Modeling a bi-objective load-dependent depreciation location-routing problem with simultaneous pickup and deliverydemand within a time window and solving it using NSGAII algorithm

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Abstract

This research is a location-routing problemthat considerslocation, allocation, and routing issues in a 3-layer supply chain madeof factories, distributorswith candidate locations, and retailers.The purpose of solving the problem is to minimize the system costs as well as delivery time to retailers so that the optimum routing is resultedand the best places for distributors are located.

Adding some constraints, we have tried to make the problem more real. The service start time of any retailers has hard and soft time-windows, with all of them having a simultaneous request for delivery and loading.The system costsincludetransportation costs, breaking the soft time-windows, construction of a distributor, renting or purchasing a vehicle, and production costs. Constraintson vehicle fuel and travel time per day,shipping routes, and the amount of fuel available in the vehicle are also considered.The objective function of this system is to minimize cost and time, andthe vehicle load-dependent fuel cost.In this research, the conceptual model of the problem is defined, modeled, and solved in small dimensions by GAMS software and NSGAII and MOPSO algorithms.

Keywords: LRP, Soft and hard time-window, Fuel constraint, Multi-objective, Vehicle load-dependent fuel cost, NSGAII, MOPSO,

1. Introduction

Location-Routing Problems (LRPs) combine two basic planning tasks in logistics.In LRPs,astheirnameimplies,decisionsonthelocationofarbitrarytypesoffacilities(plants,depots,warehouses,hubs,cross-docks,etc.)arejointlytakenwithdecisionsonthe routingofvehicles.
Itiswell-knownthatmakingthesetypesofdecisionsindependentlyofoneanothermayleadtohighlysuboptimal planningresults (Salhi, 1989).
Wedefinethetermlocation-routingproblem(LRP)asamathematicaloptimization problemwhereatleastthefollowingtwotypesofdecisionsmustbemadeinterdependently:

(i) Whichfacilitiesoutofafiniteorinfinitesetofpotentialonesshouldbeused(foracertainpurpose)?
(ii) Whichvehicleroutesshouldbebuilt,i.e.,whichcustomer clustersshouldbeformedandinwhichsequenceshouldthe customersineachclusterbevisitedbyavehiclefromagivenfleet(toperformacertainservice)?

Contrary to the basic VRP which calls for the minimization of the distance travelled, the Load-dependent Depreciation Vehicle Routing Problem (LDDVRP) objective is aimed at minimizing the total product of the distance travelled and the gross weight carried along this distance. Thus, the depreciation cost of fleet is minimized.

In the general form of LDDLRP, it is often assumed that customers have only delivery demand and it is interested in how to distribute the goods to customers with a fleet of vehicles, which can service all type of customers. However, in practice, with the development of reverse logistics and just-in-time strategy application, more and moreenterprises realize that satisfying the customers' simultaneous delivery and pick-up demand in reasonable time window can enhance the customers' satisfaction, and reduce operation cost. By taking into consideration this kind of demand structure of customers, in this paper, we present a load-dependent depreciation location routing problem with heterogeneous fleet, simultaneous pickup-delivery and time windows (LDDLRPHFSPDTW), which is a variant of the LRP. The LDDLRPHFSPDTW arises in a number of reverse logistics contexts. For example in beverage industry such as beer, juice, etc., empty bottles are collected for recycling when merchandise orders are delivered to customers, and each customer is serviced by exactly one vehicle within its time windows.In LRP_s with time window, each customer must beserved at a specific time window. If vehicles arrive before the time window "opens" or after the time window "closes," there will be waiting cost and late cost. Customers receive service within the specified period, i.e., they are not served sooner or later (Huang, 2021). An example of this would be perishable products,where not following the time window is forbidden.

The LDDLRPHFSPDTWconsists of two main sub-problems: the location routing problem with simultaneous pickup-delivery (LRPSPD) and the load-dependent depreciation vehicle routing problem (LCVRP). Since both problems belong to the class of NP-hard problems, the LDDLRPHFSPDTW is also a non-polynomial (NP) problem. Due to the difficulty of the problem itself, to the best of our knowledge, there is no previous study on the LDDLRPHFSPDTW in the literature.Therefore, to solve theLDDLRPHFSPDTW, we propose a mixed integer programming formulation for the problem.Furthermore, as our problem is a bi-objective one, we solve small sizes of problem using two evolutionary algorithms that originally search the decision space in a continuous manner including: (1) multi-objective particle swarm optimization (MOPSO) and (2) non-dominated sorting genetic algorithm (NSGA)-II.

