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ORIGINAL ARTICLE

"OPTIMIZATION OF A NETWORK ROUTING MAIL AND MESSAGING"

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Abstract :

Transportation is an important link of the supply chain as it takes charge of the physical flows which go between sites and the distribution of finished products to customers as well.

Problems that are related with the sharing of resources, platforms management (hubs) come up, without forgetting some specific cost problems.

So, companies are interested more and more to join optimal networks of distribution that serve in both reducing costs, and optimizing important resources to get to them while insuring an effective service quality.

This fact is included within problems of vehicle rounds which have always been the subject of many works of research that offers approaches of interesting resolution.

In this context, this work involves a problem modeling of networking design, also; an application related to the field of messaging services, or a new networking distribution configuration; which will be proposed by the end; that serves in optimizing costs and resources and satisfying customer's requirements in the same time.

Keywords:

distribution, modeling, optimization, synergy, network transporting, VRP, localization, AMPL.

INTRODUCTION

In recent years, the postal field has undergone a profound reform of liberalization. Many changes have occurred due to several factors, from which we cite the market's opening and the competition in the Messaging activity; furthermore, the increase of customers demand.

From this context, companies need to improve their performance, efficiency, in order to get competitive advantages, enabling them to increase their profitability, service level and market share.

The Moroccan Postal Group does not constitute an exception. It is the leader in mailing activity since it is the only organization authorized by the State to exercise such activity. Its primary mission is to guarantee a socio-economical performance by ensuring a good quality of services to citizens in a permanent way and with very good prices. It has the whole interest to integrate into optimal networks in order to minimize costs, and ensure the best of competitiveness and sustainability.

To this end, this group is involved in several projects in logistics and transportation.

From this perspective, we find out the synergy project between Mail and Parcel post, which was realized by a first step. It is concerned with the merging of both mailing and messaging pole into a single one named Pole of postal activities. This project aims; throughout the next stages, to create a coordination between the two BAM activities through several paths.

In this context, this contribution focuses on the routing component, which is to develop a new shared and optimal network between Mail and Parcel post.

We are trying to present a model which serves to design an optimal routing network for the Moroccan post, which should insure a minimization of total distances, material, and human resources for use.

FORMAL NETWORK DESIGN

We will start by presenting a formal aspect of the network design to provide an optimal configuration for the network of routing mail of the Moroccan post.

The problem of designing the networking distribution of goods is a difficult problem in the field of transportation and logistics. It involves three relevant questions:

- Where can we place the hubs?
- Which customers can we assign?
- How to do the tours?

This problem generates two levels of decision:

- A first level is strategic, it consists of identifying hubs and satellites and allocate optimally all customers to serve;
- A second operational level, which is to organize the tours to be performed.

Strategic aspect:

Generally, when we talk about a strategic decision, we are interested in a long-term decision. At this level, there is a problem which is often encountered in the logistics of transportation: it is a problem of locating warehouses.

- **Operational aspect:**
-

For the operational component that represents the short term, it deals with the problem of vehicle routing which is the most known in the world of operational research: VRP (Vehicle Routing Problem).

2.1. Warehouse location problem

2.1.1. Description

The warehouse location problem is a common problem in the industry especially in the field of logistics.

It is an NP- complete problem, which has become well known in combinatorial optimization.

In a simple way, this problem is to build a number of warehouses from a set of sites in order to serve a set of customers.

Knowing that the installation of a warehouse costs a fixed price and the delivery of customer from a warehouse generates a cost. The goal is to build warehouses, and assign each client to one and only one warehouse, by minimizing the total cost (installation cost and allocation cost).

Data:

- A finite set of warehouses F.
- A finite set of customers D.
- A finite fixed cost associated with opening a warehouse i.
- A fixed cost c_{ij} related service offered by warehouse j to customer i.

Tasks:

Search a subset X of F (warehouses to open) and an assignment of clients to this subset, σ: D → X de so that: $_i$

$\sum_{i \in X} fi + \sum_{j \in D} c\sigma(j)j$
a minimal.

