Use of improvement heuristics for solving a Vehicle Routing Problem: The case of a Moroccan company

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Abstract

This article aims to illustrate the use of improvement heuristics for solving a vehicle routing problem with time constraints. We present, at first, a state-of-the-art about vehicle routing problems (VRP) by zooming in the VRP with time windows. We then present the possible methods of resolution proposed in the literature. Subsequently, we study the case of the Moroccan post office for postal delivery in the Fes-Meknes-Oujda region. To cope with the rapid changes in its environment, Moroccan post office is engaged in a process of continuous improvement of its transport network. This approach serves both the objectives of improving the quality of service and logistical and economic rationalization. It is in this context that our work fits in. We have tried to improve the postal routing network by using the improvement heuristic based on a set of scenarios in order to arrive at a tactical planning of routing network and efficient management of vehicle fleet while respecting in the same time quality, time and cost constraints.

Keywords

Vehicle Routing Problem, Improvement heuristics, Postal sector.

1. Introduction

The vehicle routing problems are studied because of the increasing importance of transport of passengers and goods today. These problems are generally subject to several types of constraints. We find among them: capacity constraints and time constraints. Reducing the cost of transport is a major concern for decision-makers, which makes of this domain a fertile field for diverse searches. In this article, we are going to overfly the vehicle routing problems by zooming the vehicle routing problem with time windows. We present afterward, the possible methods of resolution were proposed in the literature. Subsequently, we will study the case of the Moroccan post office for postal delivery in the Fes-Meknes-Oujda region.

In this context, our work tried to improve the postal routing network by using the improvement heuristic based on a set of scenarios in order to achieve an efficient route planning serving all centers in the region by minimizing the cost of transportation and adapting their delivery windows, routes to schedule routing to preserve and improve the quality of service vehicles.

2. Problematic

Technological breakthroughs and innovations constitute real catalysts of the change of behavior of the consumers and the companies. Indeed, the postal area which is an essential component of the world economy cannot ignore the technological upheavals which announce the succession of what it was advisable to call the information society. Also she cannot remain indifferent to the various transfers of her environment of which carry the seeds the orientations held by the state and the increasing aggressiveness of the operators having emerged in its business sector recently. When the post office has to face the competition, the network stays and will stay its essential meeting place with his customers. Recognizing this challenge, the Moroccan post office is engaged in a process of continuous improvement of its route network. Such an approach serves both objectives of improving service quality and concerns of logistical and economic rationalization.

3. Vehicle Routing Problems: Literature Review

3.1 Bases of a Vehicle Routing Problems

The traveling salesman problem (TSP) is one of the most studied problems in operational research. This problem consists in finding the shortest route which visits every city one and only once while returning to the starting point (Matai et al, 2010). As problem of optimization, the TSP is NP-difficult, the time to find the optimal solution increases exponentially according to the size of the problem.

The vehicle routing problem (VRP) is an extension of the traveling salesman problem. It was introduced for the first time in 1959 by Dantzig and Ramser under the name of "Truck Dispatching Problem" and has since been the subject of intensive study for the model and solves it (Braekers et al, 2016).

3.2 The extensions of the VRP

On this basic problem come to be transplanted other constraints take account of extensions to this first problem and thus to model various problems of optimization.

- **CVRP** (Capacited Vehicle Routing Problem)

Vehicle routing problem with capacity constraint consists in delivering (or collect) a load on crossing points using a fleet of vehicles with limited capacity. Indeed, in practical cases, the tours correspond to a delivery (or collection) with certain demand on each crossing point and must therefore take into account the capacity constraints to be respected by every vehicle (Braekers et al, 2016) .

- **PVRP** (Periodic Vehicle Routing Problem)

The routing problem generalizes the periodic vehicle VRP by considering that crossing points can be served several times on the planning horizon. For every crossing point, we have a frequency of collection and of a set of possible combinations of collection. This type of problem occurs frequently for garbage collection(Braekers et al, 2016).

