes of doing things and processes, developing knowledge and competitive power. The effective supply chain management is one of the main sources of survival. Meanwhile, the use of information technology in supply chain activities has increased the potential for value creation in the chain. Generally, supply chain management emphasizes on corporate adaptability and flexibility, and has the ability to react quickly and effectively to market changes.

A set of methods used for the effective and efficient integration of suppliers, manufacturers, warehouses, and vendors in order to minimize system costs and meet service needs, the goods should be produced and delivered in the correct number and at the right time and time.

Supply chain management is the coordination in production, stock, locating and transportation among the participants in a supply chain, to achieve the best combination of accountability and efficiency for market success.

From among the objectives of supply chain management, we can refer to the reduction of costs or reduction of stocks, increasing responsibility against customers, improving supply chain relationship, reducing production cycle time, and improving coordination. One of the main challenges of supply chain management is the clients' demand to buy high quality products and services for lower cost, more appropriate delivery, more modern technology and longer lifespan, which ultimately lead to increased competition among manufacturers. In order to satisfy customers' demand at the right time, a set of issues have been developed, called vehicle routing.

Vehicle routing problem refers to a set of problems in which a number of vehicles concentrated in one or more locations should refer to a set of customers and provide a service that each has a specific demand. VRP can be investigated in a variety of situations, but vehicle routing with the capacity constraints of the primary example of a vehicle routing problem where all customers have a similar delivery date and a certain demand, there is no possibility of breaking demand. Also, all vehicles were the same and have a central base.

The cost of transportation of goods has always been a concern for producers, in order to reduce the cost of transportation, improve the competitiveness of goods in comparison with other similar goods and increase their profitability. That is why this issue has been investigated since the 1960s and many states of it are based on different applications in the real world.

1.1 Previous studies

Over the past two decades, the issue of strategic planning of supply chain networks has attracted the attention of researchers. Several review articles have been cnducted in this regard which will be discussed in more detail. Today, much research has been done on the field of LRP and VRP along with simultaneous loading and unloading, where we have introduced a number of articles for the past year.

In the work conducted by Saiyah et al., the problem of vehicle routing with the possibility of simultaneous unloading and loading is investigated and optimized using the ant colony algorithm [1]. In this work, the problem of routing the vehicle along the simultaneous unloading and loading as one of the issues of vehicle routing problem with the capacity limitations has been investigated. In this work, through the inspiration from the ants' movement in antler colony algorithm, we have tried to solve and optimize the problem using the three operators. The results of the algorithm developed on 68 sample problems up to 200 customers were investigated and indicated that this algorithm performs better than other meta-innovative methods.

In a study conducted by Karaoglan et al., the LRPSPD problem has been investigated and in order to solve the problem, two integer linear programming models of polynomial rank along with the family of effective inequalities are provided which allows the model to be solved [2]. In these two models, where one is based on nodes and the other is based on current, we tried to solve the models using a two-phase induction-based refrigeration simulation model where the results indicated that the flow-based model excels the other model in terms of computational complexity and final results.

In another study, a study was conducted on the CVRPSPD problem, which was done using an innovative method called the linear sweep algorithm for optimizing the problem [3]. The objective function in this problem is to minimize the number of machines and maximize the capacity of used cars.

In an article by Zhou et al., the issue of LRPSDP was investigated and the uses of this model have been investigated for online shopping [4]. In order to solve the problem, the genetic algorithm has been used along with a local explorer. In order to produce high-quality initial responses in this problem, a large population was produced using a two-phase method.

The problem of the distribution network [5] of the newspaper along with the recycling system has been formulated and solved using the VRP model. In this modeling, customer clustering has been used for routing, and loading and unloading is scheduled alongside the truck tour. In this work, the variable costs along with prohibited routes were investigated for the first time. In this paper, the data from a real issue in the state of Spain was studied regarding the nature of a kind of problem in literature. The meta-innovative firefly method is used to optimize the problem and its performance results have been compared with the two methods of genetic algorithm and refrigeration simulation.

The issue of VRPSPD has been studied as one of the common types of the classical VRP problem [6]. In this paper, the transport fleet is considered to be heterogeneous. In other words, the problem with the routing of the vehicle along with HVRPSPD is studied. In this article, a local search method and banned search method have been used to develop an efficient algorithm to solve the problem. The results are investigated based on a range of randomized issues that indicate good performance of the algorithm.