2.1.2. Mathematical formulation

Asking $y_i = 1$ if warehouse i is open (∀ i ∈ F) , $x_{ij} = 1$ if the customer i is assigned to warehouse j (∀ i ∈ D , ∀ j ∈ F), the localization problem warehouses without capacity constraints can be written as follows :

$$\text{Min} \sum_{i \in F} fiyi + \sum_{i \in D, j \in F} Cijxij$$

Subject to

$x\text{ij} \leq yj$	$\forall i \in D, \forall j, \in F$	(1)
$\sum_{j \in F} xij = 1$	$\forall i \in D$	(2)
$xij \in \{0,1\}$	$\forall i \in D, \forall \in j\ F$	(3)
$yj \in \{0,1\}$	∀∈ j F	(4)

2.1.3. Explanation of constraints

The objective is to minimize the warehouse opening and the cost to transport to the customer cost.

- Constraint (1) states that each customer must be assigned to an open warehouse.
- Constraint (2) requires that each customer must be served by a single warehouse.
- Constraints (3) and (4) are the integrity constraints.

2.2. Vehicle routing problem (VRP)

The vehicle routing problem occurs as the second sub- problem of LRP. It consists of developing tours in several vehicles, each of which can serve as a set of customers, by minimizing the total distance.

Other - words, the goal is to find the tour vehicle that meets customer demand at minimum cost.

Data:

- A complete graph G (V, E) with | V | = n +1 vertices.
- v_0 ∈ V is the deposit.
- v_i ∈ V \ { v_0 } is the customer i ∀ i = 1 ..... n.
- m the vehicles available on the deposit.
- The capacity of each vehicle: Q_i ∀ i = 1 ..... m.
- Q_i : is the amount requested by the client i ∀ i = 1 ..... n.
- C_{ij} : Cost of transportation of customer i to customer j .

2.2.1. Mathematical formulation

Either yik = 1 (∀ i = 1 ... n) , (∀ k = 1 ... m) i if the customer is served by the car k , and X_{ijk}= 1 (∀ i = 1 ... n) (j = 1 ∀ ... n) (∀ k = 1 ... m) if customer j is served just after customer i by vehicle k . The problem of vehicle routing is formulated as follows:

$$\text{Min} \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=1}^{m} Cij\ xijk$$

Subject to

$\sum_{k=1}^{m} yik = 1$ ∀ i = 1…..n (1)

$\sum_{k=1}^{m} y0k \quad \leq$ m (2)

$\sum_{i=0}^{n} qi\ yik \leq Qk$ ∀ k = 1….m (3)

$\sum_{j=0}^{n} xijk$=$\sum_{j=0}^{n} xjik$ = yik ∀ i = 1…..n ; ∀ k = 1…m (4)

$\sum_{vi\in S} \sum_{vj\in S} xijk \leq |S|$-1 ∀ k = 1…..m ; ∀ S ∈ V\0 ; |S|≥ 2 (5)

yik ∈ {0,1} ∀ i = 0….n ; ∀ k = 1….m (6)

xijk ∈ {0,1} ∀ i = 0….n ; ∀ j = 0….n ; ∀ k = 1….m (7)

2.2.2. Explanation of constraints

The objective of this model is to minimize the total cost of touring to complete.

- Constraint (1) requires that each customer must be served by a single vehicle.
- The number of outbound vehicle deposit shall not exceed the number of available vehicles. This is modeled by the constraint (2).
- Constraint (3) indicates that the amount carried by a vehicle must not exceed its capacity.
- Ensure that the number of incoming arcs equalize the number of outgoing arcs for each city is expressed by the constraint (4).
- Constraint (5) avoids the sub towers.
- The constraints (6) and (7) are integrity constraints.

3. Software Resolution

3.1. Software market

IT progress has resulted in an increase in software or enabling modelers to solve mathematical programs, including operations research, with a large number of variables and constraints.

- Among this software, we include AMPL, Lingo, Xpress, OPL Studio and OSL software.
- Their operation is based on two phases: a first phase of modeling, and a second for resolution.
- Compared to the resolution step , the modeler begins by compiling the model to detect syntax errors if they exist, once the syntax is correct , it goes to the loading of data (numeric values) in matrix form, this level , a second syntax check is performed which leads to a treatment by a solver .

3.2. Choice of software AMPL

For solving the proposed model, we have chosen as modeler, AMPL. The latter is one of the most known and used software. It is distinguished by its flexibility to call all existing solvers, which allowed several publishers of algorithmic codes to make a reference to promote their solver.

By being a very powerful for solving optimization problems, it offers simple concepts to formulate problems in a language that is understood by humans, and evaluate solutions by integrating solvers appropriate resolution, as Cplex.

