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Management and Organization of the Real Agri-Food Supply Chain with the Cost of Waste Degradation

Fethi Boudahri, Zaki Sari

Manufacturing Enginneering Loboratery of Tlemcen, Tlemcen, Algeria

Fathi_boudahri@yahoo.fr.com

Abstract—*The supply chain of agricultural products and in particular perishable products is a critical issue in the supply chain management field due to high safety and quality risks associated with the delays in the products delivery. The supply chain of agricultural has received a great deal of attention lately due to issues related to public health. Something that has become apparent is that in the near future the design and operation of agricultural supply chains will be subject to more stringent regulations and closer monitoring, in particular those for products destined for human consumption (agri-foods). The supply chain of agri-foods, as any other supply chain, is a network of organizations working together in different processes and activities in order to bring products and services to the market, with the purpose of satisfying customers' demands.This work is concerned with the planning of a real agri-food supply chain for poultry products. For this concrete case we chose two products namely chicken and turkey-cock meat. More precisely the problem is to redesign the existing supply chain and to optimize the distribution planning. Furthermore, environmental costs of road transportation in terms of CO2 emissions are taken into account in the computations. The proposed integrated approach permits to minimize the total costs of the agri-food supply chain not only in terms of economy but also in terms of public health (ecology).*

As mentioned in our paper, the entire problem is decomposed into two problems, and each sub problem is solved in sequential manner, to get the final solution. LINGO optimization solver (Version12.0) has been used to get the solution to the problem..

Keywords— **Agri_food Supply chain; distribution network; optimization; CO2 emissions.**

I. INTRODUCTION

The study of supply chains and networks has grown rapidly as an area of academic interest from the early 1990s onwards. Economic, sociologists and management scholars acknowledged that studying firms individually could not sufficiently explain real life phenomena and did not lead to useful recommendation for partitioners.

Agri-food supply chains (ASC) is the term used to define logistics networks which encompasse production and distribution activities of agricultural or horticultural products from the farm to the consumers, see [1]. In particular the management of perishable products is a relevant issue in the ASC management domain, since the sellers cannot wait for the best favourable market conditions unless the quality and safety of their products deteriorate, see [17]. These products must therefore be rapidly shipped from the sellers to the customers. Moreover the demand of consumers on healthy products is ever increasing and regulations of the authority are more and more stringent. In addition to these factors, the variability in the demand and price of these products with limited shelf life adds complexity to the supply planning of these already critical supply networks. This explains the growing attention paid to the ASC in the literature, see [4]. ASC are formed by the organizations responsible for production (farmers), distribution, processing, and marketing of agricultural products to the final consumers. The supply chain of agri-foods, as any other supply chain, is a network of organizations working together in different processes and activities in order to bring products and services to the market, with the purpose of satisfying customers' demands [2]. The aim of this work is coordination of decisions for location, allocation and transportation of products to achieve an efficient and green logistic network design and distribution planning. The approach chosen is a location-routing formulation which consists in addressing a vehicle routing problem in which the optimal number and location of the slaughterhouses are to be determined simultaneously with the distribution routes to the customers in order to minimize the total costs [3]. The study of agri-food chains and networks can be divided into three streams [18]. One stream is supply chain management Food safety has become the subject of significant public and regulatory attention in various countries. Food safety is often an experience or credence attribute that consumers cannot detect through search activities prior to purchase [5]. The handling and consumption of poultry meat is recognized as a major cause of foodborne illness in humans globally particularly when eaten raw, undercooked or recontaminated and stored following cooking [17]. This implies that the traditional supply chain practices may be subject to revision and change. One of the aspects that may be the subject of considerable scrutiny is the planning activities performed along the supply chains of agricultural products. This study is an extension of a published work, where we add the cost of waste degradation to protect the environment.

II. STATE OF THE ART

Supply-chain management (SCM) is the integrated planning, coordination and control of all business processes and activities in the supply chain to deliver superior consumer value at least cost to the supply chain as a whole while satisfying the variable requirements of other stakeholders in the supply chain [6]. In this definition a supply chain is a series of (physical and decision-making) activities connected by material and information flows and associated flows of money and property rights that cross organizational boundaries. The supply chain not only includes the manufacturer and its suppliers, but also (depending on the logistics flows) transporters, warehouses, retailers, service organizations and consumers themselves [5].

A. Design supply chains:

The network design problem consists in selecting the facilities to open in order to form a production-distribution with minimal overall costs and the highest customer service levels [6].