2. Literature Review

Since the load-dependent depreciation for location routing problem with heterogeneous fleet, simultaneous pickup-delivery and time windows is not addressed in the literature, we briefly review the related literature to this problem.

In 1981, Schrage (Schrage, 1981) proposed vehicle routing and scheduling problem with time window constraints as an important area for progress in handling realistic complications and generalizations of the basic routing model. Feng (Feng, 2011) divide the VRPTW with delivery and pickup into five categories. Wang and Lang (Lang, 2008) proposes multi-period vehicle routing problem with recurring dynamic time windows.

In the general form of LRP, it is often assumed that customers have only delivery demand. Mehrjerdi et al. proposed a greedy clustering method (GCM) to solve the capacitated location routing problem (Mehrjerdi Y Z, 2013)with fuzzy demands.Prodhon(C., 2011) proposed a nonlinear mathematical model for the periodic location-routing problem and designed a hybrid evolutionary algorithm.The location routing problem with simultaneous pickup-delivery is an extension of the LRP in terms of types of the customers' demand, which was first proposed by Karaoglan(Karaoglan, 2012). They proposed a nonlinear mathematical model for the LRPSPD and designed a two-phased heuristic approach based on simulated annealing algorithm to solve the problem.

In many VRP problems, the travel distance between customers or the total travel time between cities is considered as a cost and becomes an objective function. In the real world, it is sometimes necessary to calculate other costs such as minimizing vehicles, travel time, and reducing waiting time (Yutao Qi, 2015). Therefore, it is necessary to use special techniques to calculate the objective function. Such problems are called multi-objective vehicle routing problems(MOVRP).

3. Problem Definition

In this problem, a three-layer supply chain with factoriesat the highest, distributorsat the second, and retailersat the lowest level is considered. There are candidate sites for distributors to be located, while retailers and vehicles are to be assigned to these distributors, as well as shipping routes being designed from distributors to retailers.A heterogeneous fleet of vehicles is available for delivery of products to retailers, in which vehicles have different speeds, capacities, fuel consumption, and purchase costs.After being located,the distributors must be assigned to a factory. Each vehicle is assigned to only one distributor, and the start and end of its route would be from the same place. Two time windows, hard and soft, are defined as time limits for serving retailers. The hard time window, [a_i, bi], means that it is not allowed for a retailer i to be servedearlier than time a_i and later than time b_i.The soft time window,[Es_i, Ls_i],is in place to penalize those deliveries done earlier than time Es_i and later than timeLs_i. This deviation will continue as long as the hard time window is not violated.Every retailer has two types of definite demand;delivery and pickup. Basedon the former, products are loaded from the distributor and delivered to the retailer, while the latter is a basis for vehicle to be loaded in retailer zone and continues its path to the distributor.

The system costs in this research include the cost oftransportation, the fixed cost of using the vehicles, the cost of distributors being constructed in candidate locations, the cost of breaking the soft time window, and the cost of production.

There are two types of retailers, R_1 and R_2. The type R_1 retailers are those with fuel station while R2 retailers does not have any.Each retailer is serviced only once ina route and by one vehicle. Each vehicle is used in one route only and is assigned to only one distributor. Anotherconstraint of the problem is the time limit for returning the vehicle to a distributor. In other words, a time limit is defined for returning to the distributor.Loading (pickup) operation for each retailer is done after delivery of goods.In terms of system costs

4. Mathematical model

Sets

D	Distributor Candidate Location Set
F	Set of Factories
R	Set of Retailers
K	Set of Vehicles
R_1	Set ofRetailer locations where it is possible to refuel.
R_2	Set ofRetailer locations where it is not possible to refuel.