3.3. The solver Cplex

Cplex solver is edited by ILOG, which solves linear problems through exact resolution methods such as algorithm of separation and Branch -And- Bound .

3.4. Implementing a model in AMPL

This modeler has a very beneficial option. It can generate two types of files:

A first file called model: It contains the formulated model by the appropriate language AMPL. This file must have as an extension fichier.mod.

A second file Data: Contains data reporting parameters used in the model. The file extension must be under datafile.dat form.

To run a model using AMPL, Just enter commands in a first phase loading template file, and in a second phase loading the data file to pass the resolution.

4. Application

4.1. Location hubs

4.1.1. Description

The choice of national axes or hubs is relevant to design the routing network of Moroccan post, since it causes a direct effect on the total distance traveled, which define the cost of transport.

Remembering that the network will be shared between the messaging activity and the e –mail one, and the centralization of all mails and parcels will be performed at the national platform in Casablanca mail PNC.

We will not discuss the choice of Casablanca as a national platform (large hub) to connect all national roads, which is justified by strategic location reasons. On the contrary, we integrate in our choice 6 axes which we assign to build cities that are served by these lines in order to minimize the total distance.

For cities affected by this new configuration of network routing Mail and Parcels, we chose the next twenty eight cities:

Rabat, Kenitra , Larache , Tangier, Tetouan, Khemisset , Meknes, Fez, Taourit , Taza Guercif, Oujda, Berrechid , Settat , Khouribga, Benimellal , Marrakech , Safi , Agadir, Tiznit, Guelmim Bouizakarn , Tarfaya , Tan Tan and Laayoune .

Data:

- A set V of cities.
- The distance between the platform at Casa city i Di.
- The distance from city i to city j, d_{ij}.

Tasks:

Find a subset of G belonging to the set V (axes to open) and the allocation of cities " belonging to the set X = V \ G " in this subset G, σ : X → G to minimize the following quantity:

$$\sum_{i\in G} Di+\sum_{j\in X} d\sigma(j)j$$

4.1.2. Mathematical formulation:

$$\text{Min}\sum_{i\in V} Diyi+\sum_{i\in V}\sum_{j\in V} dijXij$$

Subject to

$Xij \le yj$	$\forall\ i\in V$	(1)
$\sum_{j\in V} Xij = 1;$	$\forall i \in V$	(2)
$\sum_{i\in V} Xij \ge yj$	$\forall j \in V$	(3)
$Xii = yi$	$\forall i \in V$	(4)
$\sum_{i\in V} yi = k$	$\forall i \in V$	(5)
$Xij \in \{0, 1\}$	$\forall\ i\in V, j\in V$	(6)
$yi \in \{0,1\}$	$\forall i \in V$	(7)

4.1.3. Explanation of constraints

In this model, the objective function minimizes the distance from the platform at Casablanca to the city which is the hub and the distance from the hub to the cities served by the latter.

Note that:

$$\begin{cases} Yi = 1 \text{ if the Casablanca city i is open } \forall i \in V \\ Yi = 0 \text{ if } \forall i \in V \end{cases}$$

$$\begin{cases} Xij = 1 \text{ if city i is served by the Casablanca city j } \forall i \in V, \forall j \in V \\ Xij = 0 \text{ if } \forall i \in V, \forall j \in V \end{cases}$$

- Constraint (1) means that each city must be assigned to an axis already open.
- A city must be served by an axis that is unique, which is expressed by the constraint (2).
- Constraint (3) requires the use of an axis, that is, an open shaft must necessarily serve at least one city.
- Constraint (4) ensures that the city being an axis cannot be served by another axis.
- The number of axes to open resulting in the fifth constraint.
- The constraints (6) and (7) define the binary variables .

4.2. Interpretation of results

After implementing the first model in AMPL , we found that:

- Rabat as an optimal hub to serve Kenitra, Khemisset , and Meknes.
- Casa- Larache as a national focus that will serve Tangier and Tetouan.
- Taza optimal hub for the region of the SOUTH that will serve Fez Guercif Taounate Taourit, Al- Hoceima , Nador and Oujda .
- Berrechid is also an important hub for Settat and Khouribga .
- Safi and Marrakech will serve Benimellal .
- Bouizakarn to serve Agadir, Guelmim, Tiznit, Tarfaya , Tan Tan and Laayoune .

