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Modelling and optimization for improving the performance of agri-foods supply chain for milk products.

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Abstract— Human consumption of agricultural food in general, and milk in particular, is the subject of clear and intense interest in recent times, which has led dairy producers to follow a strict processing requirement to ensure consumers a fresh and safer milk, imposed by the Design and Operational Authority of the agricultural chains, which imposes closer monitoring and severe rigor, especially when it has become a public health issue. This work is concerned with the planning of a real agri-food supply chain for milk product for the city of Tlemcen in Algeria. Specifically, the challenge is to redefine the existing supply chain and optimize distribution planning. The management of perishable products is a relevant issue in the ASC management domain, since the sellers cannot wait for the best favorable market conditions unless the quality and safety of their products deteriorate. These products must therefore be rapidly shipped from the sellers to the customers. In addition, consumer's demand for healthcare products continues to grow and government regulations are tightening. In addition to these factors, the variation for these time-limited products and their prices makes it difficult to plan purchases in supply networks.

Keywords— Food supply chain, Modelling and optimization, Two-echelon location–routing problem, milk product, Environmental influence.

I. INTRODUCTION

Presently, the economic world is experiencing a major development of the customer-client relationship based on the provision of production, speed of delivery, and the development of delivery networks at a good rate and above to satisfy the global market. This has forced economic institutions to look for new ways to boost competition and respond to the wishes and demands of customers [1].

In cooperation with the organizations responsible for the production of farmers, the term agri-food chains were created to describe the activities from production to distribution, the equivalent of the agricultural commodity chain in the article. Product safety Limited shelf life and control over other relevant properties [2].

But these requirements and rigor have made things more complicated, making the management of the basic supply chain more difficult than other supply chains[5,6]. Food supply chains have been defined into two types first; Fresh products are highly perishable crops such as fresh milk, meat, fruits and vegetables whose age can be measured in days. And non-perishable products can be stored for longer periods of time, such as cereals, potatoes, nuts.[7]. Food safety is most often an experience or a trait of trust through which the consumer discovers its quality and ensures its sustainably [8]. This paper which is an extension of works conducted in the literature deals with a simulation study of agri-food supply chain problem. It aims to present a mathematical model in order to find the appropriate location and allocation of unite of supply chain.

In this framework, the study was recorded by dairy companies sending trucks of raw milk to individual farmers throughout the city of Tlemcen and its suburbs to collect the milk collected and direct after processing and it must be preserved by means of cooling after processing, of course, and the supply chain was redesigned to achieve abundance and improve distribution to dairies and retailers.

Based on the coordination of site decisions, specialization and transport of products an agricultural food supply chain for dairy products has been studied for the city of Tlemcen, Algeria, in order to achieve an efficient and ecological physical realization of the network. and distribution planning, including retail and dairy. (To convert dairy cows into Master milk) for the purposes of redesigning the supply chain to save money and improve the distribution of dairy products from the dairy industry to retailers. The objective of the case study is to reconfigure a multi-echelon logistics network and multi-products, with the aim of stabilizing the prices of milk and these derivatives throughout the year and with well-studied prices and the contribution of all citizens in the city of Tlemcen.

II. Literature Review

These problems affect the countries economically, socially and environmentally, and it is crucial to consider sustainable solutions to avoid serious adverse consequences. “Sustainability is defined as maintaining the ability to be permanent while ensuring the continuity of diversity and productivity as a term” (Business Dictionary, 2018).

The aim of this paper is to present a literature review of the perishable supply chain management modeling and optimization approach focusing on loss minimization along the supply chain, particularly on perishable foods and the papers are analyzed based on the objectives, models used and solution approach in the selected researches [10]. Wuxue Jiang [9] analyzes the optimization strategy and various cost factors of food cold chain supply network and and develops a kind of model of food supply chain logistics network

Mariantonietta Fiore [4] creates a conceptual agri-food supply chain optimization model and based on it, defines key characteristics for the selected agri-foods. Viktorija Vostriakova [3] presents the appropriateness of LEAN logistics tools using, in particular, Value Stream Mapping (VSM) for minimizing logistic losses and Simulation Modeling of possible logistics distribution system improvement results. The objective of this study is to define the prevailing Supply Chain Management system in Milk Collection and distribution across Pakistan.

