International Journal of Industrial Engineering and Operational Research (IJIEOR)

Contents lists available at IJIEOR

International Journal of Industrial Engineering and Operational Research

journal homepage: http://ijieor.ir

Volume 6, No. 1, 2024

Modeling and Solving the Warehouse Location Problem and Vehicle Routing by Considering the Depreciation Depending Cost on the Amount of Load On the Vehicle by Hybrid Genetic Algorithm

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ARTICLE INFO

Received: 2024/01/05

Revised: 2024/01/25

Accept: 2024/02/12

Keywords:

Hybrid Genetic Algorithm, Vehicle Routing Problem, Route Type, Multiple Warehouses, Time Limit.

ABSTRACT

The vehicle routing problem (VRP) is one of the most well-known topics in complex combinatorial optimization problems. In the current research, several warehouses send goods to customers. The start time of the service has two timed windows, hard and soft, and each customer has a request for delivery and loading at the same time. The main goal of solving the minimization problem is to minimize system costs, including displacement, fixed cost of vehicles, cost of not respecting the soft time window, and additional cost due to depreciation caused by the amount of load on the vehicle. In this research, first, the conceptual model of the problem is defined and modelled, and then, considering the complexity of the problem, a hybrid genetic algorithm is used. In this hybrid genetic algorithm, the particle swarm algorithm first creates the initial population, and neighbourhood search is used in each step after mutation.

1. Introduction

The transport routing problem was first introduced (Psaraftis H., 1980) was raised. The classical VRP problem includes several customers, each with a certain level of demand. A central warehouse supplies this demand. Each customer is precisely once by one device vehicle and is serviced. The goal of solving the problem is to find a path that serves all customers and has the

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Available online 02/13/2024

2676-3311/BGSA Ltd.

lowest cost. The costs of the problem include the distance and the number of vehicles (Barrie M. Baker, 2003, Mingzhou Jin, 2008). The most straightforward VRP problem can be considered the travelling salesman problem. In the travelling salesman problem, all customers are visited on the same route, and the travelling salesman does not have a load capacity limit (D.L. Applegate, 2006) . VRP is one of the problems for which an exact answer has not been provided in large sizes, and as the volume of examples expands, solving the problem using precise methods, including LINGO software or GAMS or other exact solution methods, becomes impossible. So far, different types of VRP problems have been raised, and certain restrictions and conditions have been added to this problem. Based on that, various types of VRP problems with different names, characteristics, new solutions, and modelling have been invented.

2. Background research

Over time, various types of VRP problems have been created, and each of these types of vehicle routing problems has different models and features.

If the capacity constraint is added to the existing problem, the CVRP problem will be converted. In the CVRP problem, the vehicle has a limited capacity. Therefore, using multiple vehicles or routes may be necessary instead of one vehicle. But such matters have no distance limit (T.K. Ralphs, 2004).

If there is a travel length limit (in terms of distance or time) to DVRP, it is said that, therefore, we will face two types of constraints in these issues. One is the constraint of the vehicle capacity, and the other is the maximum distance the vehicle travels in one route (P. Toth, 2002).

With forgiveness, time conditions, and constraints, there are new questions for VRP with a time window when hard one from these constraints is. At the issues, VRP with time window when a hard customer with the request specified to the device one navy carry transfer homogenous that the capacity of each the device vehicle limited is, serves first and end of every direction to store the end done and service to the customer at the period when special do accept, and it is not possible to perform service outside this period. Here is also a target, minimal to-do space for a trip. Customers in the period specified done service receive they do that mean sooner and later from the time specified service are not (jean berger, 2004). This problem is abbreviated as VRPTW said by solomon (solomon, 1987) it has been invented. A strict time window is defined for serving each customer; that is, the vehicle is allowed to serve the customer in a certain period, which means that the goods must be delivered to the customer within the time frame (a, b), for example in the case of perishable foods, it is forbidden to eat them too late or too soon. Such issues are abbreviated VRPTW is shown.

Single-wareroom problems are attractive and easy, but they are not suitable for companies with more than one warehouse, and sometimes more than one warehouse is considered a problem (Sašo Karakatič, 2015) is called a multi-warehouse routing problem (MDVRP); each customer is served by only one warehouse, and each route starts from the same warehouse and ends at the same warehouse (Somayeh Allahyari, 2015, Thibaut Vidal, 2015)

In solving VRP problems, the goal is to minimize costs. In many VRP problems, the travel distance between customers or the total travel time between cities is considered a cost and placed in the objective function. But in the real world, sometimes there is a need to calculate other costs, such as minimizing the number of vehicles used, travel time, and waiting time (Yutao Qi, 2015) Therefore, it is necessary to use special techniques to calculate the objective function. Such problems are called multi-objective transport routing problems (MOVRP); for example, it is possible to mention reducing the number of vehicles and minimizing the distance travelled by the vehicle.

However, another type of VRP problem involves two types of customers. The customer delivered the first type of goods from the warehouse. The second type of customer includes suppliers who send goods to the warehouse. This is one of the issues of VRPB (Daniel Palhazi Cuervo, 2014).

In some studies, researchers, information question particle for direct object specific at opinion do not get but given i see possible or fuzzy considered to be. Because the information we have about the problem is not certain. In VRP with request fuzzy information can from roy experience to hand came to be to as example said will be that request customer about 40 is the mean unit for example between 20 up to 70 the unit is that this the amount of can one number fuzzy triangular be (erbao cao, 2010).