- **HFVRP** (Heterogeneous Fleet Vehicle Routing Problem)

The vehicle routing problem with heterogeneous fleet is an extension of CVRP: in every vehicle k corresponds a capacity of collection noted Qk. To solve this problem, besides the construction of the tours, it's necessary to determine the number of vehicles of every type to use. Two variants of this problem have been discussed in the literature: the HVRP with limited car fleet and the HVRP with unlimited car fleet (Soonpracha et al, 2014)

- **MDVRP** (Multi- Depot Vehicle Routing Problem)

In this type of problem, several geographically distributed deposits exist. A tour in this problem is ensured by a vehicle which leaves and returns at the same initial deposit. In this case, the goods can leave several possible origins, without favoring one of them a priori (Kim et al, 2015).

- **VRPSF** (Vehicle Routing Problem with Satellite Facilities)

When network configurations different at the original problem are considered, we can define another category of variants, that of the problem of tour vehicle with satellite filling which appears when vehicles leave and must return a unique deposit but can, during their tours stock up on satellite warehouses of filling (Lambert et al, 2015).

- **DCVRP** (Distance-Constrained Vehicle Routing Problem)

When vehicles have autonomy to respect (especially in the case of electric vehicles or limitations relating to driving time), another possibility may be considered, the problem of vehicle-distance tour includes constraints limiting the total distance traveled by vehicles (Lambert et al, 2015).

- **TCVRP** (Time - Constrained Vehicle Routing Problem)

The TVRP is posed as an extension of the VRP to take into account the phenomena such as congestion. Indeed, with increasing traffic on the roads, travel time between two points often depend on moment considered during the day. In TVRP, the cost (or time) of transport between two customers i and j will thus be a function of the period Ti which the vehicle leaves the customer i, Cij (Ti) (Braekers et al, 2016).

- **VRPPD** (Vehicle Routing Problem with Pickup and Delivery)

The problem of collection and delivery has the same properties as the VRP. It adds to these the fact that every customer introduced two geographically different positions: the first one for collecting product and the second for the delivery of the latter. This will directly lead to a precedence constraint to add to the problem of classical VRP knowing that, in a tour, every operation of delivery must be preceded by the respective operation of collection(Braekers et al, 2016).

- **VRPSPD** (Vehicle Routing Problem with Simultaneous Pickup and Delivery)

The vehicle routing problem with simultaneous pickup and delivery is a variation of the CVRP in which one, several or all customers have, not only demand delivery, but also a pickup. It is thus a question of finding optimal set of tours to both deliver and collect the quantities required by the customers (Liu et al, 2013).

- **VRPB** (Vehicle Routing Problem with backhauls)

This problem is an extension of VRP including two types of knots: knots of delivery and knots of collection. In a VRPB delivery points will receive a quantity of product coming from the deposit and the knots of collection will take a quantity of product returned to the deposit. The critical point for this problem is to organize in the first one, the deliveries to empty the contents of the vehicle to be able to collect the new products. The sum of products to deliver so that the sum of products to be collected does not have to exceed separately the capacity of vehicle (Liu et al, 2013).

- **VRPTW** (Vehicle Routing Problem with Time Windows)

The Vehicle Routing Problem with Time Windows is one of the most studied extensions. The basic problem is the VRP to whom we add a constraint on the schedule of passage of knots. These hourly constraints translate limits on the date of arrival and departure as well as the time slot of every knot of the network (Baldacci et al, 2012). This extension represents numerous cases concrete of management of tours of vehicles. In the literature, this problem is handled with two manners: either by considering that the temporal windows are strict and must be thus absolutely respected, or by considering that the temporal windows are flexible and can't be respected thus (Zhi et al, 2009).