Parameters

r_i	Amount of delivery request from retailer i
Pi	Amount of pickups request from retailer i
S_i	Service time to retailer i (unloadingoperation)
Q_k	Loading (pickups) capacity of each vehicle k
a_i	The earliest time allowed to service the retailer i in a hard time window
b_i	The latesttime allowed to service the retailer i in a hard time window
M	Optional large number
ES_i	The earliest time allowed to service the retailer i in the soft time window
LS_i	The latesttime allowed to service the retailer i in the soft time window
W_2	Cost per unit time deviation from the earliest time allowed in the soft time window
W_3	Cost per unit time deviation from the latesttime allowed in the soft time window
$fix_k^{/}$	Fixed cost of using a vehicle k
C	Cost of consuming one unit of fuel
fix_d	Cost of constructing a distributor candidate location d
AT	Minimum amount of fuel allowed in the vehicle
DAY	The length of a working day
dx_{ij}	Distance from node i to node j
full	Fuel tank capacity
V_k	Speed of k Vehicle
cap_d	Candidate capacity location of the distributor d
$\overline{cap}_f$	Capacity of factory f
FC_k	The amount of fuel consumption of the vehicle k per unit distance

Decision variables

X_{ijkd}	Variable zero and one, if the vehicle k belonging to distributor d travels from node i to node j is equal to one and otherwise, it is equal to zero.
ts_i	Time to start service to the retailer i
$L0_k$	The amount of load on the vehicle k when leaving the distributor
L_j	The amount of cargo remaining on the vehicle after servicing the retailer j
Z_d	Variable zero and one; If the distributor d is constructed, it is equal to one; otherwise it is equal to zero.
E_i	Time deviation from the earliest time allowed to serve the retailer i in the soft time

	window
L_i	Time deviation from the latest time allowed to serve the retailer at the end of vehicle k route in the soft time window
sf_k	Return time of vehicle k to the distributor
de_d	Distributor Center d Demand
Y_{df}	Variable zero and one; If distributor d is assigned to factory f, it is equal to one; otherwise it is equal to zero.
A_i	Determines the amount of fuel on the vehicle
$cost_i$	Depreciation cost due to the amount of load on the vehicle from the retailer i to the next node
ic_{kd}	Depreciation cost due to the amount of load on the vehicle from thedistributor d related to vehicle k to the first retailer of each route

$$\min \sum_{k\in K}\sum_{d\in D}\sum_{j\in R\cup D}\sum_{i\in R\cup D} X_{ijkd}\,.FC_k.dx_{ij}.\mathrm{C}\ ,+W_2.\sum_{i\in R} E_i + W_3.\sum_{i\in R} L_i + \sum_{d\in D} Z_d.fix_d.$$

$$+\sum_{d\in D}\sum_{k\in K}\sum_{i\in R} X_{dikd}.fix_k^{/} + \sum_{f\in F} Y_{df}.de_d.Cp_f + \sum_{i\in R} cost_i + \sum_{d\in D}\sum_{k\in K} ic_{kd}$$

The first objective function is to minimize the set of costs.The first part is related to the objective function,representing the replacement cost. The second and third parts are the cost of not complying withthe soft time window. The fourth part is the fixed cost of the distributor. The fifth part represents the fixed cost of the vehicle, and the sixth part represents the cost of production.The seventh and eighth parts are the costs ofdepreciationresulted from the load on the vehicles.

$$\min z \sum_{i\epsilon R} ts_i$$

The service time is minimized in the second objective function.

Subject to:

1. $\sum_{d\in D}\sum_{k\in K}\sum_{i\in R\cup D} X_{ijkd} = 1 \qquad ,\forall j \in R$
2. $\qquad ,\forall d \in D, k \in K$
3. $\sum_{i\in D\cup R} X_{ijkd} = \sum_{i\in D\cup R} X_{jikd} \qquad ,\forall d \in D, k \in K, j \in R$
4. $\sum_{d\in D}\sum_{i\in R\cup D} X_{dikd} \leq 1 \qquad ,\forall k \in K$
5. $\sum_{i\in D, i\neq d}\sum_{j\in R} X_{ijkd} = 0 \qquad ,\forall d \in D, k \in K$

6. $\sum_{i \in R} \sum_{j \in D, j \neq d} X_{ijkd} = 0$ $\quad , \forall d \in D, k \in K$

7 $X_{iikd}=0$ $\quad , \forall d \in D, k \in K, i \in D \cup R$

8. $S_i + \frac{dx_{ij}}{V_k} + TS_i - M.\left(1 - X_{ijkd}\right) \leq S_j$ $\quad , \forall d \in D, k \in K, i \in D \cup R, j \in R$