4.3. Synthesis

National focus of our new routing network are as follows:

- Casablanca- Larache.
- Casablanca- Rabat.
- Casablanca- Taza.
- Casablanca- Berrechid.
- Casablanca- Marrakech.
- Casablanca- Bouizakarn

The following figure shows the new configuration of the routing network:

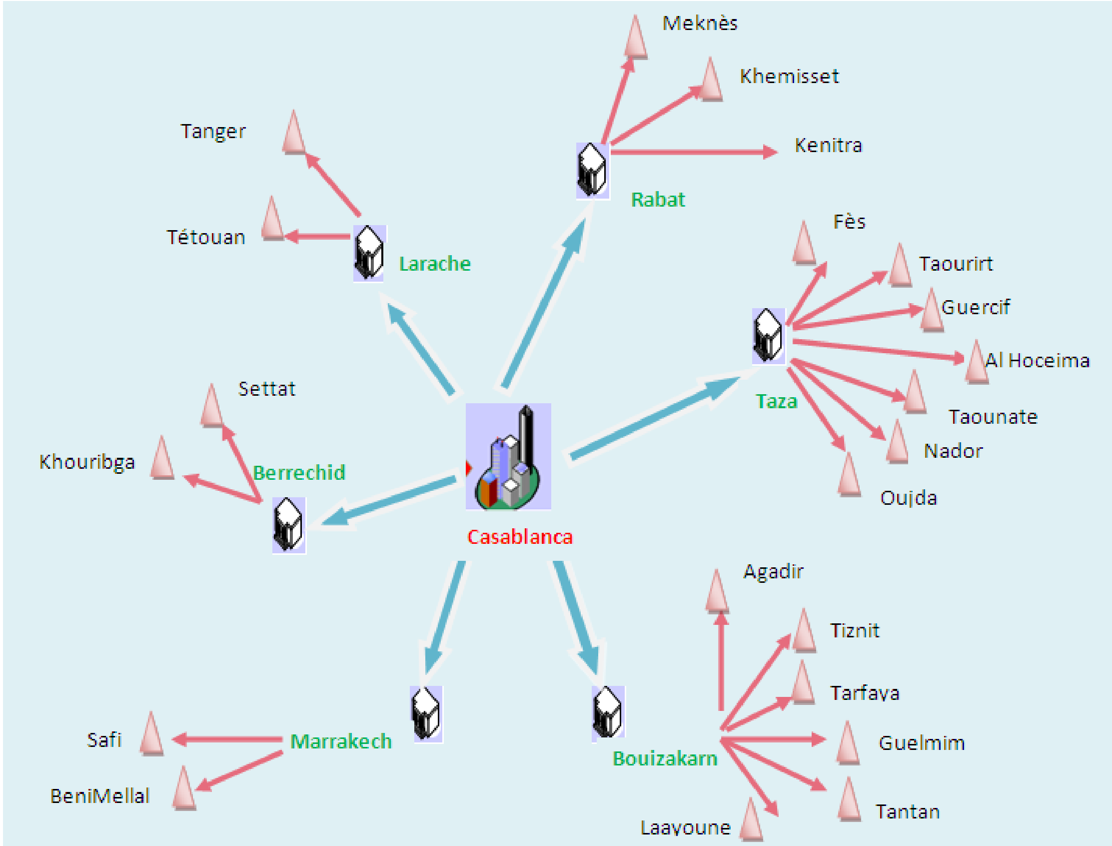

Figure 1: New configuration of the routing network used by AMPL

Up to this point, we were able to locate the best hubs for our network routing. We were also able to determine the optimal allocation of cities to these hubs.

Our next step will involve the organization of tours to serve the cities from the hub to which they are assigned, with the optimization needed to achieve vehicles.

By this end, we will find ourselves in front of the vehicle routing problem (VRP) .

5. Organization of vehicle routing

5.1. Description

Through the model presented above, we have identified areas of national or routing hubs, and proper allocation of cities to these points of connection.

Alternatively, we designed subnets, each of which is built as a platform represented by the hub, and by all cities that are affected by its networking.

To maximize the distance and number of vehicles required to serve the cities from the hub relative to each subnet, it is important to organize tours from the platform to meet all demands with a minimum cost.

It is important therefore to know the number of vehicles available on each platform (hub), the capacity of each vehicle, and the demand assigned to each city hub.