In some other articles, customer demand is determined randomly; for example, it is said that customer demand follows a continuous uniform distribution function (charles gauvin, 2014). One from constraint hi addition done at the issues VRP navy the device vehicle heterogeneous is. Give means that level loading equipment vehicles together different (çağrı koç, 2014). In some issues, VRP speed equipment vehicles in the days were different, and there was a difference, and the same will not always be the same (yiyo kuoa, 2009). In the matter of classic VRP or the same simple service to customer in a day item opinion is but in a different way than the issues VRP is called periodic [11]servicing at one the period when at commented will be that this time may be two or how many days be (lúcia m.a. Drummond, 2001).

One other topic question VRP at the state of time window when soft VRPSTW is the problem of the device vehicle with time window when soft like the device vehicle classic has one store central been and the number of customer existence it has to be serviced. Target minimal to do cost movement is. The time window when discussing done sign the giver constraint when at one period may be this period has the earliest and the latest time it is the start of service. At the face compliance not doing this period, cost compliance not doing window when to additional costs will be (ali kourank beheshti, 2015).

One of the new conditions and restrictions is simultaneous delivery and loading. This means that after receiving the goods from the vehicle, the customer should deliver other goods to the vehicle to return to the warehouse, which is one of the new topics in the field of VRP issues. In these cases, the customer receives and sends the goods simultaneously (a. Serdar tasan, 2012). This type of problem is abbreviated as VRPSDP.

Classic vehicle routing problems include the warehouse, the customer, and the vehicles to serve the customers. In these issues, the vehicle loads the desired load from the warehouse, serves the customers along the way, and returns to the warehouse again. In these issues, the number of vehicles and warehouses is limited. Vehicles cannot accommodate more than their capacity (duygu taş, 2014)

The capacity of each vehicle has a limit, and each vehicle can move a certain amount of load; according to this issue, the initial loading of the vehicle in each load must be less than the capacity of the vehicle, as well as the amount of available load along the way. On the vehicle, it should be less than the capacity of the vehicle.

This research includes some of these constraints and features in one article. The existence of several constraints together in one problem increases the complexity of the model and requires new modelling. In addition, considering the cost of depreciation depending on the load on the vehicle is also an innovation that did not exist in previous articles.

3. Description and explanation of the problem

In this article, a problem of water location and water path has been investigated. In the first step, the number of candidate places for building a warehouse is chosen according to reducing system costs and providing timely service. The duty of serving customers is the responsibility of warehouses and vehicles belonging to them. Two time frames are defined as time limits for customer service. The first constraint is the hard time window. In a hard time window, allow serving customer i earlier than time a_i and later than time b_i does not exist. The second constraint is the soft time limit period once [Es_i, Ls_i], meaning that if you serve the customer i sooner from time Es_i and later from time Ls_i if it is done, the customer will be serviced, but the system will be fined, but this deviation will continue until the strict time window is not violated, in which case no service will be performed at that time. In this system, vehicles are homogeneous, and vehicle capacity is limited. Therefore, the initial loading and load on the vehicle during the route cannot exceed the vehicle's capacity. Each customer has two types of demand. Delivery requests are based on which goods are loaded from the warehouse and delivered to the customer, and loading requests are based on when the goods are loaded from the customer and returned to the warehouse. There are candidate locations for warehouse selection. The cost of building the warehouse is added to the system for each selected warehouse. One of the objectives of the problem is to determine a route that starts from a specific warehouse and returns to the same warehouse at the end of the route. Each warehouse has several vehicles that can be used. A fixed fee is imposed on the system for each means of transportation used. In this study, the system costs include the following.:

The cost of moving the means of transportation along each route

- The fixed cost of using transportation
- The cost of building a warehouse in the candidate's of the warehouse
- Not respecting the soft time window.
- The amount of cargo causes the cost of depreciation on the means of transportation.

In this matter, the following constraints should be observed to be observed:

- Every route r it starts from a warehouse and ends in the same warehouse.
- Every customer is only at y k mess y r, and it is a means of transmission it is serviced.
- Any means of transportation in one route is only used and assigned to one warehouse.
- For each customer, the loading operation is done after the delivery of the goods.

- All vehicles are homogeneous in all warehouses.
- The maximum load on the vehicle at any point of the route does not exceed the vehicle's capacity.
- The hard time window constraint is not violated in any way.

3.1 Mathematical model

In the desired mathematical model, in the graph $G = (V, E)$, V represents the set of points, and E is the set of graphs. Set V into two sets $V c = \{V 1,\dots, V c\}$ and $V d = \{V n +1,\dots, V n + d \}$ is divided and represents the set of its customers and the set of warehouses and n .The display shows the total number of customers and d is the total number of warehouses. The customers are divided into two types: type C_1 and type C_2. C_1 type customers are the customers whose vehicles can be refuelled at the location, and C_2 are customers whose vehicles cannot refuel at the customer's location.