The problem of vehicle routing is classified as an NP-hard. However, all the parameters of this issue are considered to be decisive. By entering the uncertainty of the parameters, especially the demand parameter, the complexity problem becomes more complex. In a study conducted by Berhan, the issue of the vehicle routing problem simultaneous with unloading and loading has been studied in random conditions [7]. The study was conducted in Addis Ababa and has been planned for the Urban Public Transport Fleet. This issue is based on actual data and is solved using the Clark-Wright algorithm.

In another study, the VRPSPD issue was studied and solved using the genetic algorithm [8]. The two intersection and jump operators have been investigated in this article, and the algorithm performance has been investigated on a range of sample issues.

In this study [9], a specific work has been conducted on 3E-LRPSPD issue which we previously described in detail in the previous sections. Node-based modeling has been used to formulate the problem in this study, and the unbalanced set is used to solve the model. Also, the results of the proposed method on sample issues extracted from the literature of the subject have been reflected.

2. Methodology

The problem of LRPSPD is one of the NP-hard group, and the models presented in this field are not solvable through precise algorithms, especially in case of problems with medium and large dimensions, finding the optimal solution through these algorithms is impossible. The use of innovative and meta-innovative algorithms on these problems is essential in order to find optimal solutions. The algorithm developed in this study is similar to other algorithms in this set of issues in two stages of optimization. In the first stage, the problem of locating and finding the optimal distribution and recycling points is selected, and in the second, the problem of routing transport vehicles is solved using the output of the first stage. These two steps must be combined in such a way that the combination of this compound can help improve the results.

In this research, after the development of the initial solutions, we use the genetic algorithm to optimize and solve the problem.

2.1.Adjusting the Parameters of the Algorithm

In order to determine the optimal value of the effective parameters of the algorithm, we carried out numerous experiments to extract the outputs of the algorithm on the sample problem. The population of the algorithm is one of the determinant parameters in optimization, and the greater the number, the greater the search in the problem space and the greater the variety of answers. It should also be noted that the increase of this parameter also increases the volume of computations. The number of generations of genetic algorithms also determines the results; this parameter determines optimization in several steps. In each stage, a number of operators are applied to the population and are transferred to the next generation based on the merits of superior prototypes. By examining the convergence process of the algorithm results, it can determine how many generations are sufficient for optimization. Intersection and mutation rates are also adjusted according to the nature of the problem, and it should be noted that increasing the intersection rate will increase the local search and local optimization in the neighborhood of the discovered solutions, and the rate of leap to the contrary is optimized and through creating new solutions from other problem areas, it causes diversity in population and prevents early maturity of the results. The sudden matching of the population of the answer in the early generations of the algorithm is called early maturity.

According to the following diagram, which is the output of the genetic algorithm on the sample problem, we can find that the optimal global answer is obtained by the algorithm and the values of the target function in the GAMS software and the developed algorithm are equal. Also, thorough details of the response include the variables X, YP, YR, ZP, and ZR are also matched.

In the following figure, you see the algorithm's convergence method; in this figure, the best obtained answer is determined by the algorithm with green triangles, the best sample answer in the generation is determined by the blue stars, the mean value of the target function in the population with a yellow plus sign, and the worst answer of the population was determined by red. As can be seen, after the 50th generation, no development has been observed in the optimum amount of the algorithm, and the best answer has remained fixed and other answers have been drawn to this answer. By continuing this process, the other symbols on the diagram will also be pulled to this value, and there will be further convergence where the continuation of generations after the 80th generation has stoped due to the heaviness of the calculation. The following table summarizes the results of numerous algorithm performances.

