Logistic Management in a Fresh Food Firm: A Case Study

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Abstract An efficient and effective logistic system is a strategic objective in any business. This paper presents a real case study of routing problem on a food industry firm. The simplest case of route optimization is the traveling salesman problem. In this paper there are capacity restrictions and different demands at each node. Then, the problem is classified as a capacity vehicle routing problem. In this paper the Neural Network and Tabu Search algorithms, based on previous literature, are used to solve the problem.

Key words: CVRP, Neural network, Tabu Search, Logistic Management

1 Introduction

Logistic is an essential area in business competitiveness. The delivery of goods from a warehouse to local customers is a critical aspect and therefore it can be considered as a source of competitive advantage (Euchi and Chabchoub, 2010). Logistics management has especially relevance in high competitive industries such as food industry, where the logistics costs constitute an important percentage of the total costs and the product requires to be served with severe punctuality (Tarantilis and Kiranoudis, 2002). The food industry is interested in reducing...
transport costs maintaining quality of the services, especially when dealing with fresh and perishable products. An efficient and integrated system of activities is involved in processing and transporting products from the supplier to the consumer (Brito et al., 2012). For a range of goods labelled as perishables, particularly food, their quality degrades with time is very high. It can be mostly mitigated with lower temperatures, but takes time and coordination to efficiently move a shipment and every delay can have negative consequences. An inefficient distribution system causes that the products will not reach to their destinations on time and the ordered volume reducing the storage and raising the cost considerably because there are many products that are returned by traders, and it complicates to set the optimal logistic decision (Tarantilis and Kiranoudis, 2001). It is essential to determine the optimal routes with the main objective of minimizing the distance, costs and time, maintaining quality of services (Faulin et al., 2011).

In this paper it has been considered a real case study of a Spanish firm leader in the fresh meat industry. The main objective has been to improve the profit and the competitiveness of the firm based on the logistic operations, minimizing transportation cost employing optimization algorithms. The use of computerized methods in distribution processes often results in savings ranging from 5% to 20% of transportation costs (Toth and Vigo, 2002). Given a set of customers with known geographical locations and demands, the problem consists of designing an optimal number of routes that minimizes the total distance travelled. Each route starts and finishes at the depot and each customer is visited exactly once. This is the called travel salesman problem (TSP). This paper the TSP is expanded to a vehicle routing problem (VRP) because there are different demand requirements at each node, and different capacities for vehicles. In this paper is considered the static and deterministic basic version of the problem, known as the capacitated VRP (CVRP). In the CVRP all the customers correspond to deliveries, deterministic known in advance demand, the vehicles are the same. It is also taken into account a single central depot, where only the capacity restrictions for the vehicles are imposed, and the objective is to minimize the total cost needed to serve all the customers (Paolo, 2012).

The food industry has been considered previously by Hsu and Feng (2003). The objective function of these problems usually involves distances, costs, number of vehicles and delivery time (Faulin et al., 2011). The authors have not found in the literature any research work that can solve the problem presented in this paper taking into account the purchase volume, frequency of orders, type and prices of the products demanded by the customers.
2 Case Study and Problem Description

This case study was conducted in an important firm in fresh food industry with a large commercial structure, including a logistic department expanded and consolidated throughout the Spanish market, with a relevant presence in the EU market, principally Portugal, Italy and France. In the Spanish market, the firm has segmented the market in the following areas in order to maximise the operations control: Central Area, North of Andalucía, West of Andalucía, East of Andalucía, Extremadura and Castilla y León. This research has been focused in the region of Extremadura.

Originally the routes design is done by the experience of the workers and they do not use any formal mathematical method or specific software. The firm chooses new customers without any logistical or economic criteria, only to maximise the sales. The result is that there are a large number of customers based on a politic of maximising the sales, but it generates a significant growth of logistics costs. The transport costs are approximately 52% of total logistic costs and 7% of the total costs, depending of the volume transported.

This work is focussed to reduce the total cost in order to maximise the profits, analysing the customers that are not profitable for the company (Zeithaml et al., 2001), and increasing the logistic effectiveness in order to reduce the transport cost and maximise the flexibility of the routes.

An analysis of the sales distribution percentages of 421 customer shows that approximately 20% of the total customers demand 80% of the total. The results has been taken as reference for filtering and detecting the potential customers that are important in terms of the total volume of sales, i.e. a complex and robust structure of customers does not increase the profitability of the firm because the product requires to be distributed by the enterprise, and it generates important logistic costs. A new scenario has been defined based on only 86 customers (Figure 1). The new characteristics of the customers are: a) big volume of product demanded; b) orders are done with the same frequency (twice a week); and c) large orders for the same type of products. The percentage of wholesale customer is of 71% -11% more than reference scenario, retailer customer 21% -10% less than the original scenario, and the manufacturer customer has the same percentage of 8% in both scenarios.
Many managerial problems, e.g. routing problems, facility location problems, scheduling problems, network design problems, etc., can be modeled as a VRP. VRP expand TSP and requires finding a shortest Hamiltonian tour on $n$ given cities (Gutin and Punnen 2002). The CVRP consists of finding a collection of $K$ simple routes (corresponding to vehicle routes) with minimum cost, defined as the sum of the costs of the arcs belonging to the circuits, and such that:

(i) each route visits the depot vertex.