The agri-food chain is a set of economic, administrative and political activities that are logically sequential and regulate at the same time that imposes the need to take into account the uncertainty in the strategic planning models applied to the industry, especially the planning and expectation of customer demand.

III. Material and Methods

In this step, the problem to redesign an agri-food supply chain for milk products in the city of Tlemcen in Algeria. The integrated approach to solve it is then described.

A. Mathematical Model

The mathematical model formulated for the minimization the cost of dairy product and its derivatives in the city of Tlemcen. In order to cover the entire order requested. Since the problem is highly complex, it cannot be solved in a single stage[13] . For this purpose, the entire problem is decomposed into three problems; each problem is solved in a sequential manner, while accounting for dependence between them.

B. Input parameters

i: Index for retailers(customers); $I \in I$
j: Index for regions of retailers (customers clusters); $j \in J$
k: Index for milk house; $k \in K$
l: Index for a product of class products; $l \in L$
m: Index for farms (farmers cows); $m \in M$
v: Index for vehicles classified according to their authorized gross weight; $v \in V$
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 milk-houses 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 each product l by the customer zone j;
V_{mk}: Volume of cow’s Milk shipped from areas of farms m (farmer’s cows) to milk-houses k;
FC_k: Fixed cost for establishing a milk-houses k;
D_{jk}: Euclidian distance from milk-houses k to the centroid of customer cluster j;
Cd_{kjl}: Variable cost to distribute of product l from an open milk-house k to customer zone j.
Cd_{mkl}: Variable cost to transport of product l from farm m to an open milk-house k.
Cop_m: Operational cost in the farm m.
Cop_{kl}: Operational cost of the product l in the milk-house k.
O_l: Operate time required to process a product of class l.
Q_{lk}: Capacity of treatment at milk-houses k for class l products.
D_{jk}: Euclidian distance from site k to site j in km.
N_{ljk}: Number of class l products shipped from site k to site j.
W_l: : average weight of a product of class l in ton. As in the previous phase, the weight of each product is compared to this standard weight.
$C_{jk}^{v;km}$: 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 is assessed with the quantification method developed jointly by ADEME.

C. Output parameters

Yij = 1, if the customer i is assigned to customer cluster j, = 0, otherwise;
Zjk = 1, if the customer cluster j is allocated to milk-houses k, = 0, otherwise;
Xk = 1, if the milk-houses k is open, = 0 otherwise;

D. First Step Capacitated Centred Clustering Problem

The problem (1) aims at defining the set of customer’s clusters by minimizing the total distance between these customers and the center of the clusters. 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 in Rami Musa, [11]. The Capacitated Centred Clustering Problem (CCCP) consists in partitioning a set of n points into p disjoint clusters with a known capacity. Each cluster is specified by a centroid [12]. The objective is to minimize the total dissimilarity within each cluster, such that a given capacity limit of the cluster is not exceeded.

The capacitated centered clustering problem consists in minimizing:

$$\text{MinF1}=\sum\sum\left\|(x_i - x_j) + (y_i - y_j)\right\|^2 . Y_{ij} \quad (1)$$

Contraints:

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

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

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

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

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

$$(x_i , y_i), (X_j , Y_j) \in R^2 ,\ n_j \in N,\ Y_{ij} \in \{0,1\} \quad (1.6)$$

In the above model, the objective function (1) minimizes the total distance between each point and the centroid of the cluster that it is allocated. Notice that the geometric position of the centroid depends on the points that compose the cluster, so, the position of the centroid is an unknown parameter a priori. Constraints (1.1) impose that each point is allocated to exactly one cluster. Constraints (1.2) give the number of points in each cluster. Constraints (1.3) and (1.4) locate the centroid of each cluster at its geometric center. Constraint (1.5) imposes that a total cluster capacity must be respected. Constraint (1.6) defines the decision variables, and the upper limits to the number of individuals per group.