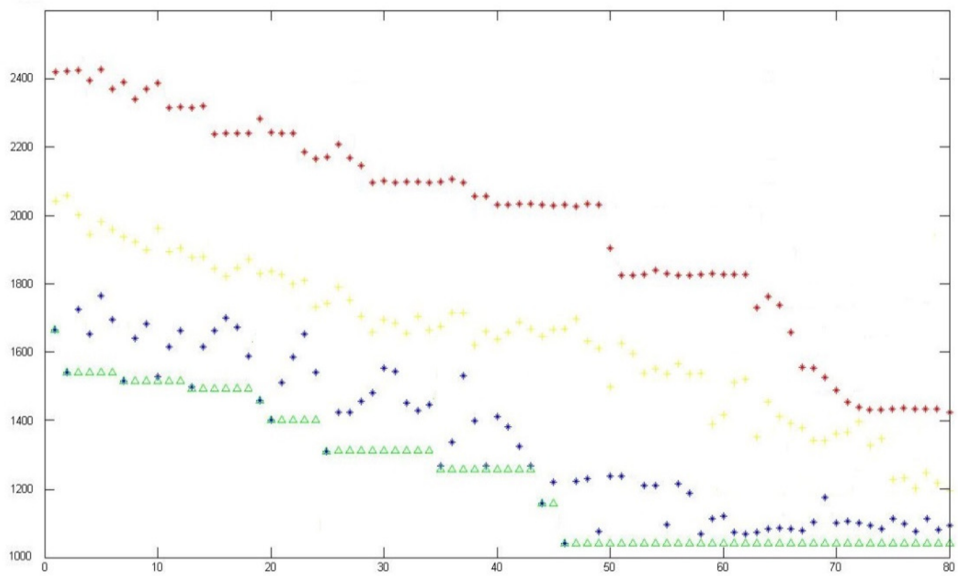

Figure 1. The diagram of the convergence of the algorithm developed to the optimal answer

In the above implementation, after performing more than 50 test runs, we were able to extract the optimal output from the algorithm, which resulted in a global optimal response in accordance with the GAMS software; that is, this is the optimal solution to the problem. In this way, the algorithm performance can be validly validated and tested to solve higher-dimensional problems.

In the final implementation of the algorithm that the generated results were obtained, the parameters of the algorithm were set as the following.

Table 1. Table of final values of parameters of the developed algorithm

Mutation operator rate	Intersection operator rate	Number of generations	Number of population
Pmu	Pcr	Ngen	Npop
0.2	0.8	80	10

3. Investigating the Performance of the Algorithm

The proposed meta-innovatuve algorithm has been implemented and codified on MATLAB software, and all issues have been addressed on an Intel Core i7 2.60GHz laptop with 8GB of RAM.

Sample problems generated for the LRPSPD problem have been categorized according to the test set produced by Prodhon [10].

This problem sample consists of 28 samples, in which the number of customers varies between 20 to 100, and the number of distribution facilities varies from 5 to 10, and customers' demand in these problems is based on the univariate distribution of U [11,20] and the capacity of the distribution facilities isconsidered in such a way that at least 2 or 3 facilities can be set up. In these problems, no demand for return has been raised, and we consider the customers' demand for returning according to their demand considering the unilateral distribution of U [5,15], using the problem examined in the reciprocating models. The capacity of recycling facilities is also defined so that at least 2 or 3 facilities are set up. For the capacity of the vehicle, we also consider two capacities of 100 and 275; these two numbers represent two different vehicles, such as pickups and trucks. The distances between nodes are also calculated using Euclidean soft. The fixed cost of setting up the facility is estimated using the generalization of the amount included in the primary problem sample to other issues. The fixed cost of using fixed-duty vehicles is considered constant.

A general overview of issues that will be randomly generated will be presented in the following table. In this table, the total number of nodes of the problem, as well as the number of nodes related to the customers, distribution and recycling facilities, as well as the number of problem samples of each type are mentioned. For each issue, 6 repetitions are considered to eliminate the effect of the random parameters of the problem.

Table 2. Number of customers, distribution and recycling nodes on sample problems

Problems	The number of nodes	The number of customers	Distribution	Recycling	The capacity of the vehicle	The number of samples
Small scale	16	10	3	3	100	6
					275	6
	23	15	4	4	100	6
					275	6
	30	20	5	5	100	6
					275	6
	35	25	5	5	100	6
					275	6
	40	30	5	5	100	6
					275	6
Medium scale	60	50	5	5	100	6
					275	6
	70	60	5	5	100	6
					275	6
	80	60	10	10	100	6
					275	6
	80	70	5	5	100	6
					275	6
	90	70	10	10	100	6
					275	6
	90	80	5	5	100	6
					275	6
	100	80	10	10	100	6
					275	6

Problems	The number of nodes	The number of customers	Distribution	Recycling	The capacity of the vehicle	The number of samples
	100	90	5	5	100	6
					275	6
	110	90	10	10	100	6
					100	6
	110	100	5	5	275	6
					100	6
	120	100	10	10	275	6
					100	6

In this division, we put the problems below 50 nodes as small issues and problems with more than 50 nodes on the middle class.