(ii) each vertex is visited by exactly one route.

(iii) the sum of the demand of the vertices visited by a circuit does not exceed the vehicle capacity.

The routing design process of the firm must optimize the number of vehicles to involve and find out the routes of each vehicle. The problem to solve can be described as a vehicle routing problem (VRP) (e.g. Faulin, 2003), with the following characteristics: (a) unknown fleet size, (b) homogeneous fleet (refrigerator trucks loading a fis volume of products), (c) single depot, (d) deterministic demand, (e) goal: minimizing distances.

The problem is formulated as a Hamiltonian cycle, i.e. the problem is defined by the graph $G = (V, E)$, where $V \subseteq \mathbb{R}^2$ is a set of $n$ cities, and $E$ is a set of arcs connecting these cities. Under these conditions, the problem can be formulated as:

Minimize: $$\sum_i \sum_j c_{ij}x_{ij},$$

where $x_{ij}$ is the binary decision variable that in case of $i < j$ has the following values:
\[ x_{ij} = \begin{cases} 1 & \text{if the arc joining cities } i \text{ and } j \text{ is used in solution} \\ 0 & \text{otherwise} \end{cases} \]

And \( c \) is the associated cost matrix of \( E \), composed by the elements \( c_{ij} \) that represents the “distance” (expressed as physical distance) between the cities \( i \) and \( j \). In this paper, cost matrix is asymmetric subject to the constraints:

\[
\sum_{j \in V \setminus \{0\}} x_{ij} = 1, \quad \text{for all } j \in V \setminus \{0\} \quad (1)
\]

\[
\sum_{i \in V \setminus \{0\}} x_{ij} = 1, \quad \text{for all } i \in V \setminus \{0\} \quad (2)
\]

\[
\sum_{j \in V \setminus \{0\}} x_{0j} = K \quad (3)
\]

\[
\sum_{i \in V \setminus \{0\}} x_{i0} = K \quad (4)
\]

\[
\sum_{i=1}^{K} \sum_{j} x_{ij} > \gamma(S) \quad \text{for all } S \subseteq V \setminus \{0\}, S \neq \emptyset \quad (5)
\]

The indegree and outdegree constraints (1)-(2) impose that exactly one arc enters and leaves each vertex associated with a customer. Constraints (3)-(4) impose the vehicles requirements from the depot. All available vehicles must be used in one route. This number of vehicles is not smaller than the minimum number of vehicles needed to serve all the customers’ demands. Constraint (5) imposes the connectivity of the solution and the vehicle capacity requirements, i.e. each route \((V/S, S)\) defined by a vertex set \( S \), is crossed by a number of arcs bigger than \( \gamma(S) \) (minimum number of vehicles needed to serve customer set \( S \)) (Toth and Vigo 2002), see (6).

\[
\sum_{i} \sum_{j} s_{ij} t_{x_{ij}} + \sum_{i} \sum_{j} f_{ij} x_{ij} \leq T^{k} \quad (6)
\]

where \( s_{i} \) is the time to serve a customer, and \( t_{ij} \) the time needed to travel from city \( i \) to city \( j \). Both must be less than total time \( T \) for each vehicle \( k \).

Finally, subtour elimination constraints (SECs; 7) are required in order to prevent undesirable subtours that are degenerate tours formed between intermediate nodes and not connected to the origin (Bektas, 2006). The restriction of Miller et al. (1960) is used (7).

\[
u_{i} - u_{j} + Cx_{ij} \leq C - d_{j} \text{ for all } i, j \in V \setminus \{0\}; \ i \neq j; \ s.t. \ d_{i} + d_{j} \leq C \]

\[
(7)
\]
\[ d_i \leq u_i \leq C \text{ for all } i \in V \setminus \{0\}; \]

where \( u_i; i \in V \setminus \{0\} \), is an additional continuous variable representing the load of the vehicle after visiting customer, and \( d_i \) is the demand of each customer. When \( x_{ij} = 0 \) the constraint is not binding since \( u_i \leq C \) and \( u_j \geq d_j \), whereas when \( x_{ij} = 1 \) they impose that \( u_j \geq u_i + d_j \) (Toth and Vigo, 2002).

There are a large number of algorithms to find the routes, but no one are feasible for large instances because they present exponentially in computational cost terms (Ganesh et al., 2007). In recent years several meta-heuristic algorithms have been proposed for the VRP (Baldacci et al. 2007): Simulated Annealing (SA), Deterministic Annealing (DA), Tabu Search (TS), Genetic Algorithms (GA), Ant Systems (AS), and Neural Networks (NN) (Gendraru et al. 2002). The problem has been solved in this paper by TS and NN algorithms.