The symbols defined in the developed model are as follows:

Sets

V_d	A set of candidate locations for warehouses
V_c	The set of customers
V	Collection of customers and warehouses
K	Collection of vehicles
C_1	A collection of customer locations where refuelling is possible
C_2	A set of customer locations where refuelling is not possible

Parameters

R_i	The amount of the customer's transfer request i
Pi	Demand amount Customer loading i
S_i	Customer service time i
n_d	The number of vehicles available at the candidate warehouse location d
t_{ij}	Travel time between nodes i and J
Q	T container Loading any means of transportation.
i	The earliest time allowed to serve the customer i in the time window hard.
b_i	The latest time allowed to serve the customer i in a tight time window.
M	Any large number
ES_i	The earliest time allowed to serve the customer i in the soft time window.
LS_i	The latest time allowed to serve the customer i in the soft time window.
$W2$	The cost of one unit of time deviation from the earliest time allowed in the soft time window
W_3	The cost of one unit of time deviation from the latest time allowed in the soft time window
$W1$	The cost of moving the vehicle per unit of distance
N	The number of vehicles available for each candidate warehouse location
F	The fixed cost of using a means of transportation
fix_d	The cost of building a candidate warehouse d
TS_i	Customer service time i

AT	The minimum amount of fuel allowed in the vehicle
cp_{ji}	Vehicle fuel consumption from node i to node j

Decision variables

X_{ijkd}	and one, if the means of transfer k belonging to warehouse d moves from node i to node j is equal to one and otherwise equal to zero
S_i	Time to start serving to node i
$L0_{dk}$	The load on the transport vehicle k when leaving the warehouse d
Lj	Amount of remaining load on the means of transmission k after serving the customer J
Z_d	Variable zero and one, if the warehouse d is equal to one and otherwise equal to zero
y_i	A variable created to prevent the creation of sub tours
E_i	Time deviation from the earliest time allowed to serve the customer i in the soft time window
L_i	Time deviation from the latest time allowed to serve the customer i in the soft time window
ic_{kd}	Depreciation cost depending on the amount of cargo on the vehicle related to vehicle k when leaving the warehouse d until the vehicle reaches the first customer
$cost_i$	The cost of depreciation depends on the amount of cargo on the vehicle when transporting goods from customer i to the next customer

$$\min\ z = W_1.\sum_{k\in K}\sum_{d\in v_d}\sum_{j\in v}\sum_{i\in v} X_{ijkd} + W_2.\sum_{i\in v_c} E_i + W_3.\sum_{i\in v_c} L_i + \sum_{d\in v_d}\sum_{k\in K}\sum_{i\in v_c} X_{dikd}.F + \sum_{i\in v_c} cost_i + \sum_{d\in v_d}\sum_{k\in K} ic_{kd} + \sum_{d\in v_d}\sum_{k\in K} Z_d\,.fix_d$$

Subject to:

$$\sum_{d\in v_d}\sum_{k\in K}\sum_{i\in v} X_{ijkd} = 1, \qquad \forall j \in v_c \qquad (1)$$

$$\sum_{i\in v} X_{dikd} = \sum_{i\in v} X_{idkd}, \qquad \forall d \in v_d, k \in K \qquad (2)$$

$$\sum_{i\in v_d}\sum_{j\in v_d} X_{ijkd} = 0, \qquad \forall d \in v_d, k \in K \qquad (3)$$

$$X_{iikd} = 0, \qquad \forall d \in v_d, k \in K, i \in v \qquad (4)$$

$$\sum_{j\in v_c} X_{djkd} \le n, \qquad \forall d \in v_d, k \in K \qquad (5)$$

$$\sum_{i\in v} X_{ihkd} = \sum_{i\in v} X_{hikd}, \qquad \forall d \in v_d, k \in K, h \in v_c \qquad (6)$$

$$y_j \ge y_i + 1 - M\left(1 - X_{ijkd}\right), \qquad \forall d \in v_d, k \in K, i \in v_c, j \in v_c \qquad (7)$$

$$\sum_{i\in v_d, i\neq d}\sum_{j\in v_c} X_{ijkd} = 0, \qquad \forall d \in v_d, k \in K \qquad (8)$$

$$\sum_{i\in v_c}\sum_{j\in v_d, j\neq d} X_{ijkd} = 0, \qquad \forall d \in v_d, k \in K \qquad (9)$$

$$S_i + T_{ij} + TS_i - M\left(1 - X_{ijkd}\right) \le S_j, \qquad \forall d \in v_d, k \in K, i \in v, j \in v_c \qquad (10)$$

$$S_i + T_{ij} + TS_i + M\left(1 - X_{ijkd}\right) \geq S_j, \qquad \forall d \in v_d, k \in K, i \in v, j \in v_c \qquad (11)$$

$$S_d = 0, \qquad \forall d \in v_d \qquad (12)$$

$$a_i \leq S_i \leq b_i, \qquad \forall i \in v_c \qquad (13)$$

$$LO_{dk} = \sum_{i \in v} \sum_{j \in v_c} r_j X_{ijkd}, \qquad \forall d \in v_d, k \in K \qquad (14)$$

$$LO_{dk} \leq Q, \qquad \forall d \in v_d, k \in K \qquad (15)$$

$$L_j \geq LO_{dk} - r_j + p_j - M\left(1 - X_{djkd}\right), \qquad \forall d \in v_d, k \in K, j \in v_c \qquad (16)$$

$$L_j \leq LO_{dk} - r_j + p_j + M\left(1 - X_{djkd}\right), \qquad \forall d \in v_d, k \in K, j \in v_c \qquad (17)$$

$$L_j \geq L_i - r_j + p_j - M\left(1 - \sum_{d \in v_d} \sum_{k \in K} X_{ijkd}\right), \qquad \forall d \in v_d, k \in K, j \in v_c \qquad (18)$$