After the implementation of the proposed algorithm on the sample problems, the obtained results were extracted in the table. As you can see, the execution time of the algorithm for each sample problem category is provided in the last column of the table indicating a very slow growth of the solving time and by 10 times increasing the number of customers, this incremental time is less than 10 times. As mentioned above, in order to examine the effect of the capacity of machines on the answer, the capacity of the device was examined in two sizes of 100 and 275, which is listed in column 6 of the table, and the next column is the number of times the algorithm is executed for each problem. Since the production of data for these problems is random, by doing so, you can neutralize the random effects of the input data and get a more general result to the problem. The number of times the algorithm runs for each problem is provided in the seventh column. In the next column, the mean value of the target function is specified, and the next column is the number of optimal vehicles for conducting problem tours.

By examining the trend of the value of the objective function from problems with 10 customers toward problems with 30 customers we can observe that this is an incremental increase which is a normal trand due to the increasing demand, because the increase in demand leads to an increase in vehicle tours and an increase in the number of distribution facilities and recycling. The interesting point is the reduction of the cost of the distribution system by increasing the capacity of the devices. This will reduce the number of vehicles and the meeting of the demand of the customers by a smaller number of vehicles.

Table 3. Results from the proposed algorithm on sample problems in small scales

			The number of facilities				The information of the obtained responses		
Problems	The number of nodes	The number of customers	Distribution	Recycling	The capacity of the vehicle	The number of samples	Average cost	Number of vehicles	Average execution of the algorithm
Small scale	16	10	3	3	100	6	7453.97	8.50	0.93
					275	6	6380.36	3.17	0.81
	23	15	4	4	100	6	13311.07	9.67	1.49
					275	6	12415.89	4.83	1.37
	30	20	5	5	100	6	17659.99	10.67	2.18
					275	6	16019.29	7.67	2.20
	35	25	5	5	100	6	23449.29	12.33	1.88
					275	6	17116.51	8.33	1.90
	40	30	5	5	100	6	36772.11	15.80	2.43
					275	6	18295.30	9.67	2.34

Considering that the demand distribution function of return has been taken into account as monotonic, considering the average return demand for each customer, we will have an average of 25 units of demand per node, where depending on the number of nodes in each stage, we can see that the number of vehicles ismore than the necessary amount. For example, for a 40-node problem that includes 30 customer nodes and 5 distribution and recycling facilities, we need about 1,000 units of demand, where considering vehicles with the capacity of 100, we will need 10 vehicles where with an optimize allocation of machines, we need about 16 vw=ehicles. Therefore, it can be estimated that about 62% of the space of the vehicles is occupied and 38% is left vacant.

Table 4. Results from the proposed algorithm on sample problems in small scales

			The number of facilities				The information of the obtained responses		
Problems	The number of nodes	The number of customers	Distribution	Recycling	The capacity of the vehicle	The number of samples	Average cost	Number of vehicles	Average execution of the algorithm
Medium scale	60	50	5	5	100	6	40804.63	18.98	3.80
					275	6	19871.62	10.40	3.95
	70	60	5	5	100	6	41024.71	21.92	4.53
					275	6	20908.16	9.71	3.97
	80	60	10	10	100	6	42955.96	23.33	5.43
					275	6	20285.95	10.60	4.22
	80	70	5	5	100	6	43680.30	25.50	5.92
					275	6	20324.65	14.44	5.22
	90	70	10	10	100	6	43964.47	26.71	6.65
					275	6	23836.37	14.28	5.93
	90	80	5	5	100	6	45285.18	36.71	6.76
					275	6	25240.39	14.36	6.60
	100	80	10	10	100	6	46285.18	38.92	6.78
					275	6	26410.39	22.57	7.13
	100	90	5	5	100	6	49620.96	39.98	6.93
					275	6	27868.72	25.94	7.93
	110	90	10	10	100	6	50367.96	53.27	7.21
					275	6	28359.72	28.59	8.44
	110	100	5	5	100	6	51600.85	59.18	7.44
					275	6	28709.90	34.23	9.41
	120	100	10	5	100	6	52410.73	63.27	7.54
					275	6	29259.41	38.34	9.45