9. $S_i + \frac{dx_{ij}}{V_k} + TS_i + M.\left(1 - X_{ijkd}\right) \geq S_j$ $\quad , \forall d \in D, k \in K, i \in D \cup R, j \in R$

10. $S_d = 0$ $\quad , \forall d \in D$

11. $a_i \leq S_i \leq b_i$ $\quad , \forall i \in R$

12. $LO_k = \sum_{d \in D} \sum_{i \in R \cup D} \sum_{j \in R} r_j \times X_{ijkd}$ $\quad , \forall k \in K$

13. $LO_k \leq Q_k$ $\quad , \forall k \in K$

14. $L_j \geq LO_k - r_j + p_j - M.\left(1 - X_{djkd}\right)$ $\quad , \forall d \in D, k \in K, j \in R$

15. $L_j \leq LO_k - r_j + p_j + M.\left(1 - X_{djkd}\right)$ $\quad , \forall d \in D, k \in K, j \in R$

16. $L_j \geq L_i - r_j + p_j - M.(1 - \sum_{d \in v_d} \sum_{k \in K} X_{ijkd})$ $\quad , \forall j \in R , i \in R$

17. $L_j \leq L_i - r_j + p_j + M.(1 - \sum_{d \in v_d} \sum_{k \in K} X_{ijkd})$ $\quad , \forall j \in R, i \in R$

18. $L_j.(\sum_{d \in D} \sum_{i \in R \cup D} X_{ijkd}) \leq Q_k$ $\quad , \forall j \in R$

19. $\mathrm{E_i} \geq (\mathrm{ES_i} - \mathrm{S_i})$ $\quad , \forall \mathrm{i} \in R$

20 $L_i \geq (S_i - LS_i),$ $\quad , \forall \mathrm{i} \in R$

21 $\mathrm{A_i} = \mathrm{full}$ $\quad , \forall i \in R_1$

22 $\mathrm{A_i} \leq A_j - dx_{ji}.FC_k + M.\left(1 - X_{jikd}\right)$, $\quad \forall i \in R_2, j \in R \cup D, k \in K, d \in D$

23 $\mathrm{A_i} \geq \mathrm{AT}$ $\quad , \forall \mathrm{i} \in \mathrm{R}$

24 $Z_d.M \geq \sum_{k \in K} \sum_{i \in R} X_{dikd}$ $\quad , \forall d \in D$

25. $M.\sum_{f \in F} Y_{df} \geq Z_d$ $\quad , \forall d \in D$

26. $de_d = \sum_{k \in K} \sum_{i \in R \cup D} \sum_{j \in R} de_d \times X_{ijkd}$ $\quad , \forall d \in D$

27. $de_d = cap_d$ $\quad , \forall d \in D$

28. $\sum_{f \in F} Y_{df}.de_d \leq \overline{cap}_f$ $\quad , \forall f \in F$

29. $SF_k \geq S_i + \frac{dx_{id}}{V_k} - M.(1 - X_{idkd})$ $\quad , \forall k \in K, i \in R, d \in D$

30 $SF_k \leq \mathrm{DAY}$ $\quad , \forall k \in K,$

31. $ic_{kd} \geq LO_{dk}.d_{di}.cw - M.(1 - X_{dikd})$ $, \forall d \in D, k \in K, i \in R$

32. $\mathrm{ic_{kd}} \leq \mathrm{LO_{dk}}.\mathrm{d_{di}}.\mathrm{cw} + \mathrm{M}.(1 - \mathrm{X_{dikd}})$ $, \forall d \in D, k \in K, i \in R$

33. $cost_i \geq L_i.d_{ij}.cw - M.\left(1 - X_{ijkd}\right)$ $, \forall d \in D, k \in K, j \in R \cup D, i \in R$

34. $cost_i \leq L_i.d_{ij}.cw + M.\left(1 - X_{ijkd}\right)$ $, \forall d \in D, k \in K, j \in R \cup D, i \in R$

35. $X_{ijkd}, Z_d, Y_{df} = 0 \; or \; 1$

36 $L_j, S_{iu}, LO_{dk}, cost_i, ic_{kd} \; \geq 0$

Constraint (1) ensures that a vehicle is imported into each retailer.

Constraint (2), any vehicle that leaves the distributor returns to the same distributor at the end of the route.

Constraint (3) ensures thatthe same vehicle that enters that node to serve each retailer exits that node.

