Dynamic Vehicle Routing Problem with Simultaneous Delivery and Pickup : Formulation and Resolution

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***Abstract*—This article treat a fundamental optimization problem encountered by most distribution companies. The Dynamic Vehicle Routing Problem with Simultaneous Delivery and Pickup (DVRPSDP) is a special variant of the VRP, in which new clients comes when the working day has already begun, and a number of vehicles have started their tours, in a way that each customer requires simultaneous delivery and pickup. These new customers must be included in the planned tours as early as possible with a minimum total travel distance.**

A rich literature review of the problem is carried out. A mathematical model has been formulated for the DVRPSDP, and it is tested with Cplex to provide optimal solutions for small instances. A memetic algorithm has been used to resolve the problem, the proposed algorithm is a combination of the genetic algorithm with a local search method.

***Index Terms*—DVRP, Reverse logistics, VRPSDP, Optimal model, memetic algorithm.**

I. Introduction

The transportation of goods is a main component of the supply chain; transport costs is the cost that most affects the total cost of the product, which is why companies are seeking to design an efficient distribution system that guarantees the minimization of transport costs while meeting the constraints of customers who require very short service times.

In recent years, reverse logistics has become an increasingly important part of corporate logistics services, so leading companies, large and small, are seeking to adopt a more environmentally friendly approach by integrating environmental preservation into all stages of supply chain management. Among the measures taken by these companies are the collection of reusable or recyclable packaging, empty packaging and end-of-life products.

On the other hand, with the rapid development of e-commerce new customers are received throughout the day, so companies must meet the needs of these new customers while respecting their requirements, then this has become possible thanks to modern means of communication and geographical location, because the dispatcher can track on his computer the position of vehicles, which facilitates the task of integrating new customers into already planned tours.

By creating a distribution logistics that combines both aspects, i.e. the environmental protection aspect and the dynamic aspect, we end up with a dynamic and inverse distribution logistics that aims to optimize the delivery of products to clients and the simultaneous pickup of reusable or empty packaging in order to recycle them, in a context where new customers who have a demand for delivery and collection appear when the working day has already started, which requires their integration into planned tours or creating new tours.

In this context, a very important variant of the VRP is created and studied: The Dynamic Vehicle Routing Problem with Simultaneous Delivery and Pickup (DVRPSDP).

In this work, we start by a rich literature review,next we propose a mathematical model of our problem and its resolution with Cplex, and then apply a memetic algorithm for this special variant of the VRP. The rest of this paper is presented as follows: Section II presents a detailed and relevant literature review of our problem. In section III the description of our problem is introduced. A mathematical model of our problem is described in Section IV. Section V deals the resolution of the mathematical model by Cplex. Section VI describes the principle of application of the algorithms that we have proposed for solving our problem.

II. Literature Review

Vehicle routing problem (VRP) is a general name assigned to a problem of operational research and combinatorial optimization. It consists of determining the routes for a set of vehicles available at the depot to visit a set of clients dispersed geographically, and each vehicle begins its tour from the depot and returns to the same depot.

With the application of the classic VRP in the real world, it has been faced with several characteristics and objectives of transport companies that aim to design high-performance and powerful distribution systems, these reasons have given rise to many variants of the VRP. Among these variants we will

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focus on two variants that constitute our problem, and we will review the literature of these variants before starting the literature review of our problem.

The first variant is the Vehicle Routing Problem with Simultaneous Delivery and Pickup (VRPSDP), in which it is necessary to determine the routes of a set of vehicles available at the depot to visit a number of known customers. each customer visited has a quantity to deliver and a quantity to collect, when the vehicle finishes its route, it returns to the depot to deposit what it has collected.

The VRPSDP was introduced by [22] in 1989. He proposed a mathematical model of the VRPSDP, and to solve it he developed an approach based on the construction of Clusters of customer, then Assigning trucksldrivers to clusters and finally Creating the route structure. He applied the model and approach to a real case of distribution of materials from public libraries. The test is performed at 22 branches of libraries using 2 vehicles.

Then the VRPSDP became an objective of several research due to its importance in the protection of the environment.