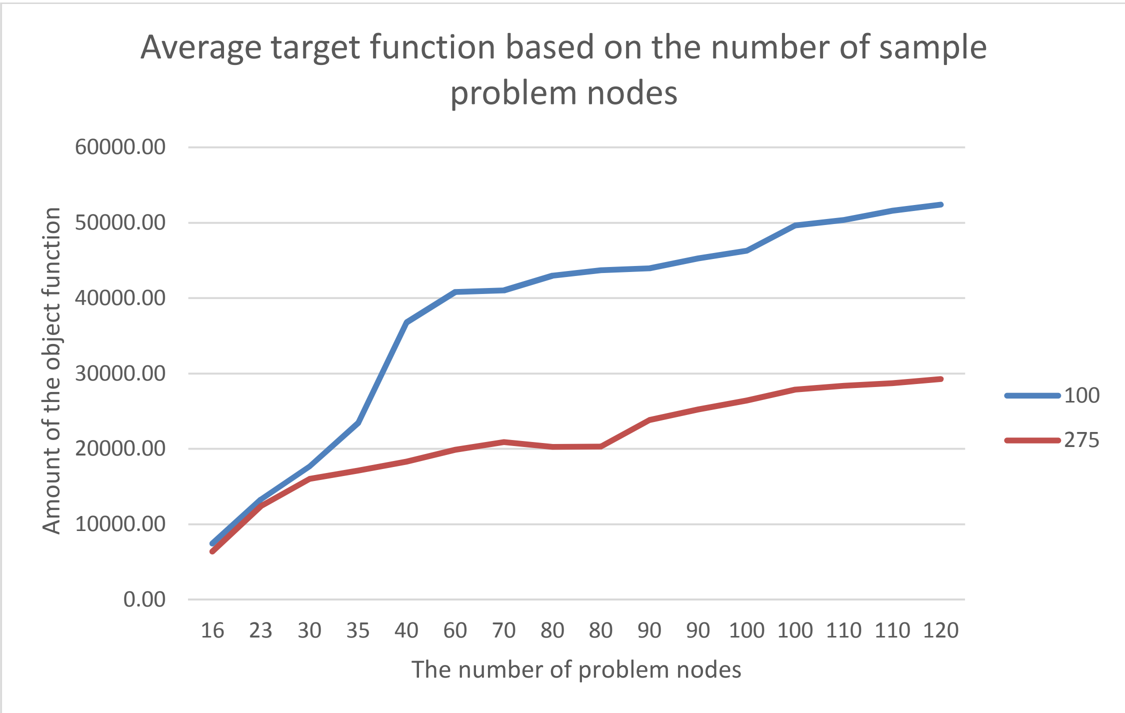

Figure 2. The diagram of the target function behavior for vehicles with a capacity of 100 and 275 in various problems

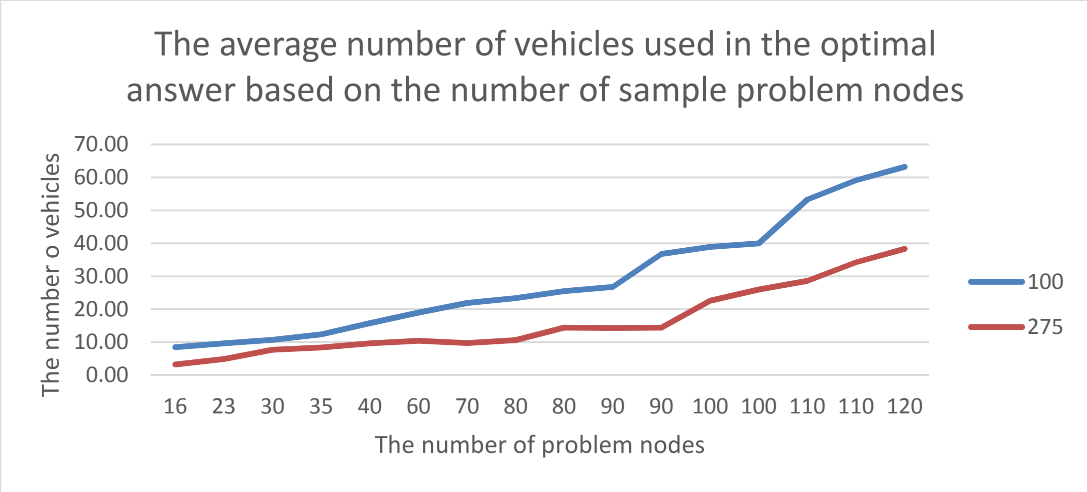

Figure 3. The behavior diagram of the number of vehicles used in the optimal answer based on the number of problem nodes

In order to compare the speed of the algorithm in solving the problems with a definite answer, we compared one of the above problems with the GAMS software, which is indicated in the table below. As can be seen, the optimal answer for the proposed algorithm has a difference of 1158, which represents a 2% gap with an optimal answer. In contrast, the solving time of these two methods has also been stated that the significant difference in the speed of the proposed algorithm is clear; it can be said that this algorithm is 15 times faster than the GAMS software.