Constraint(4): Each vehicle is used in only one distributor.

Constraint (5, 6) Ensures that if a vehicle leaves a distributor, that vehicle belongs only to that distributor.

Constraint (7): there is no edge from each node to itself.

Constraint(8 and 9) calculate the start time of service to each retailer.

Constraint(10): The start time of the vehicle is zero.

Constraint(11) Ensures compliance with the hard time window limit.

Constraint (12) calculates the amount of initial loading (pickups) of the vehicle.

Constraint (13) examines the capacity limit of the vehicle for initial loading (pickups) of the vehicle.

Constraint (14, 15) Calculatethe amount of load on the vehicle after leaving the first retailer along the route.

Constraint(16, 17) Calculate the amount of load on the vehicle after leaving the rest of the retailers.

Constraint(18) examines the vehicle capacity limit for the amount of load on the vehicle along the route.

Constraint(19) calculatesthe amount of deviation from the soft time window for retailers.

Constraint(19 and 20) calculate the amount of deviation from the soft time window for retailers.

Constraint(21) indicates thatthe amount of fuel in the vehicle fuel tank is completely full at the end of the service to retailers where refueling is possible.

Constraint (22) Calculates the amount of fuel in the vehicle's fuel tank at the end of service to retailers where refueling is impossible.

Constraint(23)ensures that the vehicle fuel limit is met.

Constraint (24) specifies established distributors.

Constraint (25): Each constructed distributor is allocated to a factory.

Constraint(26) calculates the demand of each distributor.

Constraint (27) examines the demand constraints of each distributor.

Constraint (28) examines the demand constraints of each factory.

Constraint(29) Calculates the travel time for each vehicle.

Constraint (30) examines the time limit of the travel length in a day.

Constraint(31, 32) Calculate the depreciation cost due to the vehicle'sload from each warehouse to the first retailer on each route.

Constraint(33, 34) Calculate the depreciation cost due to the vehicle'sload fromretailer i to the next node

Constraint (33) specifies variables zero and one.

Constraint (34) specifies variables greater than or equal to zero.

5. Solution by Multi-Objective non-dominated sorting genetic algorithm (NSGA-II)

The NSGAII algorithm is a well-known algorithm in which a population of answers is generated first.A proper reproductive process causes the parents to be selected at each stage. New children are formed from the selected parentswith some of the characteristics of parents, and children can better reproduce.Some components of the NSGAII algorithm have the following features.

4.1. Initial answer display

In this research, the initial answer consists of three parts. The first part includes (n + k-1) house.If n is the number of retailers, k is the number of vehicles.The initial answer consists of a row with n + k -1 cells containing ordinal numbers 1 to n + k-1.The numbers 1 to n is the retailer number.The number n + 1 to n + k-1 indicate the arrival and delivery of the vehicle to the distributors, which means the route's end and the use of another vehicle.The order of the numbers inside the columns indicates the order of service to retailers.The number n + i represents the vehicle i. The retailers that precede it represent the retailers that are serviced by that vehicle, respectively.If there is no retailer number before the vehicle number, it means that none of the retailers have been assigned to that vehicle, and the vehicle has not been used.All retailers that are located after the last vehicle number are allocated to the latest vehicles, respectively.In this section, retailers are assigned to vehicles.The second part includes (k + d-1) house.kis the number of vehicles, and d is the number of candidate locations for the construction of distributors.In this section, similar to the previous section, the used vehicles are allocated to distributors.The third part includes (d + f-1) house in which d is the number of distributors and f is the number of factories. This part, like the previous parts, the used distributors are allocated to the factories.

To better understand this issue, an example of aninitial answer display is given.This example is shown in Figure 4-1, where there are eight retailers, three vehicles, and three distributor candidate locations.In the first part, the numbers 1 to 8 represent the retailers, and the numbers 9 and 10 represent the first and second distributors.According to Figure 1, retailers 4, 6, 8 are serviced by the first vehicle, retailers 1, 3 are serviced by the second vehicle, and retailers 7, 2, and 5 are serviced by the third vehicle.In the second part, the numbers 1 to 3 indicate the number of vehicles, and the numbers 4 and 5 indicate the first and second distributors.According to the provided answer, the first and second vehicles are assigned to the first distributor, and the third vehicle is assigned to the second distributor.In this answer, a third distributor is not established.In the third part, the numbers 1 to 3 indicate the number of distributors, and the number 4 indicates the first factory. According to the provided answer, the first distributor is assigned to the second factory, and the second distributor is assigned to the second factory.

