Analysis of Transport Processes Management for a Romanian Food Market

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ABSTRACT
This paper presents the study of optimization process for the products transportation for a Romanian food-market. The vehicle routing problem was solved using Lingo 13.0 software and an analysis was conducted in order to determine the optimal routes for the vehicles in the conditions of products request variation. The program developed is considering one storing place from where the products are transported to other six delivery points using three vehicles. Each vehicle has a constant capacity and a constant travel velocity.

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1. Introduction
The process of analysis and determination of the optimum routes for the vehicle transportation is a problem very much analyzed in the research literature [1−10]. The problem of routes determination such that a certain function related to the distance, cost, e.a., to be optimized is known as the „Vehicle Routing Problem“ (VRP) [1−4, 7].

If a certain time period is established for the vehicle arrival in one place, the problem becomes the well known „Vehicle Routing Problem With Time-Window“ (VRPTW) [5, 6, 8−10], an extension of the VRP analysis. Each vehicle departs from the storing place and delivers the products to some intermediary distribution center towards the final destination and, then, it comes back to the storing place. For each delivery point of the route there is a time period when the products are expected to be delivered. The quantity of the products delivered must not exceed the vehicle maximum capacity such that on the route each vehicle can supply the established distribution centers.

VRPTW problem received two development directions: VRP with a „soft time window“, (VRPSTW) and „VRP with a „hard time window“ (VRPHTW) [6, 10] where it is not accepted to deliver the products outside the established time period. VRPSTW is a version of VRPHTW problem where it is accepted to deliver the products outside the established time period, if a penalty is paid.

Vehicle Routing Problem is solved using conditions as the following:
(1) Each vehicle has a fixed capacity;
(2) Each client is served by only one vehicle;
(3) All the requests satisfied by one vehicle must not be greater than the vehicle capacity;
(4) There are problems where a distribution center can receive products from more than one vehicle or the condition that one vehicle must supply only one distribution center can be imposed;
(5) It is possible to establish a time range for the delivery process of each distribution center;
(6) The travel speed of the vehicles can be constant or it can vary such that a vehicle arrives at the destination point exactly in the time period established beforehand.

The last two possible conditions were developed especially for the food transportation, for the fresh products whose quality deteriorates in time. This is another category of problems treated in the literature and that complete the numerous categories of problem solved by vehicle routing problems.

A great number of software were developed having as aim the improvement of the products distribution management in a distribution network. These software are establishing the optimum routes as a function of the distribution centers requests, the vehicles tracking in the traffic, the fresh products quality monitoring such that the products beneficiary and the transportation company can decide in real time if they want the products to be transported further. The products quality losses can also be established as a function of transportation route or time, penalties can be calculated, e.a.

Section 2 of this paper analyses the optimum routes for a Romanian food-market. Lingo 13.0 [11] software was used for modeling the distribution network: it consists of one storing place and other six distribution centers.
centers. The length of the connections have been established and the products requirements for each
distribution center have been registered. Considering the depot as the starting point and all the other centers
as distribution points of the network, we developed a program, using this software, that establishes the
transportation routes for the products such that the distribution centers receive the products in the optimum
conditions required by the objective function.

Section 3 of this work presents the results obtained using the mathematical model; the software showed
that there are necessary a number of four transports to be effectuated while the company has 3 vehicles with
a capacity of 3.5 tons each. The variation of the transportation routes is established considering oscillations of
the products requirements. Variations of the products requirements for each distribution center were
analyzed successively.

Section 4 presents the conclusions of this work. It offers an useful method for the establishment of the
transportation routes toward the products distribution centers of an Romanian food market.

2. The numerical simulation of the transportation process

The simulation of the supply chain for a Romanian food market is realized using the Lingo 13.0 software.
The objective function that was optimized received the expression presented by equation (1):

\[ \sum C_{ij}X_{ij} \]  

where \( C_{ij} \) is the products transportation costs between the nodes i and j of the distribution network.
Considering that the travel velocity of the vehicle is constant, this cost is proportional with the distance
between the two points of the distribution network. \( X_{ij} \) is the quantity of products transported by a vehicle
between the two points; \( X_{ij} \) is not equal with the quantity that will be delivered in the point „j”, if the
transportation is taking place from the node „i” to the node „j”; it is equal with the quantity of products in the
vehicle that is transported on the distance \( i \rightarrow j \).

The distribution network has the store place, point 1 in Figure 1, and other six points, the nodes 2-7 in
Figure 1. Figure 1 also presents the distances between the network points, the possible connections and the
production requests for each node (written in the rectangles above each node).