There are several methods and techniques that have been used to solve VRPSDP. We will mention the most relevant ones. For example [10] described the important role played by the VRPSDP in the reverse logistics. He suggested an insertion-based heuristic which is based on three insertion criteria: Travel Distance (TD), Residual Capacity (RC), and Radial overload, to solve the problem.

Angelelli and Mansini [2] were the first to developpe an exact approach based on the Branch and Price methods to solve the VRPSDP with time windows. The same technique is used by [9] to solve the VRPSDP.

Chen and Wu [7] have solved the VRPSDP using the insertion-based process to create a good initial solution, then a hybrid heuristic based on the record-to-record travel, tabu lists, and route improvement methods are suggested to improve the initial solutions.

Gajpal and Abad [13] proposed an approach to resolve the VRPSDP, this approach is based on an Ant Colony System (ACS) algorithm that uses 3 local search schemes: 2-opt scheme, the customer insertion/interchange multi-route scheme, and the sub-path exchange multi-route scheme.

Bárbara de Cássia Xavier Cassins Aguiar et al. [5] solved routing problems capacited vehicles with heterogeneous fixed fleet and delivery and simultaneous collection by meta-heuristic Particle Swarm Optimization Discrete Adapted (PSODA). He applied the proposed approach to a real case of school transportation.

An heuristic algorithms is proposed by [19] to solve VRPSDP with time windows. The first heuristic is based on a genetic algorithm that relies on chromosome permutation, split procedure, and local search. The second heuristic is a tabu search that is based on route assignment attributes of clients, an augmented cost function, route re-optimization, and attribute-based aspiration levels. He applied these heuristics in a very important area, the home health care logistics.

Ai and Kachitvichyanukul [1] developed a particle swarm optimization (PSO) algorithm to solve the VRPSDP. And Subramanian et al. [29] suggested a greedy randomized adaptive search procedure that uses a variable Neighborhood descent method to perform the local search for solving the VRPSDP.

The second variant is the Dynamic Vehicle Routing Problem (DVRP), in which new customers appear when the working day has already started and vehicle tours are planned, so the new customers must be included in the working day.

The DVRP with capacity and time duration constraints was introduced by [17]. And after the DVRP became the object of several researches and it has known several extentions, among these researches we have the work of [24], he gave a description of the dynamic vehicle routing problem, and proposed his approach of dividing the DVRP into a sequence of static VRPs. Each static VRP is solved with Ant Colony System and the method is applied to a real case in Suisse. The same algorithm is used by [28] to solve the capacitated DVRP with time windows, split delivery and heterogeneous fleets. The algorithm was tested on a real problem of Liage airport in order to optimize the journey of their fueling vehicles.

Necula et al. [26] also proposed the resolution of the dynamic VRP with time window using an ant colony optimization algorithm. But this time this algorithm is combined with the local search method which improves the solutions found by ants and a heuristic insertion which aims to minimize the number of vehicles used.

Euchi et al. [11] proposed the resolution of the dynamic VRP with a hybrid meta-heuristic approach that uses an Artificial Ant Colony based on 2-opt local search.

Franklin et al. [12] suggested a Genetic Algorithm approach to solve the dynamic VRP using the approach adopted by [24]. The proposed algorithm has given good results in terms of minimizing travel costs. This algorithm is also used by [21], he proposed a mathematical model of the dynamic VRP, and developed a solution to the problem based on the genetic algorithm combined with some heuristics for the construction of the initial population and the crossover.

Luo et al. [20] presented a mathematical model of the dynamic VRP with stochastic requests for emergencies. He developed a hybrid algorithm based on C-W saving algorithm with the capacity of vehicles and time window to build the initial solution, and the tabou search to optimize the solution.

Until now, little paper has been published on the DVRP with pickup and delivery in which new customers arrive for delivery or pickup when tours are already planned.

Berbeglia et al. [6] proposed a rich literature review of the DVRP with pickup and delivery. He presented a number of frameworks of the problem and studied the concepts of all the solutions that were proposed to solve it.

An neighborhood search heuristics is proposed by [14] to resolve the DVRP with a pickup and delivery. The neighborhood structure is based on ejection chains and tabou search, and it has given good results in optimal time.

