Optimization of agricultural products transportation from Morocco to Europe

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1 Introduction

The agricultural products play an important economic, social and environmental role in Morocco. They are one of the most creative sectors in our country and their transportation requires the use of several modes of transport (road, sea, air and rail). In this paper, we are interested in the problem of multimodal transport of Moroccan vegetables and fruits to Europe so as to give to the decision-makers the best strategy that will enable them to plan the export of their products. The objective is to propose and to solve a mathematical model for minimizing the total transportation cost and the maximal supplementary time needed to ensure delivery of these products to the customers. This problem is different from the available studies of the literature [1, 2, 3].

The problem consists to transport an agricultural product from a set of distribution sites N to a set of customers C. The export can be ensured using door-to-door services from a distribution site i to a customer j which requires a cost $c_{ij}$ and a time noted $t_{ij}$. It can be also transported by multimodal links via a pair of terminals $(k, m)$ chosen among potential sets of terminal H for the origin area and T for the destination area. In this case, a multimodal transportation cost $c_{ij}^{km}$ has to be paid and a transportation time $t_{ij}^{km}$ is required. Note that the distribution sites are characterized by a limited capacity $C_i$. While each customer is known by its demand $d_i$, the latest delivery time $L_i$ and the maximal supplementary time $TW_i$ allowed in the case of delays. Because products must be delivered in good quality, the total transportation time must not exceed the lifetime $LF$ of the product transported.

The formulation requires three decision variables. The first one $X_{ij}$ is the amount of products transported from each site of the origin area to each customer of the destination area. The second and the third are binary decision variables which decide if unimodal and multimodal links are used or not. They are noted $x_{ij}^{km}$ and $u_{ij}$ respectively. These questions will be raised in the formulation presented in the following section.

2 Mathematical formulation

We formulated the problem as a multi-objective mathematical model. It is presented in the following.

The objective function (1) minimizes the sum of unimodal and multi-modal transportation cost of agricultural products.

$$\text{Min} \sum_{i \in S} \sum_{j \in C} X_{ij} \times \left( \sum_{k \in H} \sum_{m \in T} c_{ij}^{km} x_{ij}^{km} + c_{ij} u_{ij} \right)$$

The objective function (2) minimizes the maximal supplementary time needed for ensuring delivery of all demands.

$$\text{Min} \max_{i \in S} \max_{j \in C} \left( 0 + \sum_{k \in H} \sum_{m \in T} x_{ij}^{km} t_{ij}^{km} + u_{ij} t_{ij} - L_i \right)$$
Constraints (3) satisfy demands of each customer \( j \) in the destination area (Europe).

\[
\sum_{i \in S} x_{ij} = d_j \quad \forall \ j \in \mathcal{C}
\]  \tag{3}

Constraints (4) are for taking into consideration the limited capacity of production associated to each production site \( i \) in the origin area (Morocco).

\[
\sum_{j \in \mathcal{C}} x_{ij} \leq C_i \quad \forall \ i \in S
\]  \tag{4}

Constraints (5) and (6) make in relation the decision variables of our model. If the transport is not ensured between an origin-destination nodes then no amount of the product are transported between both sides. Moreover, the reverse is also true. If there is no amount given by a production site to a customer then unimodal and multi-modal links between both sides are not considered.

\[
x_{ij} \leq M \left( \sum_{k \in \mathcal{H}} x_{ij}^{km} + u_{ij} \right) \quad \forall i \in S, \quad \forall j \in \mathcal{C}
\]  \tag{5}

\[
\left( \sum_{k \in \mathcal{H}} x_{ij}^{km} + u_{ij} \right) \leq x_{ij} \quad \forall i \in S, \quad \forall j \in \mathcal{C}
\]  \tag{6}

Constraints (7) ensure that if products are transported from a production site to a customer, the path chosen between both sides may be unimodal or multimodal using one pair of terminals.

\[
\sum_{k \in \mathcal{H}} x_{ij}^{km} + u_{ij} \leq 1 \quad \forall i \in S, \quad \forall j \in \mathcal{C}
\]  \tag{7}

In constraints (8) the supplementary time needed between any origin-destination nodes must not exceed the maximum time \( DW_j \) allowed by the customer concerned.

\[
\sum_{k \in \mathcal{H}} x_{ij}^{km} \cdot t_{ij}^{km} + u_{ij} \cdot t_{ij} - L_j \leq DW_j \quad \forall i \in S, \quad \forall j \in \mathcal{C}
\]  \tag{8}

In constraints (9) we take into consideration the expiration date of the product transported from each site to each customer.

\[
\sum_{k \in \mathcal{H}} x_{ij}^{km} \cdot t_{ij}^{km} + u_{ij} \cdot t_{ij} \leq Lf \quad \forall i \in S, \quad \forall j \in \mathcal{C}
\]  \tag{9}

Formulations (10) define the decision variables used in the proposed model.

\[
x_{ij} \geq 0, \quad x_{ij}^{km} \in [0,1], u_{ij} \in \{0,1\} \quad \forall i \in S, k \in \mathcal{H}, m \in T, j \in \mathcal{C}
\]  \tag{10}

We solved this problem by using metaheuristic approaches and we studied the efficiency by performance metrics. The model and the method proposed are tested on a real network Morocco-Europe. As perspectives, we also aim to introduce the uncertainties on data of the problem.

References