4	6	8	9	1	3	10	7	2	5

1	2	5	3	4

3	2	4	1

Figure1.Example of the solution matrix

Table2.soloution of example

Retailers	Distributor	Number of vehicle	Rout
2	1	1	4-6-8
2	1	2	1-3
1	2	3	7-2-5

4.2. Parental selection

In the proposed algorithm, new parents are selected after calculating the fitting of the objective function of each chromosome and sorting the population based on the overcoming conditions to create a new population. The tournament method has been used for each time of parental selection.In this method, the first two chromosomes are randomly selected. Each of the answers that were in the better rank will be selected as the first parent. The two chromosomes are first randomly selected to select the second parent, and the answer with a better rank is selected as the second parent.

4.3. Crossover operator for producing new children

The two-point crossover method has been used to create new children after selecting two parents by the tournament method. In this method, two crossover points are randomly selectedfor each part of theinitial binary answer.The genes between these two points are passed directly to the first offspring in the first parent, and the remaining genes are copied in the first offspring in the first offspring, respectively.

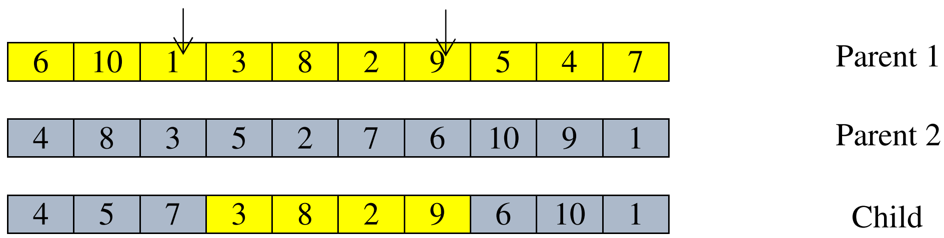

Figure2.crossover operator for each part

4.4. Mutation operator

Each child may change randomly to generate a random number after implementing the crossover operator. If this number is less than the mutation rate, the child is changed by the mutation operator.In the first step, the two genes are randomly selected for genetic mutation, and in the second step, the numbers inside the two genes are swapped.

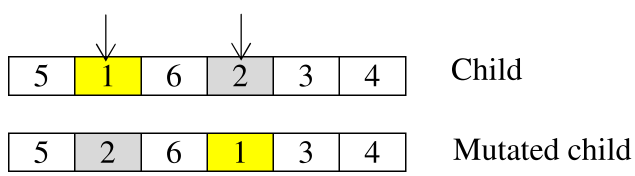

Figure3. Mutation operation for each part

6. Numerical results

An example is generated with eight retailers and three candidate locations for distributors and two factories randomly to verify the validity of the proposed model. The obtained answer GAMS software is reviewed and analyzed.Complianceof constraints and correctness of the value of the objective function from GAMS software is checked to verify the model.The GAMS softwareanswer is shown schematically in Figure 4.In this answer, the distributor is constructed in locations 1 and 2 and not constructed in the third place.In both distributors, two vehicles are used, and Figure 7 represents the routes.The bestobjective function value obtained from GAMS softwarewas 2323 for the first objective function and 521 for the second objective function. The calculations show that the obtained values were exact.

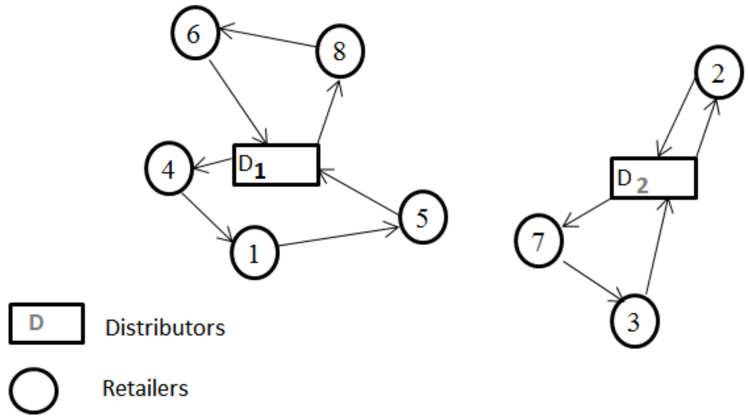

Figure4.Problem Solving

The soft and hard time window limitations are examined to check the problem'sconstraints, and the results are shown in Figures 5 and 6. In each chart, the first and last time of service delivery is specified in the time window along with the real-time of service delivery. According to Figures 1 and 2, both constraints comply.