$$L_j \leq L_i - r_j + p_j + M\left(1 - \sum_{d \in v_d} \sum_{k \in K} X_{ijkd}\right), \qquad \forall d \in v_d, k \in K, j \in v_c \qquad (19)$$

$$L_j \leq Q, \qquad \forall j \in v_c \qquad (20)$$

$$cost_i \geq L_i . d_{ij} . cw - M\left(1 - X_{ijkd}\right), \qquad \forall d \in v_d, k \in K, j \in v, i \in v_c \qquad (21)$$

$$cost_i \leq L_i . d_{ij} . cw + M\left(1 - X_{ijkd}\right), \qquad \forall d \in v_d, k \in K, j \in v, i \in v_c \qquad (22)$$

$$ic_{kd} \geq LO_{dk} . d_{di} . cw - M(1 - X_{dikd}), \qquad \forall d \in v_d, k \in K, i \in v_c \qquad (23)$$

$$ic_{kd} \leq LO_{dk} . d_{di} . cw + M(1 - X_{dikd}), \qquad \forall d \in v_d, k \in K, i \in v_c \qquad (24)$$

$$E_i \geq (ES_i - S_i), \qquad \forall\ i \in V_C \qquad (25)$$

$$L_i \geq (S_i - LS_i), \qquad \forall\ i \in V_C \qquad (26)$$

$$A_i = full, \qquad \forall\ i \in C_1 \qquad (27)$$

$$A_i \leq A_j - cp_{ji} + M\left(1 - X_{jikd}\right), \qquad \forall\ i \in C_2, j \in v, k \in K, d \in v_d \qquad (28)$$

$$A_i \geq AT, \qquad i \in v_c \qquad (29)$$

$$Z_d M \geq \sum_{k \in K} \sum_{i \in v_c} X_{dikd}, \qquad \forall\ d \in V_d \qquad (30)$$

$$X_{ijkd}, Z_d = 0\ or\ 1, \qquad (31)$$

$$L_j, S_i, LO_{dk} \geq 0 \quad (32)$$

In this study, the goal is to minimize the set of costs. The first part of the objective function shows the moving cost, the second and third parts the cost of not complying with the soft time window, the fourth part is the fixed cost of the means of transportation, the fifth part is the fixed cost of choosing the candidate warehouse locations for construction. The sixth and seventh parts are the cost of fuel and depreciation related to the load on the vehicle. Constraint (1) ensures that each customer is transported by only one vehicle. It will be serviced. Constraint (2) ensures that the movement of each means of transportation starts from a warehouse and ends at the same warehouse. Constraint (3) shows that the vehicle cannot move directly from one built warehouse to another. Constraint (4) indicates that transportation cannot go directly from one node to the same node with a mane. Constraint (5) guarantees that the number of vehicles leaving each warehouse is not greater than the number of available vehicles. Constraint (6) does not guarantee that every customer has the same means of transportation. The same vehicle that enters the customer for servicing will also leave it. Constraint (7) is obtained as there is no sub-tour. Constraints (8 and 9) are the results. If a vehicle is taken out of a warehouse, then that vehicle only belongs to that warehouse. Constraints (10, 11, 12 and 13) guarantee compliance with the hard time window constraint. Constraint (14) calculates the amount of initial loading of the vehicle. From the limit (15), it calculates the limit of the vehicle capacity for loading the vehicle. Constraints (16, 17) calculate the load on the vehicle after leaving the first customer along the route. Constraints (18, 19) calculate the load on the vehicle after leaving the rest of the customers along the route. Constraints (20) calculates the vehicle capacity limit for the load on the vehicle along the vehicle path. Constraints (21, 22) calculate the depreciation cost due to the load on the vehicle from each customer to the next node. Constraints (23, 24) calculate the amount of depreciation cost due to the amount of cargo on the vehicle from each warehouse to the first customer of each route. Constraints (26 and 27) calculate the deviation from the time window for customers. Constraint (28) indicates that at the end of service to customers where refuelling is possible, the amount of fuel in the vehicle's fuel tank is full. Constraint (29) calculates the amount of fuel in the vehicle's fuel tank at the end of serving the customers where it is not possible to refuel in those places. Constraint (30) ensures the vehicle's fuel consumption limit is met. Constraint (31) In this constraint, the location of the warehouse and the built warehouses are specified. Constraint (32) defines zero and one variables. Constraint (33) specifies variables greater than and equal to zero.

3.2. Providing the solution by the hybrid genetic algorithm

Genetic algorithm (GA) is a well-known algorithm in which first a population of T From the answers, creating a generation process, for example, causes parents to be selected at each stage, and from the selected parents, new children are formed that have some of the characteristics of the parents. and children can continue to reproduce better. The GA in question has various components, including the following.