3 Results

3.1 Neural Network Algorithm

The origin of the Neural Network (NN) is usually employed in combinatorial optimization problems for calculating routes for the structure and characteristics of the case study presented in this paper (Leung et al., 2004). NN is based on concepts related to human brain mechanism, and they are inspired in the neuron system. NN consists of processing units, called artificial neurons, organized in layers. One of the advantages of NN is that requires a minimum computational cost compared with the required by exact algorithms and other heuristics algorithms. NN is an algorithm that can learns from a reference solution set. This process is done by an adaptive form where the connection between neurons to implement the desired behaviour is adjustment. New advantages have been found in self organization, where NN organizes the information received during training time, and it can work online, i.e. the computational operations are carried on parallel minimizing the information lost during the process, etc. (Sivanandam et al., 2006). The NN can be single layered, with an input and output layer, or multiple layered, e.g. with an input, hidden and output layer - net (Sivanandam, et al., 2006). In this paper is employed a multiple NN because it leads to obtain consistent results and solves this type of problems efficiently (Figure 2).

The number of neurons in the input and output is determined automatically. However, the number of hidden layers and neurons in each hidden layer has been defined by multiple combinations tested for NN. The NN approach in this paper is based in the following functions:
• **Pdv Function**: This function creates a weight matrix, which gives an importance weight to the entries. It also creates a route pattern, generating a vector path or solution.

• **Geper Function**: It generates the permutations necessary for the \( pdv \) function.

• **Dpdv function**: It founds the path starting from the vector generated by a function called \( pos \).

• **Fc Function**: \( Fc \) does the learning to obtain the reference optimal solutions. \( fc \) depends of \((N, A)\), where \( N \) is the number of nodes and \( A \) represents the matrix of distances between the different nodes.

![Fig. 2 Neural Network with three layers](image)

### 3.2 Tabu Search Algorithm

The tabu search (TS) algorithm is based on artificial intelligence using the concept of memory. It has been implemented through simple structures. TS is one of the most used algorithm in empirical researches in VRP with excellent results (Brandão, 2011). In this sense Courdeau and Laporte (2004) noted that: “While the success of any particular method is related to its implementation features, it is fair to say that tabu search (TS) clearly outperforms competing approaches”.

TS explores the solutions by moving in each iteration from a reference solution to the best solution in its neighborhood. A neighborhood to a reference solution is defined as any solution that is obtained by a pair wise exchange of any two nodes in the solution. This always guarantees that any neighborhood to a feasible solution is a feasible solution. The new solution may be deteriorated when is moved from one iteration to another (Ganesh et al., 2007). In order to avoid this, there is a list that contains recent modification occurred during the transformation from the current solution called tabu list. Tabu list allows new solutions only if the method improves the best solution obtained. The TS approach in this paper uses the following two primary functions:

• **Tabu Function**: This function is responsible for doing all the possible permutations for finding the minimum route.
• List Function: This function contains the tabu list which includes the solutions that have been explored in order to not consider these solutions.

TS also employ the tabu function \((A, \text{path})\), where \(\text{path}\) is a vector composed by the initial solutions.

Table 1 presents the total distances corresponding to the routes defined by the firm. The proposed algorithms provided reliable and practical solution with considerable improvements in operational performance, reducing total distance and time in comparison with previous scenario given by the company for the same routes.

<table>
<thead>
<tr>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (Km) / Time (H)</td>
<td>Distance (Km) / Time (H)</td>
<td>Distance (Km) / Time (H)</td>
</tr>
<tr>
<td>Before</td>
<td>Neural</td>
<td>Neural</td>
</tr>
<tr>
<td>1237.3 / 20.15</td>
<td>922 / 15.45</td>
<td>925.8 / 14.54</td>
</tr>
<tr>
<td>Neural Network</td>
<td>1353.5 / 21.23</td>
<td>804 / 13.55</td>
</tr>
<tr>
<td>Tabu search</td>
<td>1442.6 / -</td>
<td>874.5 / 12.45</td>
</tr>
</tbody>
</table>

It can be seen that the solution generated by TS and NN methods is almost the same, but solution given by NN is more feasible than that obtained by the TS based on the location of populations. In both algorithm, time constrains are satisfied (two work days, 16h), and allow delivery with actual vehicle availability and capacity.

However, the computational cost is different due to the TS algorithm uses a heuristic method that is fixed, however NN employs a learning process. NN algorithm is much more useful than the TS algorithm when the number of nodes is big, and the NN method generates possible solutions is the same to the number of entries elevated, whereas in the method of the TS generated number of possible solutions raised according to the input nodes.

4 Conclusions

This paper has shown that an uncontrolled number of customers causes an important increasing of logistics costs, reducing the profit of the firm. This paper shows that implementing the Tabu Search and Neural Network algorithms for solving various instances of CVRP can significantly reduce the transportation costs that occur during the delivery process.
In accordance with the findings of this study, new opportunities for research are presented. The first opportunity for research deals with the reconfiguration of customer portfolio based on profitability criterion. Secondly, is possible to optimize the transport costs minimizing the distance covered using VRP algorithms.

5 References