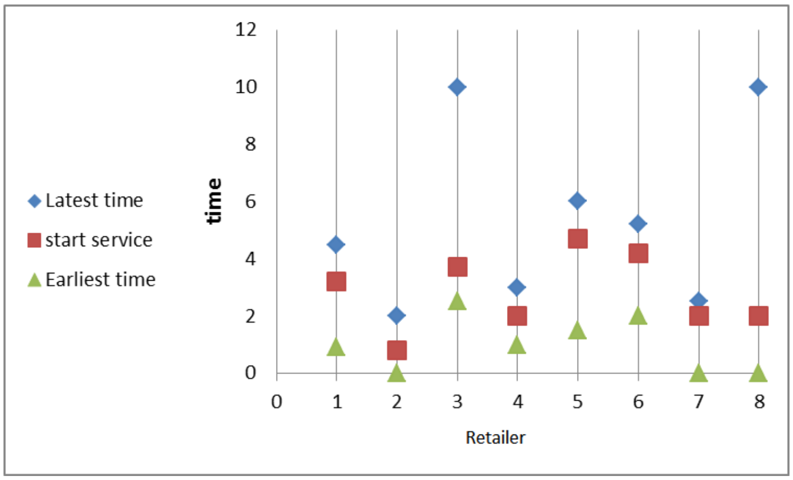

Figure 5.Compliance check for soft time windows

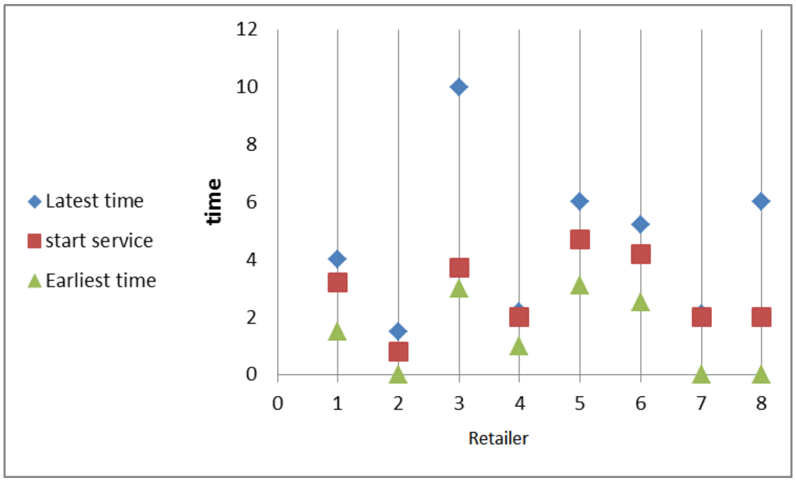

Figure 6.Compliance check for hard time windows

Figure 7 examines the initial loading (pickups) constraints. Figure 8 evaluates the constraint of load on the vehicle. As shown in Figure 7, number 1 means distributor 1 route 1,number 2 means distributor 1 route2,number 3 means distributor 2 route1, and number 4 means distributor 2 route2.The constraint of the amount of load on the vehicle has never been violated in Figures 7 and 8.