Concerning some hubs, we will not seek to apply a model to determine the optimal develop tours, since the path is straight from the hub to the cities that are affected.

This concern:

- Rabat hub, in which Kenitra, Khemisset and Meknes cities are affected.

- Larache hub, which serves the cities of Tangier and Tetouan.

In addition, we will seek to develop the best tours from:

- aza hub serving Fes, Guercif Taourirt Taounate Al- Hoceima , Nador and Oujda .
- Marrakech hub to which Safi and Benimellal are affected.
- Berrechid hub for Settat and Khouribga .
- South Bouizakarn hub , which serves Agadir, Tiznit, Guelmim, Tarfaya , Tan Tan and Laayoune

Regarding the application of the Courier and Parcel that should be delivered to each city, we tried to take the average of the requests made during a month.

Concerning the vehicle availability, we considered a reallocation of vehicles dedicated to the delivery at the identified hubs.

Data model:

- A complete graph G (V , E) with | V | = n +1 vertices (subnet)
- $v_0 \in V$ is the hub (platform).
- $v_i \in V \setminus \{ v_0 \}$ i represents the city . ∀ i = 1 ..... n (cities assigned to this hub).
- Set of m vehicles available on the platform.
- Qi: the capacity of each vehicle. ∀ i = 1 ..... m.
- q_i: The amount requested by the city i . ∀ i = 1 ..... n.
- D_{ij}: Distance between city i to city j.

5.2. Mathematical formulation

If the following decision variables:

$$\begin{cases} Yik = 1 \text{ if city i is served by vehicle k } \forall i = 1 \ldots n, \forall k = 1 \ldots m \\ Yik = 0 \text{ otherwise } \forall i = 1 \ldots n , \forall k = 1 \ldots m \end{cases}$$

$$\begin{cases} Xijk = 1 \text{ if city j is served immediately after city i by vehicle k } \forall i = 0 \ldots n , \forall j = 0 \ldots n , \forall k = 1 \ldots m \\ Xijk = 0 \text{ if } \forall i = 0 \ldots n , \forall j = 0 \ldots n , \forall k = 1 \ldots m \end{cases}$$

This problem can be modeled for all subnets (hubs) as follows:

$$\text{Min } \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=1}^{m} Dij\ xijk$$

Subject to.

$\sum_{k=1}^{m} yik = 1$ ∀ i = 1…..n (1)

$\sum_{k=1}^{m} y0k \le m$ (2)

$\sum_{i=1}^{n} qi\ yik \le Qk$ ∀ k = 1….m (3)

$Xiik=0$ ∀ i=0…..n ; ∀ k=1….m (4)

$\sum_{j=0}^{n} xijk = \sum_{j=0}^{n} xjik = yik$ ∀ i = 1…..n ; ∀ k = 1…m (5)

$\sum_{vi \in S} \sum_{vj \in S} xijk \le |S|-1$ ∀ k = 1…..m ; ∀ S ∈ V\0 ; |S|≥ 2 (6)

$yik \in \{0,1\}$ ∀ i = 0….n ; ∀ k = 1….m (7)

$xijk \in \{0,1\}$ ∀ i = 0….n ; ∀ j = 0….n ; ∀ k = 1….m (8)

5.3. Explanation of constraints

The objective of this model is to minimize the total distance of de tours which will be performed.

- Constraint (1) ensures that each city is served by a single vehicle.

- The number of outbound vehicle platform must not exceed the number of available vehicles. This is modeled by the constraint (2).
- Constraint (3) indicates that the sum of the quantities transported by a vehicle must not exceed its capacity.
- Constraint (4) indicates that a city cannot be served immediately after itself.
- Ensure that the number of incoming arcs equals the number of outgoing arcs for each city is expressed by the constraint (5).
- Constraint (6) avoids the sub towers.
- Constraints (7) and (8) are the integrity constraints.

5.4. Resolution

The results which were provided by the solver Cplex in AMPL will be described for each of the previously identified hubs.

5.4.1. Taza Hub

Recall that the cities served by the hub are:

Fez, Taourirt Guercif Taounate Al- Hoceima , Nador and Oujda.

Based on the results provided by AMPL , a vehicle with a capacity of 8 tonnes will serve Fez, while a vehicle of 14 tonnes capacity will serve starting from Taza,Guercif followed by Taourit and Oujda Nador, Al Hoceima and then ended by Tatounate .