The design problems of supply chains are often complex by nature due to their direct relationship with economic, organizational and social sector. For this reason, the design of a successful logistics network (in its various forms: location, production, distribution, routing, location/allocation, choice of suppliers, etc. ...) has attracted, in recent years, the attention of industrial and scientific community

B. location Problems

The location problem is to determine the location of one or more sites, so as to optimize a mathematical function that depends on distances between these sites and a set of potential users. The study of location theory began formally in 1909 when Albert Weber considers a problem of locating a warehouse to minimize the total distance between the warehouses and customers. After Weber, Hakimi in 1960 had considered a more general problem that considers the location of one or more sites in a network in order to minimize the total distance between customers and these sites, or to minimize the maximum distance.

C. Problems allocation

The allocation problem is to assign processing or manufacturing to the sites and determine the flow between the various network sites.

D. location-allocation Problems

In a location-allocation problem, we distinguish the term localization that refers to the determination of the locations of sites (sites of production or distribution centers), and the term allocation that refers to assigning activities to production sites, distribution centers or customers.

Osman ALP et al. (2003) have proposed in their paper [7] a new genetic algorithm for the problem of site locations (facilities). This algorithm is simple and gives good solutions. The purpose of the model is to select the best location of the P sites to serve N points (areas) of application to minimize the distance between these sites and demand points.

M. J. Canos et al. (2001) defined the classic problem of localization of P-median as the location of P facilities to cover the requested command with the minimization of the total transport cost. They assume in their work [8] that these costs are directly proportional to the distance covered and the quantity of products transported.

Guy Aimé Tanonkou et al. (2006) have addressed the design problem where plants location and supplier selection decisions are integrated. In this study [9], they assumed that the retailer will make a random demand for one type of product and delivery time between each supplier and each distribution center is constant and no delivery time between distributions centers (DCs). The problem is to select suppliers, the location of distribution centers and the allocation suppliers to distribution centers (DCs) and allocation the retailers to distribution centers (CDs), with the aim to minimize the total fixed distribution centers location costs, running inventory and safety stock costs at the distribution centers and transportation costs through the network. The authors have found that the problem is NP-hard, have proposed the Lagrangian relaxation approach to solve this problem.

M.T MELO et al. (2008) presented in their paper [10] a literature review of models of plant location and planning strategy for supply chain. The authors have noted the interest shown by several researchers treating stochastic cases. The authors' note that the tactical and operational decisions (routing and mode of transport) strongly depend on the decision of the location of sites and that integration decisions in Supply Chain Management is less studied.

Omar Ahumada et al. (2009) gave in this paper [4] the main contributions in the field of production and distribution planning for agri-foods. The authors have focused particularly on those models that have been successfully implemented. Then, they have classified this model according to relevant features, such as the optimization approaches used, the type of crops modeled and the scope of the plan.

Antonio Augusto et al. (2010) presented a solution for the CCCP (capacitated centered clustering problem) using the CS (clustering search) algorithm that uses the concept of hybrid metaheuristics, combining metaheuristics with a local search in a clustering process [11].

Rami Musa et al. (2010) have proposed in their paper [12] a novel algorithm to solve the transportation problem of the cross-docking network. The objective of this work is to minimize the total shipping cost of transporting pallets from a set of I suppliers to a set of J customers through K cross-docking distribution centers. Ant Colony Optimization (ACO) algorithm was used to solve the problem on hand. Authors have solved a numerical example for verification and demonstrative purposes. They found that our proposed solution reduces significantly the shipping cost in the network of cross-docks.

Sérgio Barreto et al. (2007) discuss in their paper [13] the location routing problem (LRP) and consider a discrete (LRP) with two levels: a set of potential capacitated distribution centers (DC) and a set of ordered customers.

LusineAramyan et al. (2006) provide a literature review on existing performance indicators and models, and discuss their usefulness in agri-food supply chains [1].

Tsola et al. (2008) have studied in their work [5] the impact of poultry slaughter house modernization and updating of food safety management systems on the microbiological quality and safety of products.

III. PROBLEM DESCRIPTION

The problem to redesign a real agri-food supply chain for poultry products in the city of Tlemcen is presented.