3.3. Show the initial answer

In this research, the initial answer consists of two parts. The first part contains (n +k-1) houses. If n is the number of customers, k is the number of vehicles. The first answer consists of a row with n +k -1 cells in which numbers from 1 to n+k-1 are placed. The numbers 1 to n are customer numbers, and numbers n+1 to n + k -1 indicate the arrival of the vehicle to the warehouse, the end of the route, and the use of the vehicle. It is a hot transfer. Placing the numbers in the columns shows the order in which the customers are served. Number e n + i represents the transmission medium i is mm, and the customers before it indicates the customers served by that means of transportation. If there is no customer number before the vehicle number, none of the sub-customers have been assigned to that vehicle. The means of transportation has not been used yet. All customers who are placed after the last vehicle number will be assigned to the last vehicle in order. The second part contains (k+d-1) houses. Where k is the number of vehicles and d is the number of candidate locations for warehouse construction. Similar to the previous part, the used vehicles are assigned to the warehouse, and the serial numbers from 1 to d + k -1 are placed in them. Numbers a to k are vehicle numbers, and numbers k+1 to k+d - 1 indicate the number Warehouse M, the number of vehicles that precede the number The warehouse is located indicates the vehicles that are assigned to that warehouse. For example, in Figure 1, eight customers are served by two warehouses and three means of transportation for the service available. In Figure 1, vehicle number one is assigned to warehouse two and serves five, two, three, and eight customers, respectively. Vehicle number two is assigned to warehouse one and serves customers six, seven, and one, respectively, and vehicle number three is assigned to warehouse two and serves customer four.

4	10	1	7	6	9	8	3	2	5
3	1	4	2						

Figure 1. Example of the solution matrix

Table2. solution of example

Route	Number of vehicles	Number of depots
5-2-3-8	2	1
6-7-1	1	2
4	1	2

The particle swarm algorithm is implemented to create the first population. An appropriate and improved initial population has been produced and is used as the initial population in the GA. In each stage, for sophistication, the best answer from the previous stage is directly transferred to the next stage. In the next step, parents are first determined using the tournament operator to determine the rest of the members of the new population. Then, the child is created using the intersection operator and then the mutation operator.

After calculating each Chromosome's fit value, the new parent is selected to create T New in the GA algorithm. The tournament method has been used for each selection of parents. In this method, first, the two chromosomes are randomly selected and each of the answers is a value It had a better fit; it is selected as the first parent. The two chromosomes are randomly selected to select the second parent, and each answer is a value. It was a better fit, and was chosen as the second parent.

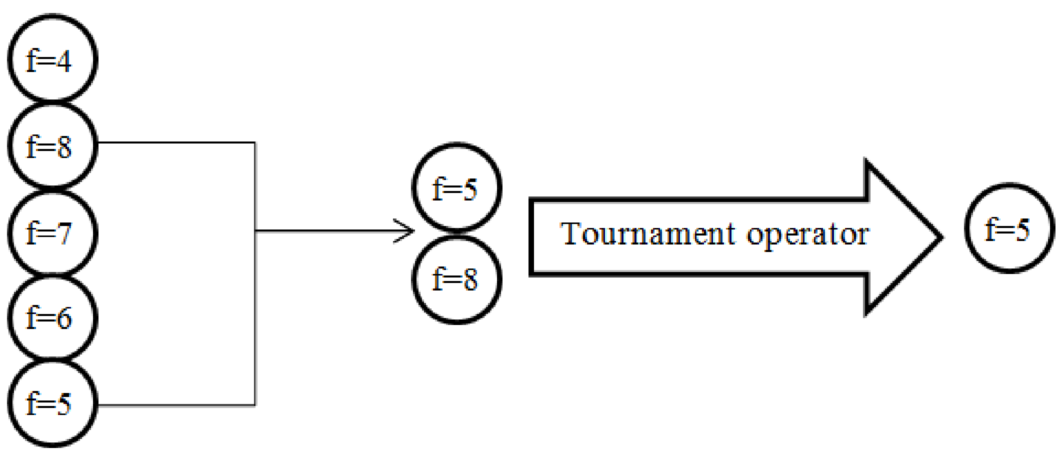

Figure 2. Tournament operator

After calculating each Chromosome's fit value, the new parent is selected to create T New in the GA algorithm. The tournament method has been used for each selection of parents. In this method, the two chromosomes are randomly selected, and each answer is a value. It had a better fit; it is selected as the first parent. To select the second parent, first, the two chromosomes are randomly selected, and each answer is a value. It was a better fit, and was chosen as the second parent.

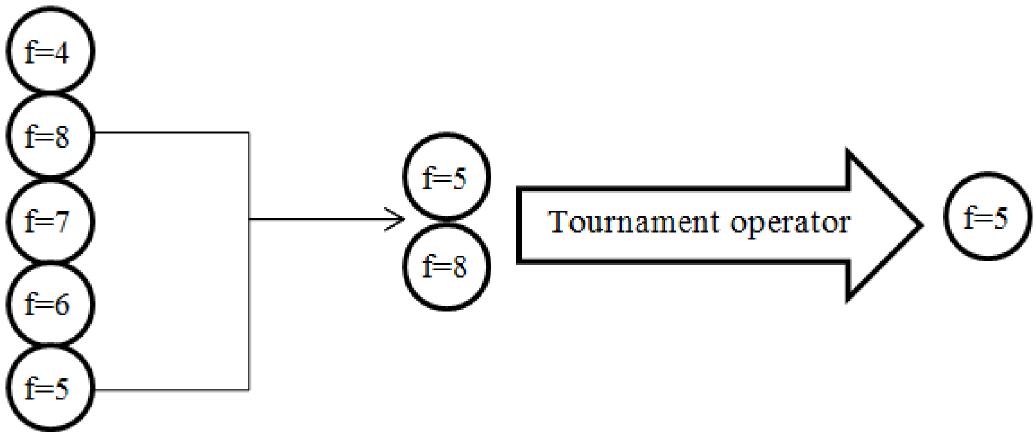

Figure 3. Tournament operator

After selecting two parents by the tournament method, the two-point crossover method has been used to create new children, based on which, for each part, two points are randomly selected on the two parents and each from the parents' particle for the direct object from points Selection done, From Both separate and with Movement genes, A new child will be created.