E. Second Step Location-Allocation

Localization is often considered the most important success factor for a private or public sector organization. Location-allocation is a problem which consists simultaneously of locating resources and allocating them demand points. The objective of location-allocation models is to optimize: the number of locations of sales sites; consumer allocation to these points of sale.

In this step, we deal with the problem of location/allocation of milk production houses by the deterministic three-level model with a specific capacity. This optimization allowed us to locate the milk unit as well as the assignment of production units to breeders and the assignment of different customers to units of localized production. unit of milk and its derivatives as well as the allocation of production units to breeders and the allocation of different customers to localized production units. This problem aims to minimize the sum of the cost to transport items from farms to milk-house open and milk-house to customer zones and the costs associated with locating and operating manufacturing milk-houses and farms. The mathematical model of this problem is given as follows:

MinF2=

$$\sum_{k\in K} FC_K X_K + \sum_{l\in L}\sum_{v\in V}\sum_{k\in K}\sum_{j\in J}\left(C_{jk}^{v;km} + w_l * N_{ljk} * C_{jk}^{v;\frac{t}{km}}\right) * D_{jk} Z_{jk} + \sum_{l\in L}\sum_{m\in M}\sum_{k\in K}(Cd_{mkl} + Cop_{kl} + Cop_m) * V_{mk} X_k \quad (2)$$

Contraints :

$$\sum_{k\in K} Z_{jk} = 1,\ \forall j \in J \quad (2.1)$$

$$\sum_{j\in J} N_{ljk} * Z_{jk} = Dcc_{lj},\ \forall l \in L,\ \forall k \in K \quad (2.2)$$

$$\sum_{k\in K} N_{ljk} * O_l \le Q_{lk} * X_k,\ \forall l \in L,\ \forall j \in J \quad (2.3)$$

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

$$Z_{jk} \in \{0,1\}\ \ \forall j \in J ,\ \forall k \in K \quad (2.5)$$

$$X_K \in \{0,1\}\ \ \forall k \in K \quad (2.6)$$

The objective of the problem (2) is a cost function composed of fixed and variable costs. The fixed costs are linked to the opening of milk-houses and include investment costs for the land, the land tax and the milk-houses units. The variable costs include the economical as well as the ecological transportation costs. Equalities (2.1) specify that a cluster j can be served by only one 209 milk-houses. The set of constraints (2.2) stipulates that the demand on class l product at cluster j must be completely met. Inequalities (2.3) are capacity constraints at milk-houses k. Inequalities (2.4) guarantee non negativity of the products flows. Last, constraints (2.5) and (2.6) impose binary conditions.

IV. Results and Discussion

In this section the model is applied to the problem. 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 data for problem 1 are: the coordinates (geographical positions) of the different customers i(xi, yi) presented in table1 and the demand of retailers for each product where it depends on the number of inhabitants for each area. Results of the first step calculations are summarized in table 1.

Table 1. Capacitated centred clustering results.

Cluster N°	nj	Cluster's centre position	Assigned customers
1	12	(8819.19 ; 5632.02)	111/112/113/114/ 115/116/199/200/ 201/202/203/204
2	10	(8854.72 ; 5646.22)	7/125/126/ 127/128/129/130/ 131/132/132
3	8	(747842 ; 5177.42)	113/134/135/136/ 137/138/139/140
4	11	(8880.51 ; 5638.30)	62 /163/160/159/1 58/8/198/197/195