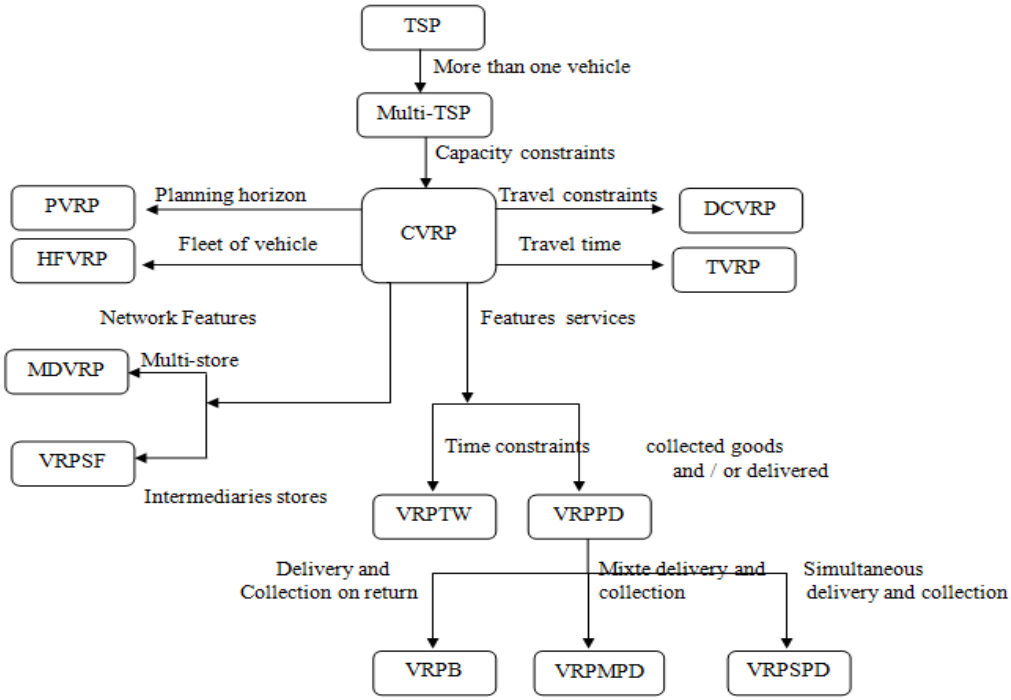

Figure 1. The extensions of the VRP

4. Methods and techniques for solving VRP

Resolution methods devoted to VRP and its variants are mainly classified into two categories: exact methods and approximate methods (Baldacci et al, 2012). The following diagram summarizes the methods of resolution:

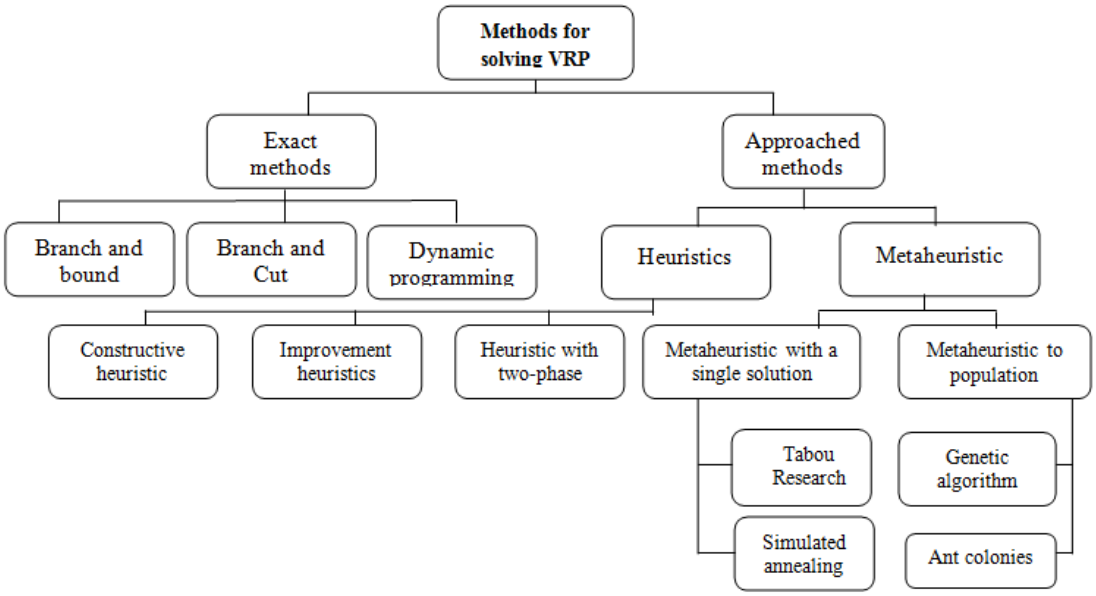

Figure 2. The methods of solving VRP

5. Methodology of resolution

5.1 The delivery network of Fez-Meknes-Oujda region: Current situation

The mail network of the region Fes - Meknes - Oujda account 104 agencies classified by category and distributed on all the regional territory. It covers the region of the north center, of Meknes and the oriental region by the existence of ten regional axes in narrow relation with flat national shape mail. The figure below represents the network of the region Fez - Meknes - Oujda:

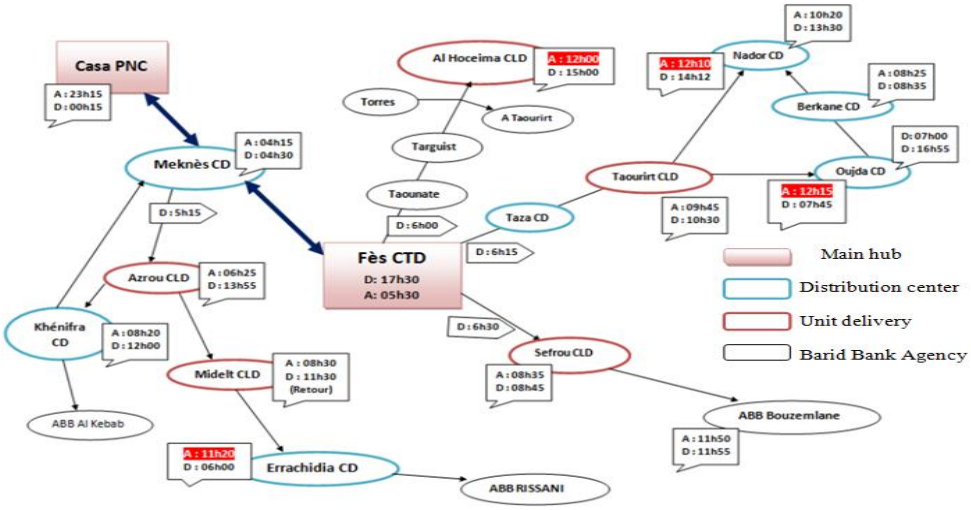

Figure 3. Structure of the delivery network of FMO region[1]

Despite major recent efforts on postal presence, much remains to be done in adapting the network to customer needs. This is evident in the rate of implementation of "time End to End J+1" that represents only 25% while the target is about 80%[2]. Several factors are at the root of this problem, namely:

[1]Service order of the Fez-Meknes-Oujda regional transport routes, Operations Department, DR AP Fez-Meknes-Oujda, Postal Activities Center, 2013.
[2] Objective of the Contract Program 2012.

- Delay of arrival of the mails at the center Errachidia CD (Arrival at 11h20 so distribution at J +2);
- Delay of arrival of the mails in Al Hoceima center CLD (Arrival at 12h00);
- Delay of arrival of the mails at the center Oujda CD (Arrival at 12h15) and center Nador CD (Arrival at 12h10);
- Lack of coordination in the routing circuits;
- Inadequate means of transport safe and regular;
- Long stay sort of mails;
- Non-compliance with judgments for the delivery and management of mails;

These problems are opposed to improving the quality of service at the FMO region. Therefore deduced problem is what shook the tactical organization of routing circuits to deliver all nodes at minimum costs and respecting the commitments of quality and timeliness.

5.2 Approximate to a Vehicle Routing Problem with Time Windows

The problem is a generalization of the vehicle routing problem with time windows. The target network consists of about 8 distribution centers, 5 units with a hub for processing and distribution to Fez closely with Casa national platform of mail. The hub Fez is the point of arrival and departure of vehicles. It has a fleet of heterogeneous vehicles which ensures the delivery of mails in each distribution center. And a team of drivers / conveyors handle this transportation network.