The network considered in this work is composed of customers and slaughterhouses from the city of Tlemcen and surronding areas. The aim is to redesign the supply chain in order to make savings and improve the distribution of chicken and turkey from the slaughterhouses to the retailers. As noted by [19] in their review on location analysis applied to agriculture, there is a need to consider the uncertainty in the strategic planning models applied to the agricultural industry, in particular to plan and forecast the demand from customers. In this work, to address uncertainty arising from the demand on poultry products from customers, the choice was made to capture the real demands on these products by studying them. To this purpose, more than three years have been required to observe the real flows of chicken and turkey distributed from the slaughterhouses to the retailers. The conclusion was that the distribution planning lacked efficiency leading sometimes to unsatisfied demands and increased prices at retailers. In addition to that, an integrated model was chosen to better plan the activities of the supply chain and generate savings. As the problem is complex by nature, the proposed solution approach has been divided into three main steps. Indeed a clustering based location-routing model is addressed in a sequential manner to optimize the products flows. The first problem is to group customers which can be retailers into clusters provided that the demands on poultry products for each customer which belongs to a cluster is satisfied. The study performed on real data allows to suppose that these demands are known in advance. Then, when the capacity for the delivery of each cluster is calculated, a capacitated plant location problem is solved in order to decide which slaughterhouse has to be open, closed or reopen for the considered planning horizon. Last, a classical routing problem is tackled in order to define which routes are the cost-effective ones. Limited capacities at potential slaughterhouses and for the refrigerated delivery trucks are additional assumptions made for this study. Let us recall that the demand on poultry products is supposed to be know in advance. Last the problem is formulated in a way that helps minimizing environmental costs of the supply chain. More precisely, the overall CO2 emissions caused by transport are quantified and their costs are added to the classical transportation costs. The production-distribution system design problem involves the determination of the best configuration regarding location, size, technology content and product range to achieve the firm's long-term goals [15].

The sets and indexes used in the model are as follows:

A. Model parameters

i :Index for customers; $i \in I$,

j : Index for customer clusters; $j \in J$

k :Index for slaughterhouse; $k \in K$

l : Index for products; $l \in L$

v:Index for vehicles classified according to their authorized gross weight; $v \in V$

$I = \{1,\ldots\ldots.r\}$ for Set of customers;

$J = \{1,\ldots\ldots.t\}$ for Set of customer clusters;

$K = \{1,\ldots\ldots.s\}$ for Set of slaughterhouses;

$L = \{1,\ldots\ldots.p\}$ for Set of products;

$V = \{1,\ldots\ldots.q\}$ for Set vehicles;

x_i, y_i : Geometric position of the customer i;

x'_j, y'_j: Geometric position of the customer cluster j;

x_k ,y_k : Geometric position of the slaughterhouse k;

n_j :Number of customers assigned to customer cluster j;

Q_j: Capacity of a vehicle that travels to the customer cluster j;

Dc_{li}: Demand of customer i for product l;

Dcc_{lj}: Demand for a product l by the customer cluster j;

V_{ljk}: volume of l product sshipped from customer cluster j to slaughterhouse k;

FC_k: Fixed cost for establishing a slaughterhouse k;

D_{jk}: Euclidian distance from slaughterhouse k to the centroid of customer cluster j;

p_l : Unit volume of the products;

$C_{jk}^{v;km}$: Transportation costs per kilometer from site k to site j by vehicle v. These transportation costs involve costs for operating vehicle v, infrastructures costs, fuel consumption when v is empty and tolls;

$C_{jk}^{v;t/km}$: Transportation costs per ton/kilometer from site k to site j by vehicle v. These costs are for fuel consumption per ton and environmental costs;

These latter are calculated in two steps. First the emission factor per vehicle per ton. kilometer are assessed with the quantification method developed by ADEME. Then carbon dioxide emissions due to transportation are priced with the European Trading Scheme of carbon allowances on the European Energy Exchange, see [16].

Q_{li} : Slaughterhouse Capacity i for product l;

C_{lk}: Cost of waste degradation per unit of chicken, not influencing on the environment.

B. Decision Variables

Y_{ij} = 1, if the customer i is assigned to customer cluster j, = 0, otherwise;
Z_{jk} = 1, if the customer cluster j is allocated to slaughterhouse k, = 0, otherwise;
X_k = 1, if the slaughterhouse k is open, = 0 otherwise;

C. Model formulation

The mathematical model formulated for the minimization of Total Cost (TC) transportation in the city of Tlemcen (Algeria) (see Fig. 1) in order to cover the entire order requested. Since the problem is highly complex, it cannot be solved in a single stage.

For this purpose, the entire problem is decomposed into two problems; each problem is solved in a sequential manner, while accounting for dependence between them.

The objective criterion is decomposed into the following problems:
(1) Capacitated Centered Clustering Problem (CCCP) [problem 1].
(2) Location- Allocation Problem [problem 2].