The mathematical model of the products distribution in the network presented by Figure 1 imposes two
conditions:

1. the quantity of products distributed to each node must be equal to the request made by each center
to the storing place. The Lingo 13.0 software allow us to impose this request as follows:

\[ @FOR(NODES(J)| J\#NE\#1:
    @SUM(NODES(I):V(I,J)*X(I,J)-V(J,I)*X(J,I)) = D(J)); \]  

2. From the storing place, the quantity of product delivered is equal to the products requests We are
imposing this request as follows:

\[ @FOR (NODES(J)|J\#EQ\#1:
    @SUM(NODES(I):V(I,J)*X(I,J)-V(J,I)*X(J,I)) = -@SUM(NODES(L):D(L)); \]

We considered that each vehicle has a constant capacity of 3.5 tones.
3. An essential condition is that the quantity of products transported by one vehicle must not exceed the maximum capacity of the vehicle; this condition is imposed for each road sector. In Lingo 13.0 software, this request has the following form:

\[
\text{FOR} (\text{NODES}()[]|\#\Ne\#1: \\
\text{FOR}(\text{NODES}(I): \text{X}(I,J) \leq 3.5));
\] (4)

3. Numerical simulation results and discussions

The program we constructed is delivering the results as a matrix \(X(i, j)\) whose values present the quantity of products transported between the nodes \(i\) and \(j\). A zero value for \(X\) represents a connection that is not leading us to an optimum product distribution in the network. On the contrary, a value different from zero for \(X\) presents a road used by the a vehicle in an optimum products distribution. Figure 2 presents the results of the products distribution optimization using Lingo 13.0 software. Figure 2 shows that:

- \(X(1, 2)\) is 3.0, in other words, a vehicle is transporting 3 tones of products on the distance 1-2; further, after delivering 2 tones of products at the distribution center number 2, on the remain distance 2-4 only 1 tone of products is transported according to the center 4 request;
- A vehicle transports 3.5 tones of products on the route 1-3 according to the center 3 requests;
- A vehicle transports 3.5 tones of products on the route 1-3, it delivers 1.5 tones to the center number 5 according to the request; there are 2 tones of products to be transported on the distance 5-6 toward the center number 6;
- 3.5 tones of products are transported on the route 1-7, 3 tones are delivered to the center number 7 and 0.5 tones will be transported further on the distance 7-6 to the center number 6;
- center number 6 receives 2.5 tones from two vehicles as follows: 2 tones on the route 5-6 and 0.5 tones on the route 7-6.
- A number of four transports are necessary for the products delivery according to the distribution centers requests. The objective function has a value of 111.

![Figure 2. Optimum vehicle routing solution](image)

Further, a detailed analysis is made for the optimum vehicle routing variation as a function of distribution center requests variation.

3.1. Optimum vehicle routing solution for distribution center number 2 requests variation

When the distribution center number 2 does not make any products request, a solution for the optimum vehicle routing could not be found. Consequently, the connection \(1 \rightarrow 4\) with a distance \(u(10km)\) was defined, Figure 3. The simulation results are presented by Figure 4; the objective function is 100.

A request of 1 tone from the distribution center number 2 leads to the optimum solution for the vehicle routing presented by Figure 5.
Figure 3. The network distribution and the connection $u(10\text{km})$

Figure 4. The optimum vehicle routing for no request from the distribution center number 2

Figure 5. The optimum vehicle routing for a request of 1 tone from the distribution center number 2
3.2. Optimum vehicle routing solution for distribution center number 3 requests variation

When there is no production request from the distribution center number 3, the optimum vehicle routing solution is presented in Figure 6. The objective function has a value of 83.

![Figure 6. The optimum vehicle routing for no request from the distribution center number 3](image)

For production requests of 0.5t, 1t or 2t from the distribution center number 3, the objective function has values of 87, 91 and 99, respectively. The routes and the vehicles loads are presented by Figure 7. As we can notice, a route 1-3 is requested every time the distribution center number 3 is placing a request.