Mitrovic-Minic and Laporte [23] dealt the dynamic pickup and delivery problem with time windows (PDPTW). He assessed the quality of the solution according to waiting time, and proposed four waiting strategies: the drive-first, the wait-first, the dynamic waiting strategy, the advanced dynamic waiting strategy, and made a comparison between the four strategies.

Hu et al. [16] studied the dynamic closed-loop vehicle routing problem with uncertainty and incompatible goods. He proposed the variable neighborhood search (VNS) to solve the VRPSDP, plus other methods to manage the uncertainty pickup. The proposed method was applied to a real case of centralized tableware disinfiction and logistics services in china's catering industry.

Lan and Xia [18] proposed a mathematical model of the dynamic delivery in VRPSDP. He developed a Hopfield Neural Network Algorithm based on particle swarm optimization (PSO). The proposed approach has produced good results.

Zhao et al. [30] addressed the VRPSDP with new customers arriving for collection only. He proposed a disruption management model to manage disruptions caused by new customers. He developed a new dispatching method using tabu search algorithm to solve the problem.

We note that the majority of the work cited deals with the DPDP in which a new customer who arrives has either a delivery or collection request, but not both, i.e. simultaneous delivery and collection requests. this is the main objective of our problem that deals with the arrival of new customers with a delivery and collection demand (DVRPSDP) which is an important problem encountered by the distribution systems of large companies but unfortunately it is not very studied by researchers.

III. Problem Description

The Dynamic Vehicle Routing Problem with Simultaneous Delivery and Pickup (DVRPSDP) is an extension of the Vehicle Routing Problem with Simultaneous Delivery and Pickup (VRPSDP) which consists in building roads for a set of vehicles from the depot to a set of clients, and each client need simultaneous delivery and pickup demands.

Our problem takes into consideration new customer orders that have appeared in time, each new customer has two kinds of demand: distribution demand and collecting demand, and they should be visited at their positions by a set of vehicles in short time minimizing the total travel cost. To serve the new customers there are 2 ways: add the new customers into the existing vehicle tours, or build new routes using the vehicles available at the depot to serve these new customers.
Fig. 1 shows an example of the DVRPSDP that contains 9 known customer orders with three vehicles and the appearance of 2 new customers.

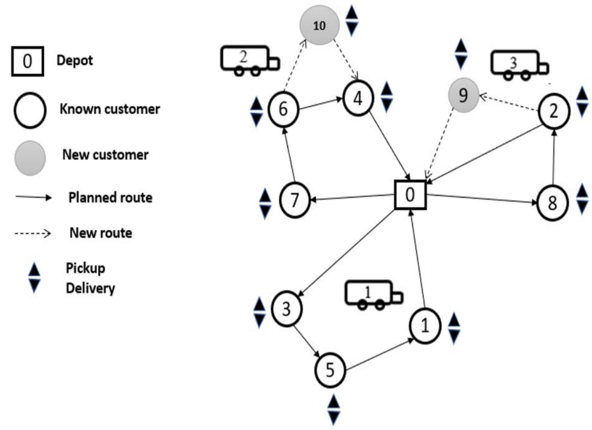

Fig. 1. Example of DVRPSDP.

To properly model and solve this problem, we will adopt the approach proposed by [24] wich consists of dividing the working day in time interval as indicated in the Fig. 2:

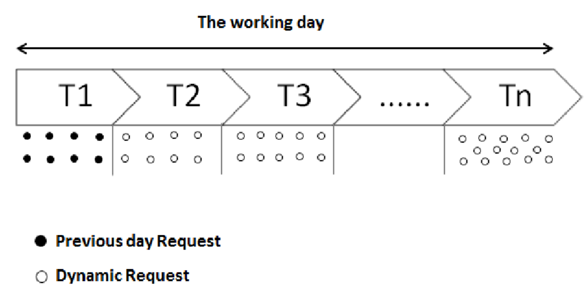

Fig. 2. The division of the working day

Each time interval represents a partial static VRPSDP, where the vehicles should deliver to all known customers and collect from them the goods.

The first static problem (starting of the working day) deals the customers known from the precedent working day, that is to say the customers received after t_{co}(time limit for receipt customers).