			/196
5	13	(7758.02 ; 6679.99)	3/4/11/102/ 103/104/117/118/ 119/120/121/122/ 123/124
6	12	(9007.11 ; 6033.94)	10/12/13/14/15/16 /20/88/89/90/91/1 05
7	12	(7540.73 ; 6046.07)	112/164/165/166/ 169/59/ 58/57/56/54/53/1
8	13	(10043.23 ; 9490.09)	79/80/81/82/83/84 /92/93/94/95/206/ 207/208
9	13	5112.69 ; 5767.09)	46/67/68/69/70/16 8/169/ 170/171/172/173/ 174/175
10	13	(7568.44 ; 5825.43)	2/9/19/60/149/150 /151/152/153/154/ 155/156/157
11	0	/	/
12	12	(7478.42 ; 5177.42)	23/26/30/32/33/34 /50/111/176/177/1 79/180
13	15	(7146.53 ; 5353.10)	21/22/27/47/65/14 7/148/ 187/188/189/190/ 191/192/193/194
14	11	(7532.64 ; 4847.30)	209/25/24/28/29/3 1/36/37/35/48/38
15	0	/	/
16	12	(10685.80 ; 9767.27)	71/72/73/74/75/76 /77/78/85/86/87/1 10
17	13	(7726.06 ; 9343.55)	144/141/142/143/ 98/96/97/99/100/1 01/145/146
18	0	/	/
19	16	(6974.03 ; 4724.97)	39/40/41/42/43/44 /45/61/62/63/181/ 182/183/184/185/ 186
21	0	/	/
22	10	(8478.62 ; 4977.42)	5/133/17/18/64/66 /49/51/52/55

This problem was to group 209 customers into clusters. For each of the resulting customers' clusters, the numbers of assigned customers as well as their reference number are given. The coordinates of the cluster center also appear in the table 1. Out of the twenty-two clusters generated, eighteen have been assigned customers. The biggest clusters are cluster number nineteen (with sixteen retailers) and number thirteen (with fifteen retailers) assigned to both and four clusters have been closed. Results of the first problem, as well as the fixed investment costs, capacities at the house milk, distances between the potential milk-house, fixed cost for the foundation of candidate milk-house, operational cost in milk-house and in farmer, cost of transportation using refrigerated trucks (Transportation costs per kilometer and Transportation costs per ton/kilometer) and the center of each cluster are the data used for the second problem. The two types of products considered correspond to milk and its derivatives. The results of the second step were recorded in table 2

The proposed solution was useful for success after the results were presented to the actors in the food supply chain.

- The remaining five milk houses had to be closed.
- Decisions on the allocation of customer clusters to localized milk-house.
- Decisions on the allocation of milk-house located to the farm.
- Quantity of each designated product type.

Table 2. Location-allocation results.

Milk-house number	Location decision	Allocated cluster number	Corresponding capacity for Product1	product2
1	Open	2	1120	200
		3	950	200
		11	1420	160
		13	1370	190
2	Close	None	0	0
3	Open	12	3980	470
		18	1000	240
		22	850	180
4	Open	1	1980	360
		9	2100	250
		17	920	140
5	Close	None	0	0
6	Close	None	0	0
7	Open	10	1950	300
		15	1420	260
		19	1375	190
8	Open	6	2 180	200
		8	1120	140
		21	1490	200
10	Close	None	0	0
11	Open	4	1950	200
		5	1720	260
		7	1310	190
12	Open	14	2690	450
		16	2190	290

The data used in the last step are the results obtained in the second step:

The distances between the clients of each cluster of customers, the demand of each customer in the customer cluster and the capacity of the truck delivery. For the last step we are interested in the delivery problem, for this we have realized this problem in the vehicle routing model. The vehicle

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routing problem (VRP) is a critical and vital problem in logistics for the design of an effective and efficient transportation network, within which the capacitated vehicle routing problem (CVRP) has been widely studied for several decades due to the practical relevance of logistics operation [14].

The results obtained in VRP are (see the three examples for clusters figure 1).

The delivery in the 4-customer cluster makes its debut on client C198 and goes through clients (C8, C158, C159, C160, C163, C62, C195, C196, C197 and C198.

The tour for VRP in the cluster of 7 customers, makes its debut from the customer C1 and ends with client C112.

The tour in the cluster of 14 customers, ranging from client C24 and ends with client C25 through clients C28, C29, C31, C36, C35, C37, C48, C38 and C209.