![Figure 7. The optimum vehicle routing for a request of 0.5, 1.0 and 2.0 tones, respectively, from the distribution center number 3](image)

3.3 Optimum vehicle routing solution for distribution center number 4 requests variation

When the distribution center number 4 is not placing any request, the optimum routes are those presented by Figure 8 with an objective function of 100. For other cases, the solution is given by Figure 2.
Figure 8. The optimum vehicle routing for no request from the distribution center number 4

3.4. Optimum vehicle routing solution for distribution center number 5 requests variation

For a request of 0.0t of the node number 5, we cannot obtain an optimum solution maintaining the other requests established initially. Only by changing the vehicles capacity to 4 tones each (Figure 9) or using two vehicles with a capacity of 3.5 tone each and another vehicle with a capacity of 5.0t (Figure 10) lead us to an optimum solution. Figure 9 has an objective function of 108, while Figure 10 has an objective function of 106.5.

Figure 9. The optimum vehicle routing for no request from the distribution center number 5
The vehicles have maximum capacity of 4t

For a request of 0.5t from node 5, we cannot obtain an optimum solution for vehicles with maximum capacity of 3.5t. An optimum solution can be obtained if the request at the node number 3 becomes 3.0t (instead of 3.5t) and if the maximum load is considered 3.0t for all the vehicles. The optimum solution, presented by Figure 11 has an optimum function of 100.

If the request from node 5 increases to a value of 1.0t and 1.5t, respectively, the optimum distribution process is presented by Figure 12 (objective function of 107) and Figure 13 (objective function of 111). The conclusion is that it would be optimum to have a request from node number 5 every day of at least 0.5 tones.
Figure 10. The optimum vehicle routing for no request from the distribution center number 5
Two vehicles have maximum capacity of 3.5t, while the third one has a capacity of 5t

Figure 11. The optimum vehicle routing for a request of 0.5t from the distribution center number 3

Figure 12. The optimum vehicle routing for a request of 1.0t from the distribution center number 5
3.5. Optimum vehicle routing solution for distribution center number 6 requests variation

Two solutions with an equal objective function of 83 were found and they are presented in Figure 14 and Figure 15 for the case of no request from the node number 6.

Figure 14. The optimum vehicle routing for no request from the distribution center number 5

Figure 15. The optimum vehicle routing for no request from the distribution center number 6

A request of 1.0t at the point number 6 leads us to the solution presented by Figure 16 (objective function is 94), while a request of 2.0t leads to the solution presented by Figure 17 (objective function is 105).
3.6. Optimum vehicle routing solution for distribution center number 7 requests variation

Figure 18. The optimum routes for a request of 0.5t, 1.0t or 2.0t from the distribution center number 7

The analysis of the numerical model of the distribution system for a Romanian food market shows that the variation of the request from the distribution center number 7 leads to small variation of the objective function. Consequently, the vehicles can maintain their routes with a small increase of the objective function.
The variation of the request from the node number 7 from 0.0t, to 1.0t and 2.0t, respectively, leads to the distribution presented by Figure 18 and variations of the objective function from 84, to 91.5 and 102, respectively.

4. Conclusions
This paper analyzes, in the beginning, the current level of the management process for the distribution of the products in a Romanian food market. Considering the storing place as the starting point and all the other centers as distribution points of the network, we developed a program, using this software, that establishes the transportation routes for the products such that the distribution centers receive the products in the optimum conditions required by the objective function.

The results obtained using the mathematical model and the software showed that there are necessary a number of four transports to be effectuated while the company has 3 vehicles with a capacity of 3.5 tons each. The variation of the transportation routes is established considering oscillations of the products requirements. Variations of the products requirements for each distribution center were analyzed successively.

The results showed the following:
- the 3.5 tons capacity is suited for the products requirements in this moment; higher capacities for the vehicles do not bring a significant improvement of the objective function or to a reduction of the transportation number necessary on a daily basis;
- there are connections that do not bring an optimum value for the transportation process; for example, the connections 2-5 or 3-4 are not indicated as being useful for any working conditions;
- it is useful to have a minimum requirement of 0.5 tons of products for the center number 5, each day; contrary, we cannot have an optimum solution;
- the absence of a requirement for the center number 7 do not bring necessarily a change for the distribution network, particularly of the route 1-6-7. Considering the connections 1-6 does not bring significant improvements for the system performance;
- no matter how small is the requirement for the center number 3 of the network, the software suggest a transport 1-3 for an optimum distribution process;
- a number of three transports, three routes, were met only for the case where there is no products requirement for the center number 5 and vehicles with a 4 tons capacity or two vehicles with 3. tons capacity and one vehicle with 5 tons capacity were used.

This model offers an useful method for the establishment of the transportation routes toward the products distribution centers of an Romanian food market. Improvements of the model could be made involving a greater complexity of the objective function, restrictions for the time period when the products can be delivered, e.a.

Bibliography