Thus, the total distance through the tour is 1153 km.

The tours will therefore be organized as follows:

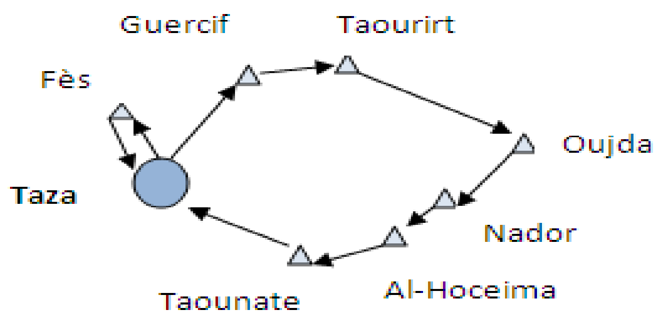

Figure 2: Tours to perform from Taza

5.4.2. Hub of Berrechid

Settat and Khouribga are both assigned to the hub cities Berrechid.

Interpretation of results:

The optimal way is to use Settat and Khouribga from Berrechid, which is to use a vehicle of 3.5 tonnes from Berrechid to Settat and then to Khouribga

This tour requires the path a distance of 205 km .

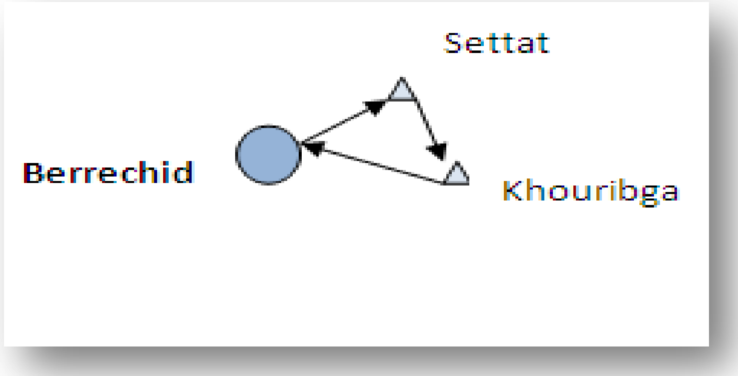

Figure 3: Tours to perform from Berrechid

5.4.3. Hub Marrakech

Recall that the only cities served by the hub are:

- Safi
- Benimellal

Interpretation of results:

We will cover a maximum distance of 710 km, proceed as follows:

- Serving Safi by a vehicle which hasa capacity of 3.5 tonnes and return to Marrakech.
- Serve Benimellal by a vehicle with a capacity of 8 tons and then return to the hub

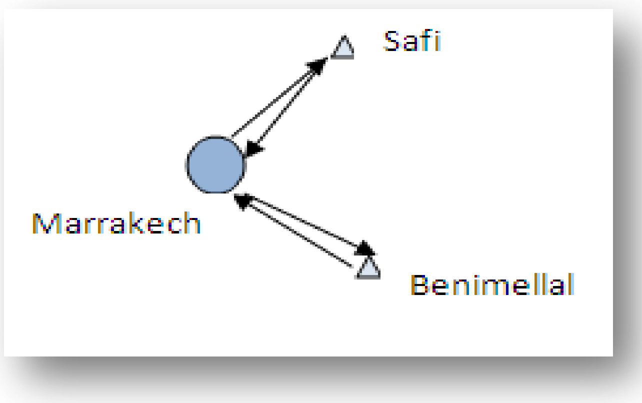

Figure 4: Touring to perform from Marrakech

5.4.4. Hub of Bouizakarn

This hub serves the cities of the south:
Agadir, Tiznit, Guelmim, Tan Tan, Tarfaya and Laayoune.

Interpretation of results:

The optimal rounding to be performed from Bouizakarn hub to cities that are made tours are as follows:

- A tour from Bouizakarn to Agadir and Tiznit provided by a vehicle capacity is 14 tons.

- A second round by a vehicle with even a capacity of 14 tonnes, which will leave Bouizakarn heading towards Tan Tan and Tarfaya, followed by Laayoune, and finally Guelmim.