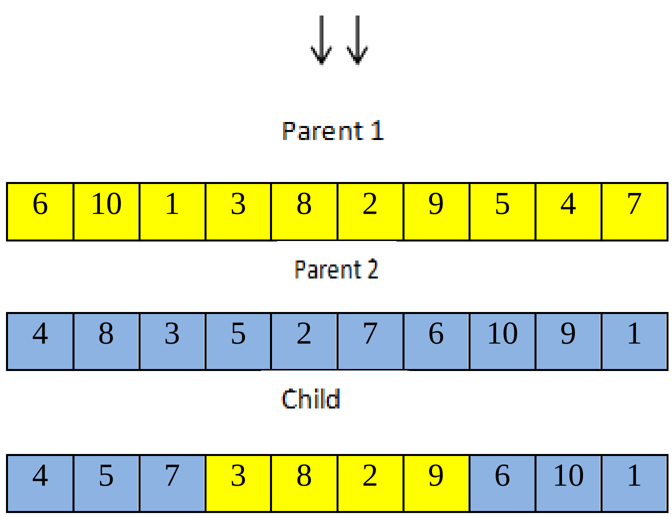

Figure 4. Crossover operator for the first and second row

After implementing the intersection operator, each child may change randomly so that a random number is generated; if this number is lower than the mutation rate, the child is changed by the mutation operator. For genetic mutation, two genes undergo accident selection in the first step; in the second step, the numbers inside these two genes are exchanged.

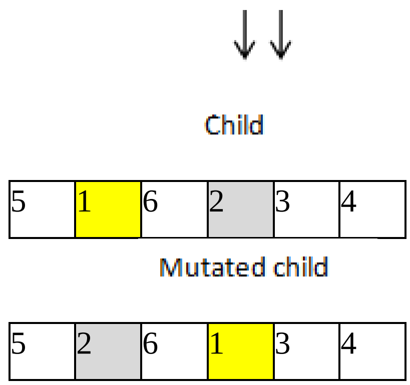

Figure 5. Mutation operation for third-line

After the mutation operation, the neighbourhood search algorithm is executed for the desired answer, and the answer will be directed to the more suitable neighbouring answers.

For evaluation, answers and calculation of the cost of each answer are used from the evaluation function. Also, the evaluation function checks the constraints of the problem, and by violating the constraints of the problem, to not choose the desired answer as a suitable answer, the value of the objective function is multiplied by a constant value.

4. Numerical results

To check the validity and accuracy of the proposed model, an example was generated by chance and the answer obtained from GAMS software is checked and analyzed. To check the model's validity, compliance with the restrictions and the correctness of the value of the objective function obtained from the GAMS software is checked. The answer obtained from Games software is shown schematically in Figure 6. In this answer, warehouses have been built in places one and two, and no warehouses have been built in the third place. In both warehouses, two vehicles are used and the routes are also shown in Figure 6. The best value of the objective function obtained from GAMS software was 2323. The calculations show that the obtained values are entirely accurate.

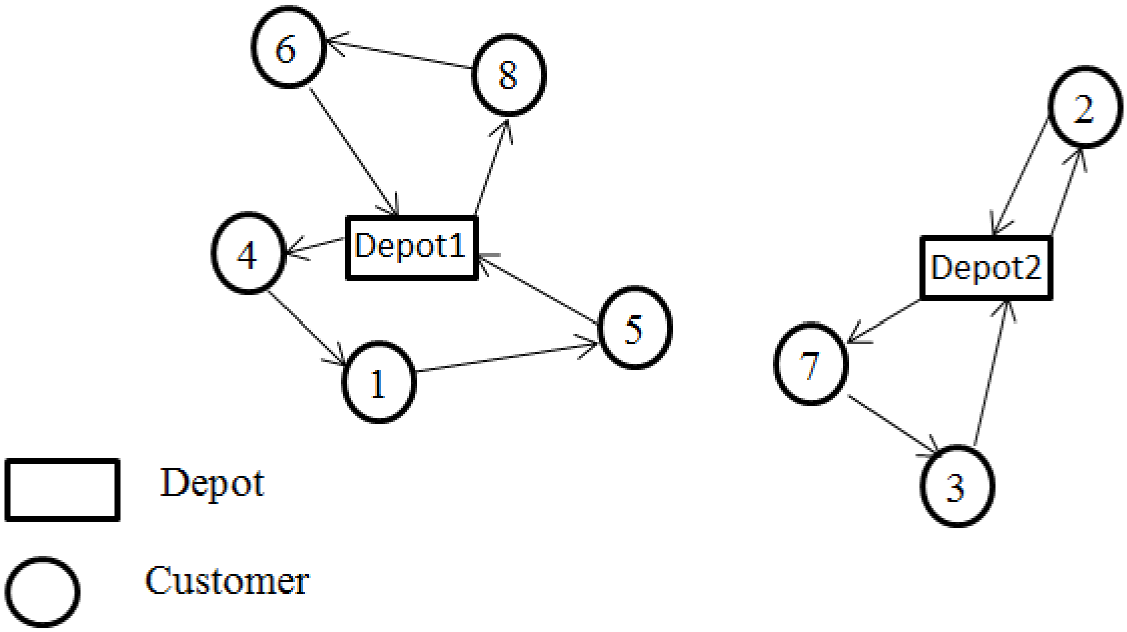

Figure 6. Problem-Solving

In the step to check the problem's constraints, first, the soft and hard time window constraints are checked, and the results are shown in Figures 7 and 8. In each diagram, the first and last time of service provision in the time window and the actual time of service provision are specified. According to charts 1 and 2, both restrictions have been met.