Table 5. Comparing the answer to one of the problems with the GAMS software

The number of nodes	The number of customers	Distribution	Recycling	The capacity of the vehicles	The number of samples	The average of costs	The number of vehicles	The average time of executing the algorithm	The optimal response of GAMs	Time of GAMs
90	70	10	10	100	6	43964.47	26.71	6.65	42806.00	103.57

Algorithm: The Genetic Meta-Innovative Algorithm for the LRPSPD Problem
Input: Problem data, problem parameters (C, FP, FR, FV, CV, CP, CR, ...) and algorithm (Npop, Pmu, Pcr, Ngen, ...)
Output: The best possible answer (Sbest, X *, YP *, YR *, ZP *, ZR *)
Step 1: Using the ECWA algorithm, Npop initial response is generated for the problem and calculate the values of the target function for these responses.
Step 2: For the Ngen, we repeat the following loop.
Step 2.1: we select the parent responses for the intersection operator with the Pcr rate and if the child's responses are justified, about 13 answers of each pair are generated (for this we create a random number for each parent response, if the rate is lower, the response is selected).
Step 2.2: We mutate the parent responses with the Pmu rate and generate new mutant responses.
Step 2.3. We calculate the values of the objective function or fitness function for the new responses. We save the best value so far.
Step 2.4: Using the roulette wheel mechanism, we randomly select the number of the next generation's selected responses.
Step 2.5. If none of the stopping conditions is reached, return to step 2.1.
Step 3: we extract the best population response as an optimal response.

4. Conclusion

In this research, the problem of locating and routing vehicles was studied in a two-level supply chain by considering the distribution depots and recycling centers. In this problem, the customers were considered with a demand of sending and receiving that both requests are met at the same time as the vehicle is visited by the vehicle. The comprised tours had the restriction that by beginning a distribution storehouse and visiting several customers, go to one of the recycle storehouses and return to the nearest distribution storehouse. Modeling this problem was done by examining the literature in a mathematical form and an MIP model was presented for this problem. In order to solve the model, a new algorithm was developed which performs optimization and problem solving by combining an innovative method to produce an initial response and a well-known meta-innovative genetic algorithm. After developing the model, the GAMS software was used in order to validate the algorithm where the results of the proposed algorithm and the GAMS software on the sample problem which was designed in a small scale indicated that the algorithm was validated and the algorithm was able to quickly reach the optimal global response in accordance with GAMS. In order to adjust the parameters of the corresponding algorithm, several implementations with different parameter series were performed, and the final parameters were announced eventually. In the implementation of the genetic algorithm, the validity of the answer is examined in each step and if not justified, the response to this response is deleted. In general, one can say:

1. In this research, a mathematical model for the 3E-LRPSPD problem was provided for locating the storage and recycling facilities in a network which is classified in the category of MIP models and is in the category of ultra-difficult problems.
2. In order to optimize the problem, an innovative algorithm was developed, which is the result of combining an innovative method with the well-known ultra-innovative algorithm. The function of this algorithm is acceptable in the accuracy of the answer, and its significant speed ensures its efficiency.
3- In this research, the optimal location of the distribution and recycling facilities was determined from the proposed nodes and the optimal truck tours were designed from these nodes starting from the distribution warehouse and passage of customers and the recycling and returning storehouse to the distribution storehouse. In performing the tours and during the visits to trucks from the customers' nodes receiving and sending requests of the customers were simultaneously performed.
4. In this study, some limitations were set for the full satisfaction of customers 'demand, so that the justified response is one where all the sent and received demands of the customers are placed on sufficient capacity tours.
5. In this research, the transport fleet was considered to be homogeneous, so that only one type of vehicle is involved carrying the load.

We also came up with the following results in this study:

1- The use of zero and one variables for activation and absence of facilities and routes between customer, distribution and recycling nodes, by observing the capacity limitations of facilities, vehicles, and the demand of our customers, we reached an MIP mathematical model.
2. In this modeling, by defining mathematical constraints on the formed tours that were stored in variable X, we could plan our preferred tours, starting from the storehouse and passing through the customers and visiting the recycling center and returning to storehouse, and by defining the particular operators that were previously defined, we made it possible to optimize these tours.
3. By examining the way the trucks were transporting between the nodes, we were able to calculate the optimal number of trucks to satisfy customers' demand and returning the returned goods.
4. We were able to perform the optimal locating of storehouses and recycling facilities and routing the trucks in order to minimize the cost of the system.

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