The next static problems deal the customers received during the precedent time interval and those that have not been assigned to vehicles yet. In these static problems each vehicle begins its tour from the last customer assigned to it, with a capacity that corresponds to the remaining capacity in the vehicle after visiting all the customers affected to it, and with a start time, which starts after visiting this last customer.

IV. Mathematical Model

The VRPSDP is modeled mathematically as weighted graph G =(V, A) where V=0,1, ..., n is the set of n+1 vertices. Vertex 0 is the depot where the vehicles stock up to start their tour and the vertex set V'=V $\backslash\{0\}$ represents the n customers. The vertex i $\in$ V' has a non negative delivery demand D_i, pickup demand P_i and a service time s_i . And A={(i,j) / i,j $\in$ V} is the set of edges . A non negative cost c_{ij} and a travel time t_{ij} are associated with each edge. A set V_d of identical vehicles of capacity Q is available at the depot. A set V_c of vehicles is in circulation.

The proposed mathematical model addresses the Dynamic Vehicle Routing Problem with Simultaneous Delivery and Pickup (DVRPSDP), with a set of vehicles available at the depot that can be used if needed. This model is based on Dethloff's mathematical model [10] that deals with the VRPSDP and Hassania's mathematical model [21] that deals with the DVRP.

A. Hypotheses

To propose our mathematical model, we consider the following hypotheses:

1) A large set of vehicles with the same capacity are available in the depot, which can be added in case of need.
2) The volume loaded by each vehicle when leaving the depot is equal to the total volume of all customers on the vehicle route and doesn't exceed the capacity of the vehicle.
3) When a vehicle has used its full capacity, it should return to the depot.
4) Each vehicle start at the last clients have been committed to it and come back to the depot(in the first time interval, the depot is considered as the last customer).
5) Each customer has distribution demand and collecting demand.
6) Each customer can only be visited by one car.

B. Notation

Sets :

- C_{T_p}: Set of new customer locations :
  - if $p = 1, C_{T_p}$ contains the customers received the previous day, but they were not served because they arrived after t_{co} (time limit for receipt customers).
  - if $p \in \{2, 3, 4, ..., n\}, C_{T_p}$ contains the clients received during the precedent time interval and those that have not yet been engaged with drivers.
- V_d : Set of vehicles available at the depot.
- V_c : Set of vehicles in circulation (vehicles that have already visited customers).
- $V = V_d \cup V_c$: Set of all vehicles.

Parameters :

- $T = \{T_1, T_2, ..., T_n\}$: The division of the working day.
- p : index of the time slice.
- 0 : Index of the depot.
- O_{pk} : is the last client visited by the vehicle k at the time interval T_{p-1} .
- D_{pk} : is the total quantity delivered to clients already committed to vehicle k at the end of the time interval T_{p-1}.
- P_{pk} : is the total quantity collected from clients already committed to vehicle k at the end of the time interval T_{p-1}.
- T_{pk} : is the end of the serving time for the last client committed to vehicle k at the time interval T_{p-1} .
- L_{0k} : Load of vehicle in circulation k $\in V_c$ when leaving the depot.
- D_j : Delivery amount of client j $\in C_{T_p}$.
- P_j : Pick-up amount of client j $\in C_{T_p}$.
- s_j : Service time of client j.
- C_{ij} : Travel costs between client i and client j.
- t_{ij} : Travel time between client i and client j.
- Q : The maximum capacity of a vehicle.
- M : Large number.

We note that $O_p = \{O_{pk}, \forall k \in V_C\}$ is the set of the positions for the vehicles k at the beginning of the time interval T_p, $N_p = C_{T_p} \bigcup \{0, O_p\}$ is the set of all nodes of the time slice p, and $c_p = card(N_p)$: is the number of nodes.

C. Decision variables :

- $x_{ij}^k = \begin{cases} 1 & \text{if vehicle k travels from client i to client j.} \\ 0 & \text{otherwise} \end{cases}$
- $y_i^k = \begin{cases} 1 & \text{if vehicle k visits client i.} \\ 0 & \text{otherwise} \end{cases}$
- L_{pk} :Load of vehicle $k \in V$ at the beginning of the time interval T_p.
- L_j : Load of vehicle after having serviced client j $\in C_{T_p}$.
- V_j : Variable used to interdict subtours; can be interpreted as position of node j $\in C_{T_p}$ in the route.