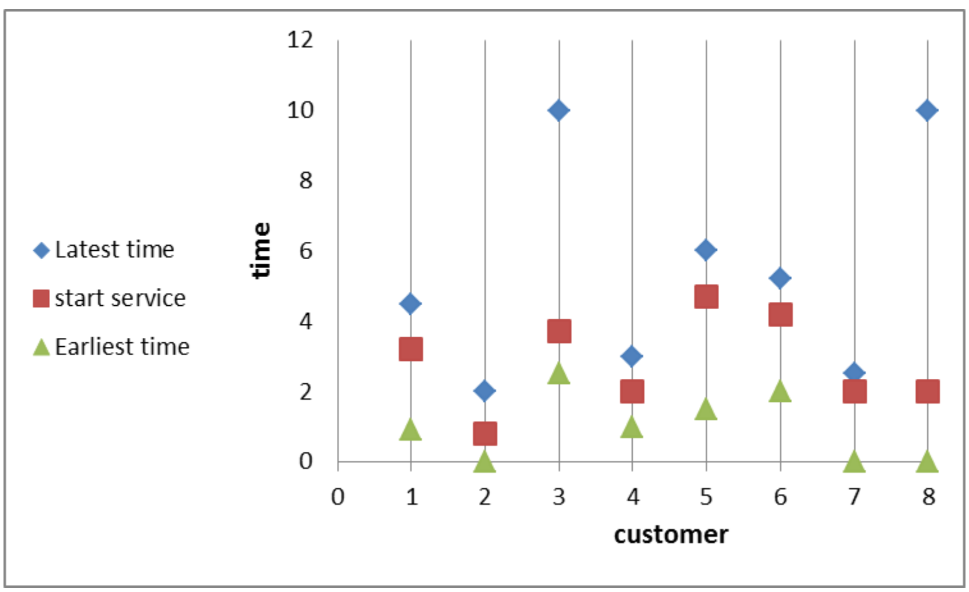

Figure 7. Compliance check for soft time windows

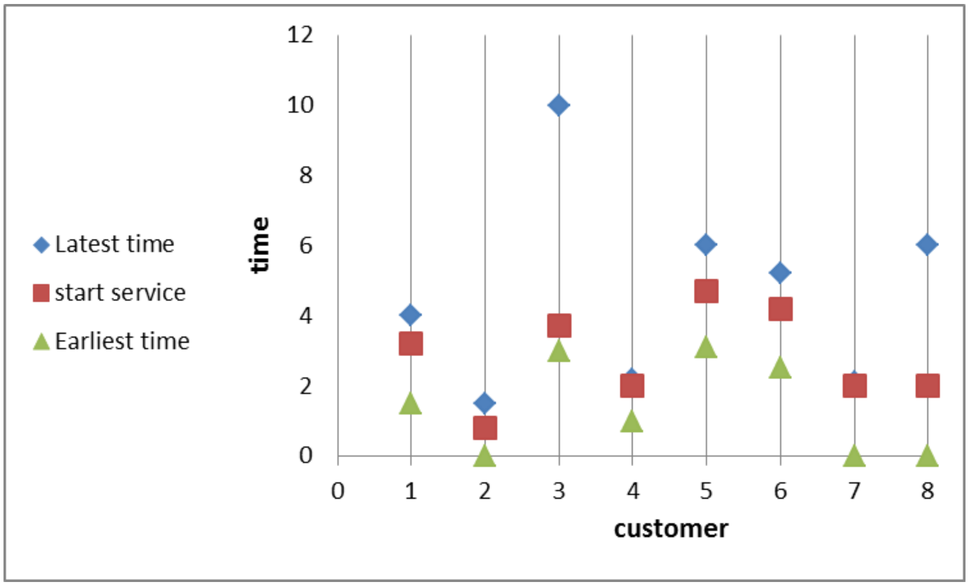

Figure 8. Compliance check for hard-time windows

Figure 9 shows the initial loading limit, and Figure 10 shows the load limit on the vehicle along the route. As it is apparent in the figures in Figure 9, the number 1 means load 1 of route 1; the number 2 means the warehouse 1 of the route 2, the number 3 means the warehouse 2 of the route 1, the number 4 means the warehouse 2 of the route 2. In Figures 9 and 10, the limit of the load available on the vehicle is never written.