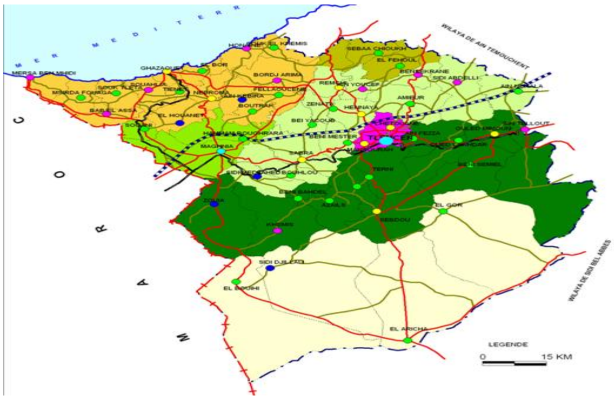

Fig 1. MAP OF TLEMCEN CITY

D. Capacitated Centered Clustering Problem (CCCP)

In a first stage, the problem of grouping the retailers into clusters is formulated as a capacitated centered clustering problem. The originality and efficiency of this approach come from the fact that it limits dissimilarity among the formed groups since these clusters are centered at the "average" of their points' coordinates, see [11].

The mathematical model of CCCP consists in minimizing:

$$\text{Min } Z1 = \sum_{k\in K}\sum_{j\in J}\left\|(x_i - x_j^{'}) + (y_i - y_j^{'})\right\|^2 Y_{ij} . (1)$$

Subject to:

$$\sum_{j\in I} Y_{ij} = 1, \forall i \in I \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

$$\sum_{k\in K} Y_{ij} = n_j, \forall j \in J \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.2)$$

$$\sum_{i\in I} x_i Y_{ij} \le n_j x_j^{'}, \forall j \in J \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.3)$$

$$\sum_{i\in I} y_i Y_{ij} \le n_j y_j^{'}, \forall j \in J \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.4)$$

$$\sum_{j\in J} (Dc_{li} * p_l) Y_{ij} \le Q_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1.5)$$

$$(x_i, y_i), (x_j^{'}, y_j^{'}) \in R^2, n_j \in N, Y_{ij} \in \{0,1\}, \ldots (1.6)$$

The The problem (1) aims at defining the set of customer's clusters by minimizing the total distance between these customers and the centre of the clusters. Constraints (1.2) specify that each customer is allocated to exactly one cluster. Inequalities (1.2) set the number of customers at each cluster. Constraints (1.3) and (1.4) define the geometric position of each cluster's centre. Constraint (1.5) imposes that a customer cluster must be less than the capacity of truck transportation and Constraints (1.6) define the space boundaries for the set of parameters and variables of the problem. It should be stressed that after the customers have been grouped into clusters, begins a second step calculation during which they have to be allocated to the slaughterhouses to be opened.

E. Location- Allocation Problem

The objective of the problem (2) is to minimize the cost function composed of fixed and variable costs. The fixed costs are linked to the opening of slaughter- houses and include investment costs for the land, the land tax and the slaughter units. The variable costs include the economics well as the ecological transportation costs.

The mathematical model is given as follows:

$$MinZ2 = \sum_{k\in K} FC_k X_k + \sum_{l\in L}\sum_{v\in V}\sum_{i\in I}\sum_{k\in K}\left(C_{jk}^{v_l km} + C_{jk}^{v_l \frac{t}{km}}\right) V_{ljk} D_{jk} Z_{jk} + \sum C_{lk}\, Dcclj\, X_k \ldots (2)$$

Subject to:

$$\sum_{i\in I} Z_{jk} = 1, \quad \forall j \in J \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

$$\sum_{i\in I} V_{ljk} * Z_{jk} = Dcc_{lj}, \forall l \in L, \forall j \in J \ldots\ldots (2.2)$$

$$\sum_{j\in J} V_{ljk} \le Q_{lk} X_k, \forall l \in L, \forall k \in K. \ldots\ldots (2.3)$$

$$V_{ljk} \ge o, \forall l \in L, \quad \forall j \in J, \forall k \in K \ldots\ldots (2.4)$$

$$Z_{ij} \in \{0,1\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

$$X_i \in \{0,1\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.6)$$

The objective function (2) minimizes total costs, which are the sum of fixed facility costs and total demand weighted distance multiplied by the cost per unit distance per unit demand.

Constraint (2.1) assumes that each customer cluster j (sets of retailers) is assigned to exactly one slaughterhouse i. Constraint (2.2) states that customer cluster j (sets of retailers) can only be assigned to open slaughterhouse. Constraint (2.3) ensures that the sum of demands covered by the slaughterhouse i does not exceed the maximum capacity of this slaughterhouse. Contraint (2.4) guarantee non negativity of the products flows.