D. Objective function :

During each time slice T_p, the mathematical model consists of minimizing the routing cost as follows:

$$Minimize \quad z = \sum_{k \in V} \sum_{i,j \in N_p} C_{ij} x_{ij}^k \tag{1}$$

E. Constraints

Under the following constraints:

$$\sum_{j \in C_{T_p}} x_{O_{pk}j}^k \leq 1 \qquad \forall k \in V \tag{2}$$

$$\sum_{i \in C_{T_p}} x_{O_{pk}i}^k = \sum_{i \in C_{T_p}} x_{i0}^k \qquad \forall k \in V \tag{3}$$

$$\sum_{i \in C_{T_p}} y_i^k \leq M * \sum_{j \in C_{T_p}} x_{j0}^k \qquad \forall k \in V \tag{4}$$

$$\sum_{k \in V} \sum_{i \in N_p} x_{ij}^k = 1 \qquad \forall j \in C_{T_p} \tag{5}$$

$$\sum_{i \in N_p} x_{is}^k = \sum_{j \in N_p} x_{sj}^k \qquad \forall k \in V, \forall s \in C_{T_p} \tag{6}$$

$$L_{pk} = L_{0k} - D_{pk} + P_{pk} \qquad \forall k \in V_c \tag{7}$$

$$L_{pk} = \sum_{i \in N_p} \sum_{j \in C_{T_p}} D_j x_{ij}^k \qquad \forall k \in V_d \tag{8}$$

$$L_j \geq L_{pk} - D_j + P_j - M\left(1 - x_{O_{pk}j}^k\right) \quad \forall j \in C_{T_p}, \forall k \in V \tag{9}$$

$$L_j \geq L_i - D_j + P_j - M\left(1 - \sum_{k \in V} x_{ij}^k\right) \quad \forall i, j \in C_{T_p} \tag{10}$$

$$L_{pk} \leq Q \qquad \forall k \in V \tag{11}$$

$$L_j \leq Q \qquad \forall j \in C_{T_p} \tag{12}$$

$$D_{pk} + \sum_{j \in C_{T_p}} D_j x_{O_{pk}j}^k + \sum_{i \in C_{T_p}} D_i \sum_{j \in N_p} x_{ij}^k \leq L_{0k} \quad \forall k \in V_c \tag{13}$$

$$T_{pk} + \sum_{i,j \in N_p} t_{ij} x_{ij}^k + \sum_{i \in C_{T_p}} s_i y_i^k \leq T \quad \forall k \in V \tag{14}$$

$$\sum_{k \in V} \sum_{j \in C_{T_p}} x_{0j}^k \leq Card(V_d) \tag{15}$$

$$V_j \geq V_i + 1 - c_p * \left(1 - \sum_{k \in V} x_{ij}^k\right) \quad \forall i, j \in C_{T_p}, i \neq j \tag{16}$$

$$x_{ij}^k \in \{0,1\} \qquad \forall i, j \in C_{T_p} \cup \{0, O_{pk}\}, k \in V \tag{17}$$

$$V_j \geq 0 \qquad j \in C_{T_p} \tag{18}$$

The objective function (1) minimizes the total cost of the routes. Constraints (2), (3) and (4) require that all vehicles start at the last clients have been assigned to it and come back to the depot. Constraint (5) imposes that each client is visited one time by one vehicle. The flow conservation constraint is ensured by the constraint (6).
Constraint (7) represents the load of vehicles in circulation at the beginning of the time slice, and the constraint (8) represents the load of vehicles coming from the depot. The Vehicle load after visiting the first customer of the time slice is limited by constraint (9). Constraint (10) ensures the vehicle load en route. Constraints (11) and (12) express that the quantity loaded in a vehicle does not exceed capacity limits.
Constraint (13) verifies the availability of deliveries. Constraint (14) assures that the total duration of each route does not exceed a predefined limit. Constraint (15) imposes that the number of vehicles added must not exceed the number of vehicles available in the depot. Finally constraint (16) is Sub tours breaking constraints.

V. Resolution with Cplex

In order to validate our mathematical model we thought to solve it with Cplex, we will use it to give the optimal solutions for small instances.