5.3 Choice of the method of resolution

To choose the method adequate for solving our problem, we used the criteria grid as a simple tool to aid decision making(Zhi et al., 2009). We chose four types of criteria: the size of the problem, the optimality of the obtained solution, the ease of implementation of the algorithm of resolution and efficiency of the method(Kahraman, 2008). To fill every compartment, we assign to each criterion a value of 1 to 5 according to its importance (Daamen & Phillipson, 2015). The following table shows the grid of criteria for the choice of solving approaches:

Choice	**Criteria**	**Problem size**	**Guaranteed optimality**	**Efficiency**	**Ease of implementation**	Total
Exact Method	Branch and Bound	2	4	3	2	11
	Branch and Cut	2	5	3	2	12
	Dynamic programming	1	5	3	1	10
Heuristics Method	Constructive H	4	1	2	4	11
	H. with two phase	3	2	3	2	10
	Improvement H	4	3	4	4	15
Metaheuristic Method	Single solution	4	3	4	1	12
	M. to population	5	3	5	1	14

Figure 4. Criteria grid

Based on this analysis, the exact methods have allowed finding optimal solutions for problems of reasonable size and generally having difficulties to face large applications (Baldacci et al., 2012). In contrast, the approximate method (heuristic & Metaheuristic) does not guarantee to find an exact solution, but only an approximation. We will retain in terms of quality of solutions, Metaheuristic are generally better than the heuristics; and in terms of ease of implementation the comparison is reversed(Mehrjerdi, 2012). Similarly, if we compare the construction heuristic to improvement heuristic, the first are much faster than the second but produce solutions of lower quality because they are less sophisticated.

As a result of this comparison we decided to use to solve our problem the improvement approaches.

5.4 The improvement heuristics

Improvement heuristics for the VRP operate on each vehicle route taken separately or on several routes at a time. In the first case, any improvement heuristic for the TSP can be applied. In the second case, procedures that exploit the multi-route structure of the VRP can be developed (Stålhane et al., 2012).

This method starts in part of an initial solution which is successively replaced by a continuation of solutions of decreasing costs. The process stops when we cannot improve any more the common solution. The main advantage

of this method lives in its big simplicity and its speed. Among the operators of exchanges most usually used we have (Mahmudy, 2016) :

- String Cross (SC): Two strings (or chains) of vertices are exchanged by crossing two edges of two different routes.
- String Exchange (SE): Two strings of at most k vertices are exchanged between two routes.
- String Relocation (SR): A string of at most k vertices is moved from one route to another, typically with k= 1or 2 (Stålhane et al., 2012).
- String Mix(SM): The best move between SE and SR is selected (Fleszar, 2013).

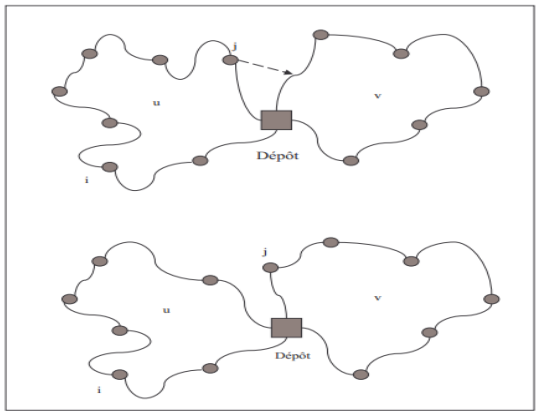

Figure 5. Example of process improvement

6. Trying to solve the VRPTW using the improvement heuristics

6.1 Preliminary Steps

Before presenting the scenarios change, it is useful to recall the method that was used to calculate the transport cost of each axis, as well as planning tour routing.

- **Calculate the cost of Transport**

Any routing operation generates during the course costs that accumulate, it is transportation costs that can be analyzed and divided into two types (Pettersson & Segerstedt, 2013) :

- **The fixed costs**: these are the ones that the company has to bear any level of business; they represent vehicle insurance, rental prices, and wages for drivers, administrative expenses.... etc.
- **The variable costs**: were those which vary depending on the use of the vehicle, namely: fuel consumption, tire wear, spare parts, tolls, maintenance and repair.

Cost of transport = Unit cost of Transport * Distance in kilometers

To calculate the unit cost of each vehicle k, for the data available, we have taken into account the consumption of fuel, salaries of driving, tolls, maintenance cost of vehicles and the rental cost.