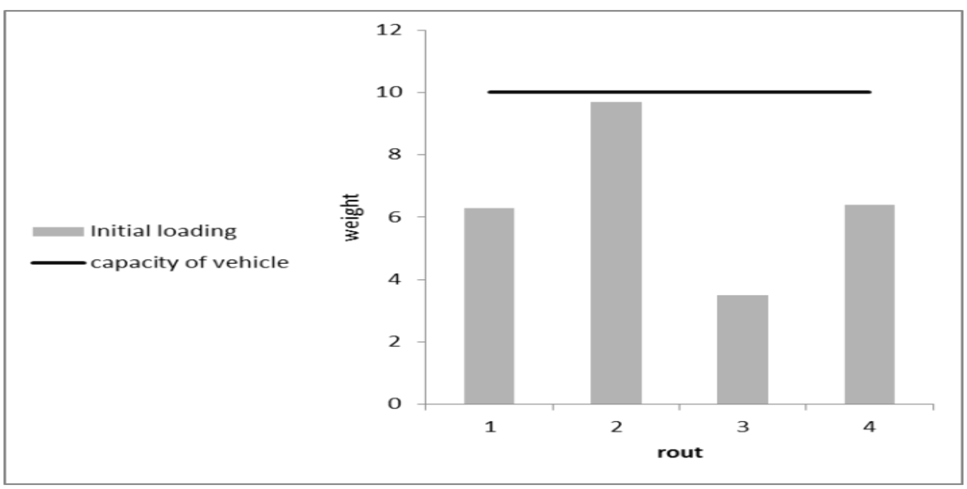

Figure 9. Compliance check for initial loading constraint

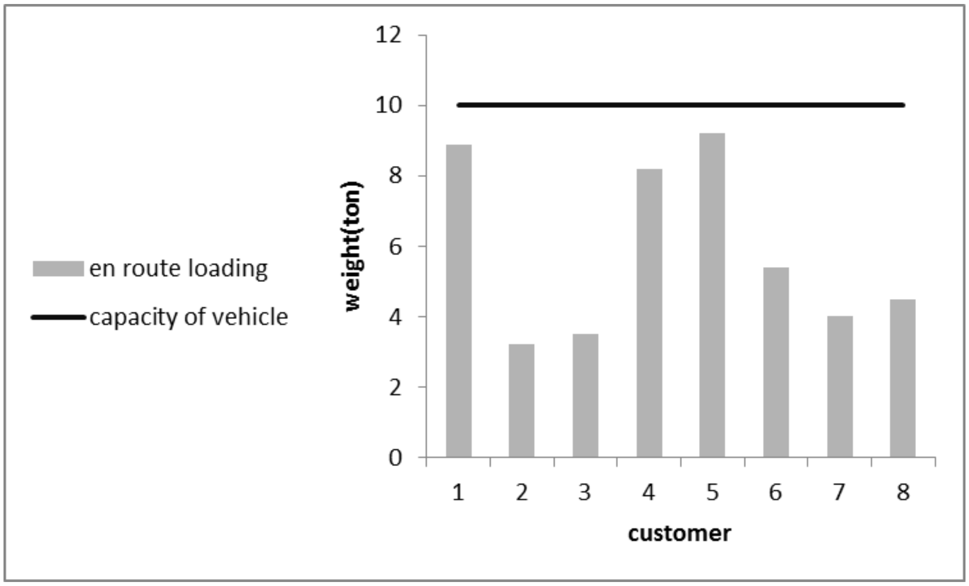

Figure 10. Compliance check for en-route loading constraint

To check the predictive temp algorithm, first, small examples were randomly generated, solved, and compared using games software and GA and placed in table number 5.

The problem designed in small dimensions has been solved 30 times using gams software, and the predictive GA, and the results are given in Table 5. Table number shows that the deviation value of the exact answer obtained from the GAMS software and the answer of the hybrid GA has an acceptable deviation, and based on this, it can be said that the GA presented in small dimensions has a suitable efficiency.

Table 8. Comparison of the answer of GA with exact solution in small sizes

Number	Mean GA	Best GA	Gap %	Exactly
N = 4	1160	1160	0%	1160
N = 5	2061	2047	0%	2047
N = 6	2112	2120	0.4%	2120
N = 7	2240	2253	0.6%	2253
N = 8	2359	2329	1.2%	2329
N = 9	3232	3320	2.9%	3320
N = 10	3820	3658	4.1%	3650

With the increase in the problem's dimensions, it is impossible to solve the problem with GAMS software or other precise methods. Examples have been created to check the effectiveness of the hybrid GA in large dimensions, and the problem has been compared with the simple GA. The results from Table 6 show that the answers from the hyibrid GA are better than those from the GA.

Table 9. Comparison of the answer GA and the Hybrid GA in large sizes

Number	GA	HGA
N = 30	3478	3473
N = 50	5324	5321
N = 100	8217	8205
N = 150	11235	11228
N = 200	15326	15307

5. Conclusion and future research

The model presented in this research has constraints and conditions. It is complex and abundant. The use of the new decision-making variable has made the modelling attractive. The article discusses the existence of depreciation costs due to the amount of load on the vehicle for the first time. It presents the hybrid GA in this research and the main innovations. After presenting the conceptual model for the problem, the mathematical model is considered, and the correctness and efficiency of the model are checked and confirmed by solving a random example using GAMS software (Ghasemi et al., 2023). The problem in question is complex (NP-Hard); therefore, a hybrid GA is presented to solve the problem in large dimensions (Khademi et al. 2021, Khademi et al. 2022, Khademi et al. 2023). In the next step, the algorithm's efficiency has been proven in large and small dimensions. As research in the future, the demand can be considered random, or the candidate areas of the warehouse are uncertain, and other meta-heuristic methods can be used to solve the problem.

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