Our test is performed on the data set A of [3] by considering only the first 10, 15, 20, and 25 customers.
To obtain the delivery and pickup demands of each client from their original demand, we used the method proposed by [27] .
For each client i of X_i and Y_i coordinates, and original demand d_i, we calculate the ratio r_i as : $r_i = min\left(\frac{X_i}{Y_i}, \frac{Y_i}{X_i}\right)$.
Then the delivery demand D_i and pickup demand P_i are calculated as follows :

$$D_i = r_i * d_i \quad \text{and} \quad P_i = (1 - r_i) * d_i$$

In the following table we have the cplex results:

TABLE I
Solutions obtained by Cplex.

Nbr of customers	Routes	Distance	CPU
10	{D - C1 - C7 - C2 - C6 - D} {D - C3 - C4 - C8 - C9 - C10 - C5 - D}	428	16min
15	{D - C12 - C1 - C7 - C13 - C2 - C3 - C6 - D} {D - C14 - C8 - C4 - C11 - C9 - C15 - C10 - C5 - D}	441	25min 5s
20	{D - C16 - C7 - C13 - C17 - C19 - C1 - C12 - D} {D - C20 - C5 - C10 - C15 - C9 - C18 - C8 - C11 - C4 - C2 - C3 - C6 - C14 - D}	450	45min 26s
25	{D - C12 - C1 - C21 - C19 - C17 - C13 - C7 - C16 - D} {D - C24 - C14 - C6 - C3 - C2 - C23 - C4 - C11 - C8 - C18 - C9 - C22 - C15 - C10 - C25 - C5 - C20 - D}	464	6h 25min

From the results table (table I), it can be seen that by increasing the size of the instances the resolution with the exact methods becomes difficult and requires a very long time, which goes up to 7 hours for some instances. and when we exceed 25 clients Cplex is not capable to resolve the problem because of the running out of memory.

The DVRPSDP is a problem related to the VRP which is NP-Complex, so the mathematical formulation is only used to solve small size problems, because it cannot find the optimal solution in a polynomial time. So in order to find a good solution for large problems in the least amount of time, we will propose a meta-heuristic solution.

VI. Memetic Algorithm

The memetic algorithm (MA) nomined by [25], is part of the family of evolutionary algorithms and is based on the

mechanisms of natural evolution; it is inspired by Darwin's theory of species evolution. It consists in combining the genetic algorithm, first introduced by [15], with local search heuristics to improve the solution. It is largely used to solve several optimization problems, because it gives good solutions to these problems when no solution method is known or the exact methods cannot give a solution within a reasonable time, among these problems we find the vehicle routing problem for which the memetic algorithm has given good results. For example [4] used this algorithm to resolve a multi-objective VRP with multiple trips, and it gave best results.
The life cycle in Fig. 3 represents the elements and mechanisms that contribute to population change. First of all, the individuals of the population are initialized and then a part of them is selected to be recombined (crossover). The new individuals created will go through a mutation, then a correction to check the feasibility of the solutions obtained. A local research heuristic is applied at the end to improve the quality of new individuals before replacing part of the initial population. The algorithm terminates after a certain number of generations or after a number of iterations without improving the solution.

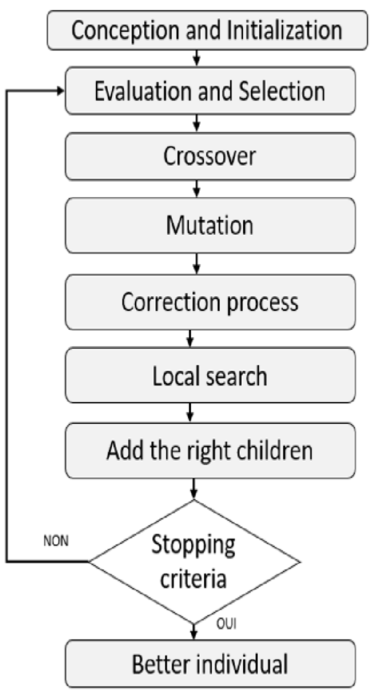

Fig. 3. Life cycle of the memetic algorithm.