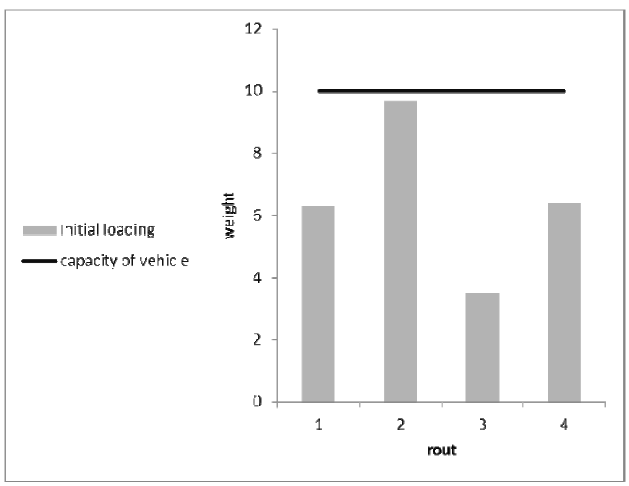

Figure 7.Compliance check for initial loading constraint

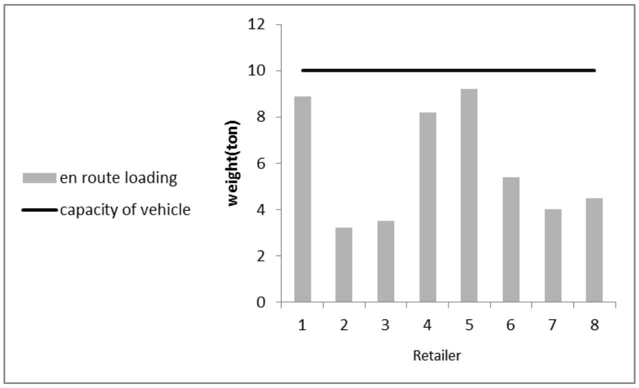

Figure 8.Compliance check for en route loading constraint

In the next step, small-scale examples were randomly generated, solved, and compared by GAMS software and genetic algorithm to evaluate the proposed NSGAII algorithm and placed in Table 5.

The small-scale design problem was implemented using the proposed GAMSsoftware and NSGAII algorithm, and the results are given in Tables 3 and 4.Table ? shows that the value of the exact answer deviation obtained from GAMSsoftware and the answer of the NSGAII algorithm for the values of the first and second objective functions have an acceptable deviation.Accordingly, the proposed NSGAII algorithm has good performance in small dimensions.

Table3.Comparison of the answerof NSGAIIwith the exact solution in small sizes for of first objective function

Number of retailers	Mean NSGAII	Gams	Gap%	Exact
N=4	1160	1160	0%	1160
N=5	2061	2047	0%	2047
N=6	2124.2	2120	0.2%	2120
N=7	2259.7	2253	0.3%	2253
N=8	2339.5	2329	0.5%	2329
N=9	3342.5	3320	0.7%	3320
N=10	3682.4	3658	0.7%	3658

Table4.Comparison of the answerof NSGAII with the exact solution in small sizes for the second objective function

Number of retailers	NSGAII	Gams	Gap%	Exact
N=4	153	153	0%	1160
N=5	183	183	0%	2047
N=6	201	201	0%	2120

N=7	225.4	225	0.2%	2253
N=8	238.7	238	0.3%	2329
N=9	252.8	251	0.7%	3320
N=10	306.8	304	0.9%	3650

It is not possible to solve the problem with Gomez software or other exact methods by enlarging the dimensions of the problem. Hence, examples were created, and the NSGAII and MOPSO algorithms were solved to evaluate the performance of the NSGAII algorithm in large dimensions. Tables 5 and 6 indicate an acceptable deviation between the mean of the answers from NSGAII and MOPSO and the superiority of NSGAII algorithm values.

Table5. Comparison of the answer of NSGAII and MOPSO in large sizes for the first objective

	NSGAII	MOPSO	scattering GA
N=30	10251	10269	0.2%
N=50	48351	48396	0.1%
N=100	73896	73987	0.2%

Table6. Comparison of the answer of NSGAII and MOPSO in large sizes for the second objective

	NSGAII	MOPSO	scattering GA
N=30	1236	1239	0.2%
N=50	1538	1546	0.4%
N=100	2369	2378	0.4%

6. Conclusions and future research

The presented model in this research has complex and frequent constraints and conditions. New decision variables make modeling attractive.At the beginning of the research, a conceptual model was presented for the expression problem. Then, a mathematical model was considered according to this conceptual model, and the accuracy and efficiency of the model were checked and confirmed by solving a random example by GAMS software.Since the problem is complex and the exact solution method of an NSGAII algorithm for a small-scale problem is presented, the algorithm'sefficiency is proved in large and small dimensionsin the next step. As future research, demand can be considered random, or warehouse candidate areas can be considered uncertain or continuous, or the problem can be considered as three objectives, and minimizing greenhouse gas emissions can be added to the objectives of the problem. Furthermore, other metaheuristic methods can be applied to solve the problem.

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