Optimal to go through these two rounds total distance is 1374 Km

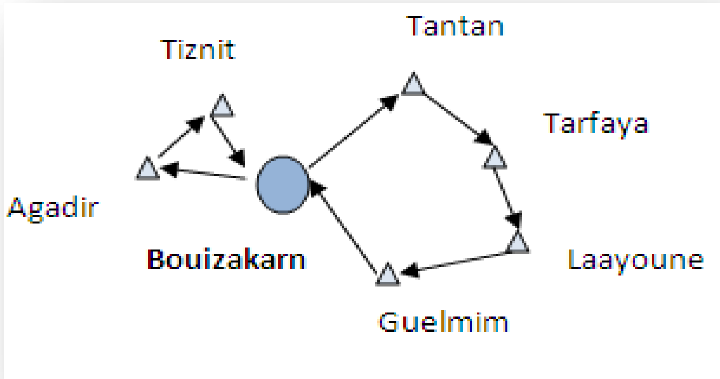

Figure 5: Tours to perform from Bouizakarn

6. Synthesis

Through the proposed model, we have a configuration of a new routing where an organization of tours was established network.

This network is as follows:

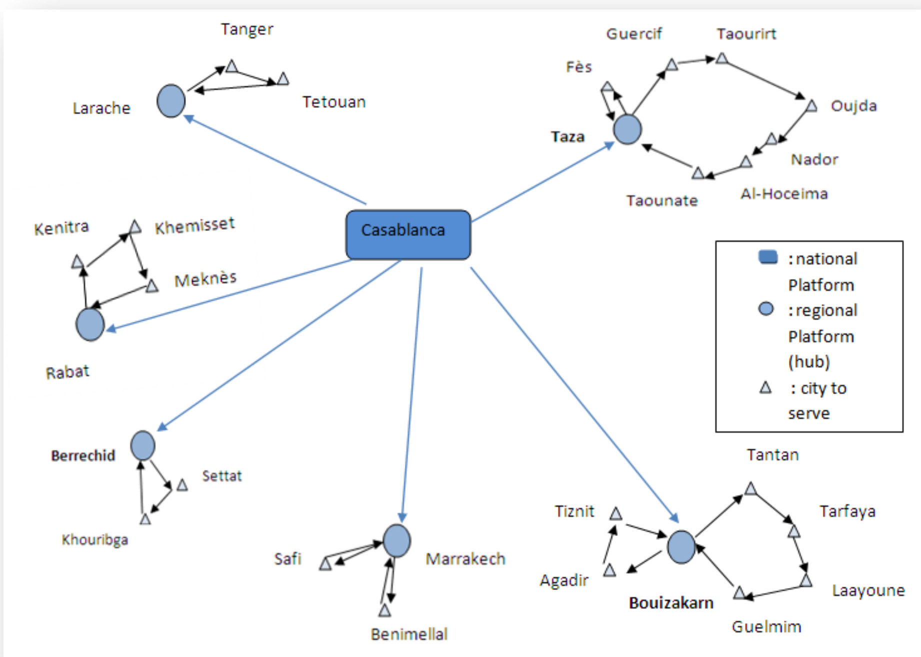

Figure 6: Final configuration of the routing network used by AMPL

7. CONCLUSION

Through this contribution, we tried to apply a model that optimizes the total distances, in a manner that reduces costs generated by transport.

Indeed, we chose in the first level, to identify six points or hubs optimal connections, which are supplied from the national platform of Casablanca, and determining the optimal allocation of cities to these hubs.

Optimal hubs that have been identified by the model are: Rabat, Larache , Taza , Berrechid , Marrakech, and Bouizakarn .

Then we moved to the second phase, which consisted in developing optimal tours starting from the hubs to the cities that are assigned. Insuring an optimization in distances and satisfying the demands as well.

This has allowed us to have the configuration of a new common transport between Mailing and Messaging.

Furthermore, we believe that treating the two decisions in two phases: in other words, to identify hubs and allocation of cities firstly, then looking for the optimal touring secondly may not guarantee a global optimality.

Thus, it would have been interesting to study both levels simultaneously and without any hierarchy.

This approach may be treated by the application of a metaheuristic GRASP type: Greedy Randomized Adaptive Search Procedure to generate optimal results in optimization problems.

In addition, this work could be enriched and supplemented by taking into account the transit time which allows to control the arrival time to the destination cities.

Thus, it was necessary to treat a multi-objective problem, which incorporates both the criterion of minimizing distances and the criterion of maximizing the level of service quality.

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