6.2 In search of optimal planning - Set of scenarios

Starting from an initial situation of the network routing, we identify the optimal organization through a set of scenario has on the basis of available data, to simulate configurations in which the cost of transport is a very important criterion from an economic point of view, while the compliance of time windows, within each distribution site, is a crucial point for quality of service.

a) Scenario 1:

This configuration is to improve the scheduling of national axis Fez - Casa in particular. Specifically, we removed the distribution center Meknes CD back to reduce the time of arrival of the vehicle at the center Fez CTD. That gives birth to two new regional axes: Fez - Khenifra - Midelt. Service orders will be the same as in the initial situation of the network routing for axes Fez-Taourirt, Fez-Boulmane, Taourirt-Oujda, Nador and Oujda-Nador-Taourirt-Bni Anzer. All delivery vehicles leave and return to the treatment center Fez CTD except for Fez axis - Khenifra, the return will stop at Meknes CD. The following diagram illustrates this new organization:

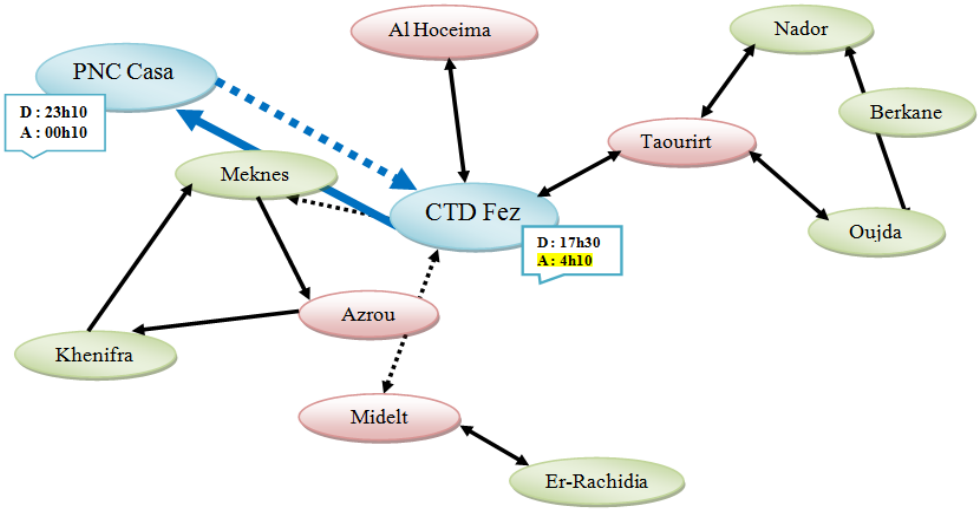

Figure 6. Schematic description of Scenario 1

- Order Service of regional axes:

Axe	Former departure	New departure	Former arrival	New Arrival	Back to the center
Fez – Al Hoceima	6h00	4h40	12h00	10:30	19h20
Fez – Midelt	4h30	4h35	8h30	8h10	15h10
Errachidia - Midelt	6h00	5h40	8h30	8h10	10h30
Fez – Meknes – Khenifra	5h15	5h00	8h20	9h40	15h45
Fez – Taourirt	6h15	5h00	9h40	7h45	13h20
Fez – Boulmane	6h30	5h30	11h50	10h50	15h00
Oujda – Taourirt	7h45	5h45	9h45	7h45	10h15
Taourirt – Nador – Bni Anzer	10h30	8h30	12h10	10h10	17h00
Oujda – Nador	7h00	10h30	10h20	13h50	20h25

Table 1. Scenario 1 - Chronology of regional axes

b) Scenario 2:

To address the problem of delay between the arrival time of the vehicle bringing the news of the distribution cell Al Hoceima and the departure time of the vehicle of the national focus, we proposed a second scenario always with the aim of improving the quality of service within the network region of the FMO. It's to create a direct contact between the national platform of mail and regional platform Fez CTD, this through the elimination of Meknes center in both directions. Dispatches reaching the Al Hoceima cell and its regions will also be sent with shipments from other regions on the same day of arrival at Fez regional center since the departure time of the vehicle of the national focus at 19h30. Configuring routing axes of the second scenario is shown in the following figure:

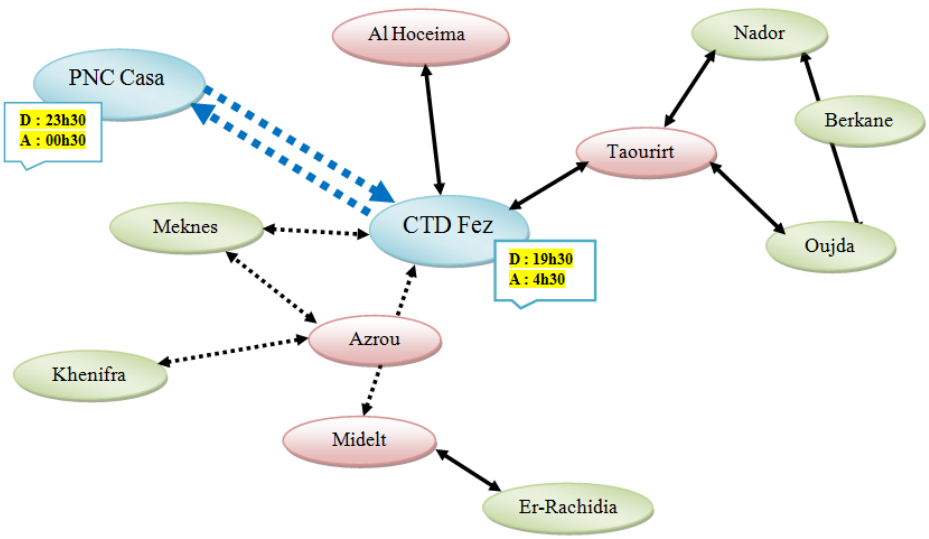

Figure 7. Schematic representative scenario 2

- Service Order of regional axes:

Axe	Former departure	New departure	Former arrival	New Arrival	Back to the center
Fez – Al Hoceima	6h00	4h45	12h00	10:35	19h25
Fez – Midelt	4h30	4h35	8h30	8h10	15h10
Errachidia - Midelt	6h00	5h40	8h30	8h10	10h30
Fez – Meknes – Khenifra	5h15	5h00	8h20	9h40	17h00
Fez – Taourirt	6h15	5h15	9h40	8h00	13h35
Fez – Boulmane	6h30	5h30	11h50	10h50	15h00
Oujda – Taourirt	7h45	6h00	9h45	8h00	10h30
Taourirt – Nador – Bni Anzer	10h30	8h45	12h10	10h25	17h15
Oujda – Nador	7h00	10h45	10h20	14h05	20h40

Table 2. Scenario 2 - Chronology of regional axes

6.3 Analysis results

This table summarizes the results obtained in the two scenarios presented earlier:

Axe	Scenario 1	Scenario 2
	Cost of transport (Dh/day)	Cost of transport (Dh/day)
Fez – Casa PNC	3190	3184
Fez – Al Hoceima	1437	1437
Fez – Midelt	1071	1071
Errachidia - Midelt	693	693
Fez – Meknes – Khenifra	785	903
Fez – Taourirt	2052	2052
Fez – Boulmane	1329	1329
Oujda – Taourirt	762	762
Taourirt – Nador – Bni Anzer	791	791
Oujda – Nador	961	961
Total	**13 071**	**13184**
Initial Cost of transport = 13690 Dh /day	**Reduction of 5%**	**Reduction of 4%**

Table 3. Cost of transport in scenarios 1 and 2

From the results, we see that the first scenario, even if it achieves the minimum cost, not clenched probably not viewed favorably, as the news reached Al Hoceima cell arrive late with respect to time of departure of the vehicle ensuring the delivery of national focus. For cons, the second scenario modeled the operation of the network in order to satisfy all the constraints of time and availability, so all items will be shipped the same day of their arrival at the Fez treatment center. Therefore, it is of interest to choose the second scenario.

7. Conclusion

This article has highlighted the different elements of routing problem in the FMO region. It fits within the vehicle routing problems with time windows. So in this work, we have presented a state-of-the-art about vehicle routing problems (VRP). We then presented the possible methods of resolution proposed in the literature. We have studied the case of the Moroccan post office for postal delivery in the Fes-Meknes-Oujda region. We have tried to improve the postal routing network by using the improvement heuristic based on a set of scenarios in order to arrive at a tactical planning of routing network and efficient management of vehicle fleet while respecting in the same time quality, time and cost constraints.
The main contribution of this work is to provide workable solutions to a real case of distribution. Among other things, network optimization product to potential savings in time and distance while promoting efficient use of transport vehicles.

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