Constraints (2.5) and (2.6) impose binary conditions.

The objective criterion of the model is considered as the minimization of total cost, which is nothing but the summation of objectives of the above two sub problems or the summation of all above costs which is given as follows:

$$\text{Min } Z=Z1+Z2$$

IV. *METHODOLOGY AND RESULTS*

As mentioned earlier, the entire problem is decomposed into two problems; each problem is solved in sequential manner, to get the final solution. Optimization Branch & Bound solver has been used to get the solution to the problem.

The inputs to the phase 1 or CCCP are the coordinates of locations of customer's i (xi, y_i), The input data can be taken from the small sized benchmark problems. For this, we used AutoCAD software to position the different customer. After solving phase 1 with the objective of minimization of total cost (Z1), we can get the centroid of each customer clusters with their coordinates (x'_j, y'_j), total number of customers assigned to each customer cluster (n_j). These results (output phase1) are configured in the table I.

TABLE I.
RESULT OF PROBLEM 1

Cluster N°	n_j	Cluster's centre position	Assigned customers nu,ber
1	1	(8819.19 ; 5632.02)	5
2	1	(8854.72 ; 5646.22)	7
3	1	(8856.22 ; 5617.00)	6
4	1	(8880.51 ; 5638.30)	8
5	8	(7758.02 ; 6679.99)	3/4/11/17/18/102/103/104
6	12	(9007.11 ; 6033.94)	10/12/13/14/15/16/20/88/89/90/91/105
7	8	(7540.73 ; 6046.07)	1/53/54/56/57/58/59/112
8	0	/	
9	7	5112.69 ; 5767.09)	46/64/66/67/68/69/70
10	8	(7568.44 ; 5825.43)	2/9/19/49/51/52/55/60
11	10	(10043.23 ; 9490.09)	79/80/81/82/83/84/92/93/94/95
12	8	(7478.42 ; 5177.42)	23/26/30/32/33/34/50/111
13	5	(7146.53 ; 5353.10)	21/22/27/47/65
14	10	(7532.64 ; 4847.30)	24/25/28/29/31/35/36/37/38/48
15	0	/	
16	12	(10685.80 ; 9767.27)	71/72/73/74/75/76/77/78/85/86/87/110
17	10	(7726.06 ; 9343.55)	96/97/98/99/100/101/109
18	10	(6974.03 ; 4724.97)	39/40/41/42/43/44/45/61/62/63
19	1	(747842 ; 5177.42)	113

The output of phase 1 along with the coordinates of locations of slaughterhouse (x_k, y_k), fixed cost for establishing a slaughterhouse k (FC_k), capacity of a slaughterhouse i (Qi) and the distance from slaughterhouse k to centroid of each customer clusters j (Dij) will become the input to the Phase 2 and it has been assumed that the number of slaughterhouses is equal to the integer part of total number of customer clusters.

After solving phase 2 with the objective of minimization of total cost (Z2), we can get location of slaughterhouses needed to cover the total demands of customer cluster j and allocated slaughterhouses k to customer cluster j, in such a way that capacity of vehicles and slaughterhouses are respected. These results (output phase2) are presented in the table II.

TABLE II.
RESULT OF PROBLEM 2

Slaughterhouse number	Location decision	Allocated cluster number	Corresponding capacity for Product1 product2
1	opened	2 3 11 13 14 16 19	680 20 680 20 420 16 375 19 395 21 395 15 454 05
2	closed	none	0 0
3	opened	12 18	380 19 340 28
4	closed	none	0 0
5	opened	1 9	680 20 405 16
6	closed	none	0 0
7	opened	4 5	680 20

		6 7 10 17	370 24 430 10 400 19 380 22 295 14

V. CONCLUSION

In recent years, many companies (production or service) are trying to reactivate their logistics networks.

The objective of this work is to reform the distribution network of chicken meat in city of Tlemcen, because of different retailers claim on the market instability of the chicken's meat (prices, lags behind the delivery, food safety ...).

To this aim, a two step mathematical model has been built and solved in a sequential manner. Once the customers have been grouped into clusters, the slaughterhouses to set up, to close or to reopen have been located, and the clusters of retailers have been allocated to them. LINGO 12 has been used to solve the three programs and to obtain exact solutions by using Branch and Bound with default parameters of the solver.

The encouraging results obtained in this work, suggest devoting our further research activities to:

- Introduce the vehicle routing to optimize the transportation problem for each cluster.
- Apply other methodologies such as heuristics and meta-heuristics to solve real life problems were size is important.

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