A. Coding the solution:

For each time interval T_p, each solution contains the routes of the vehicles, and has a specific number of customers.
Vehicle 2 starts its tour from the last customer assigned to it during the previous time interval, and visits a set of customers and at the end it returns to the depot (Fig. 4).

O_{p1}	6	2	1	**0**	
O_{p2}	5	3	7	4	**0**

Fig. 4. Example of DVRPSDP with 2 vehicles and 7 clients.

B. Initialization of the population:

In this stage, a population of individuals is generated that will be the basis for future generations. Our algorithm uses 3 algorithms to generate the initial population :

- *Clarke and Wright's heuristics :*

  It is the most popular heuristic for the VRP, introduced by [8]. It is based on the calculation of the gains made by combining two partial tour. At initialization each customer i generates a route (0-i-0) connecting it by a round trip to the depot. From two of these routes for two customers i and j, it is elementary to calculate the gain S_{ij} realized by forming a single route (0-i-j-0) as shown in the Fig. 5.

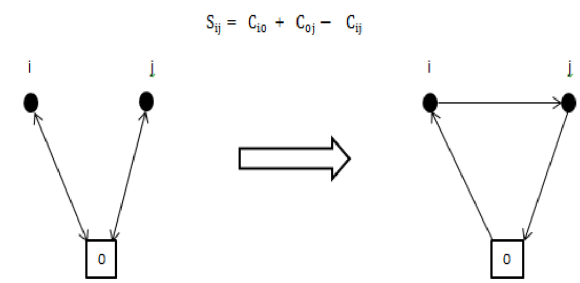

Fig. 5. Calculation of the gain S_{ij} .

  The tours corresponding to the best win are combined. A new iteration starts to recalculate the gain and merge two new tours. The algorithm stops if no merging within the constraints is possible.

- *Nearest neighbor method or k nearest neighbors:*

  This method is widely used because it is easy to implement and fast in execution. At first, we look for the closest customer to the depot, and add him to the tour. Then, the closest customer is searched for at the last customer visited and added at the end of the tour, and so on until the maximum capacity or time is reached. A new tour is launched and the addition of clients is done in the same manner until all customers are inserted.

- *Random insertion method:*

  The Random insertion is based on the random selection of clients. A tour is created, and clients are randomly selected and added to the tour one by one.The algorithm stops when all clients are added.

C. Evaluation and Selection

The initial solutions are evaluated according to their fitness function, it allows to compare individuals between them and determine the best in order to decide on its insertion in the new generation.

D. Crossover

The crossover is a genetic operator that combines two chromosomes called parents to generate a new one called child. The main reason behind the crossover is that the chromosome obtained can be better if it takes the best characteristics of each parent and is applied with a probability of crossover p_c.

E. Mutation

The mutation is a genetic operator that allows to explore the research space by avoiding that the algorithm converges too quickly towards a local optimum. It is used, with a probability of mutation pm, to the chromosomes created by the crossing step, or directly to the selected parents if the crossing is not performed.

F. Correction process

After applying the crossover and mutation operations on the parents, the constraints are violated in most cases. Therefore, it is important to perform a correction process to check the feasibility of the generated children.

G. Local Search

Local research is applied to each solution of the initial population and to each new child found through crossing and mutation operations. The proposed local improvement procedure uses two basic movements, highly responsive in solving the vehicles routing problems; reintegration and exchange. The procedure begins with the improvement of each individual's tour to be processed separately from the other tours. Then, local research is applied between the individual's tours two by two.

a) Local Search intra-tour: Local search is applied on each tour separately from the other solution tours to improve the order in which customers are visiting.

b) Local Search Inter-tour: During this stage of the local search, the interchange and reinsertion operators are performed between two different tours of the solution

VII. Conclusion

In this article, we have treated the Dynamic vehicle routing problem with simultaneous delivery and pickup, which is a special variant of the VRP, however it is not much treated by researchers because of its complexity. We started with a literature review of the variants of the VRP that make up our problem before reviewing the literature on our problem, then the mathematical model is presented and tested with small instances using Cplex, and finally a study of the proposed algorithm to solve the DVRPSDP was carried out.

As future work, the numerical experiments will be performed on instances of the literature, and the results obtained will be compared with the optimal solution found by Cplex for small numbers of clients, because until now there is no research that deals this problem.

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