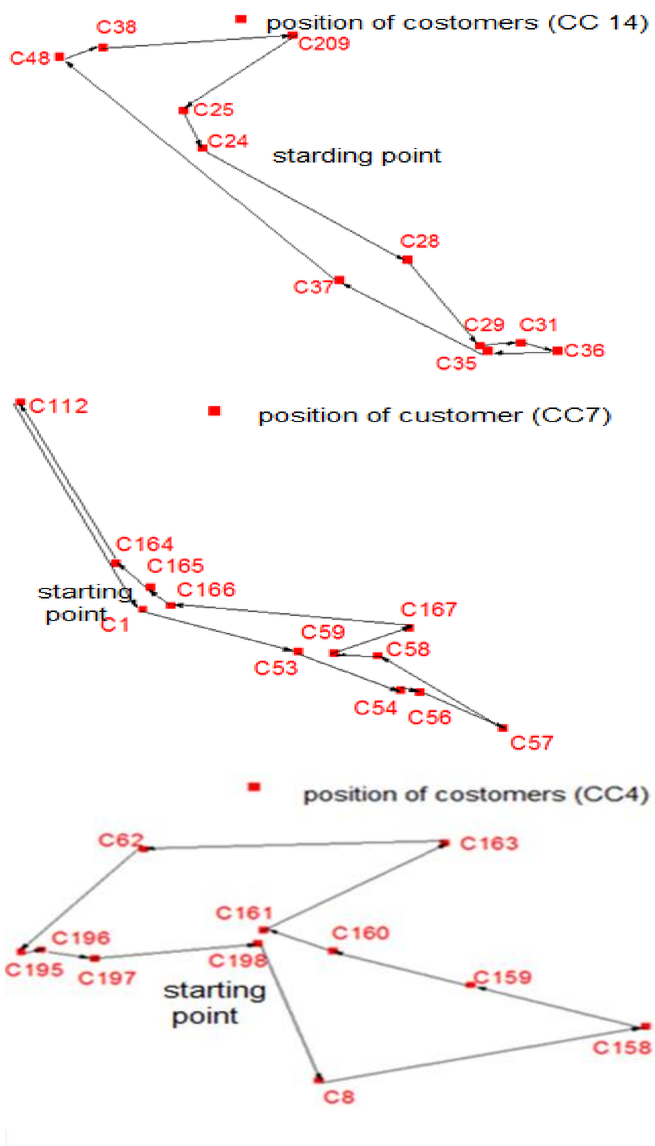

Figure 1. Vehicle Routing Problem results.

V. CONCLUSION

The instability of the dairy market (the worst delivery times and food safety) is the result of claims by various retailers that any attempt by production or service companies to reinvigorate and de-escalate the logistics network has led to the development of a three - stage mathematical model that has been solved sequentially. The first step of this work, consists in grouping the closest retailers in distance by using the CCCP model (capacitated centered clustering problem). This step we allow you to define the different clusters of customers (set of retailers) in the city of Tlemcen. To do this, we used Autocad software to position retailers in this city. Among the eighteen proposed clusters, the mathematical model CCCP allowed us to use only ten clusters.

Once the customers have been grouped into clusters, the milk-houses to set up, to close or to reopen have been identified, and the clusters of retailers have been allocated to them. The objective in the second step is to minimize milk production units and the cost of transport between farms and milk production units and retailers, within the capacity of production units dairy and the refrigerated trucks used for delivery last, environmental costs of supply chain have been included in the computations. The optimization of problem 2 allowed us to open seven milk houses out of twelve milk houses candidates as well as the assignment of the milk houses located to the selected breeders (farms) and the assignment of the different clusters of customers (set of retailers) to the milk houses located. At the end of this study, we have optimized routes for vehicle rounds to minimize transport costs and reduce CO_2 emissions during the various delivery rounds. LINGO 12 has been used to solve the two 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:

- Propose a model that includes all the countries
- Propose a model with subcontractors in the case where offer exceeds demand
- The results of this work have led to the consolidation of future research activities and the application of alternative propagation and meta-mapping methodologies

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

Boudahri, Baba ahmed performed the modeling and optimization with Lingo 12.
Boudahri and Boukli are busy measuring different distances between customers.
Belkaid and Boukli hacene organized and discussed the results.