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A Multi-Objective Framework for Dairy Products Supply Chain Network with Benders Decomposition

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Abstract: In the food sector, it is necessary to maintain quality and products from the production of dairy products to the final supply point. It aims to minimize the objective function and level of presentation required for the product provided by the analysis of Benders decomposition. The model also includes different consumer demands for consumption decisions. In this study, with the Benders decomposition algorithm, it ensured that the quality level of the service delivered as soon as possible, the warehouses delivered from the factories and the remaining shelf life kept at the maximum level.

1. Introduction

Supply chains have to plan and promote their production systems more effectively, agilely, and efficiently. The supply chain and logistics cover all system activities and resources, including products or services from suppliers to customers. Raw materials and components referred to as final products and delivered to the final customer with the supply chain. In addition, certain features affect the design performance. The food industry differs from other industries with specific legislation, product sensitivity, deterioration, storage conditions, shelf life, and changing product quality. These factors cause to increase costs. The characteristics of the food industry lead to specific requirements for transport, storage, and processing. Companies face competitive dynamic economic environment conditions.

The suggested model applied to Turkey's dairy supply chain case, which includes suppliers, dairy plants, and markets. A good supply chain model is very significant in a competitive environment in terms of practical performance for food product quality. The rapid decay of raw materials and products leads to the need for unique processing, transportation, and storage. These factors are considered the dairy industry on process design selection investigated using quality milk processing as an example to use the Bender's decomposition algorithm to avoid sub-optimization in the choice of food process design.

The rest of this article organizes as follows: In section 2, the relevant literature summarizes, and Section 3 presents the proposed modelling approach. In the beginning, the design area considers the product characteristics. After that, the Benders decomposition algorithm applies in the two stages.

In the first stage, the other says the main stage considers the objective function that determines the appropriate product volume in the supply chain. In the second stage, product designs and production volumes consider and decisions regarding supply chain operations taken into consideration.

2. Literature Survey

In this study, sustainable dairy products structure modelled with three-stage model. It considers the delivering raw materials and is the most necessary condition to deliver the products to warehouses and sales stores as soon as possible. Sustainable is the transportation of the product from the factory to the consumer while preserving its freshness. The product deliveries to the customers without any deterioration in quality. Simultaneously, the model solves with the Benders decomposition method in different situation alternatives.

Our study considers the balance of the production capacity with demand and customer demands, sales with operation plans. Our study covers the different planning decisions with the demand and production limitations and demand and capacity comparisons. Existing supply chain and production models have to consider the environmental threads and food security of future generations. Interactive and more efficient tooling and production system, a higher storage level obtained from the factory storage area, meeting the warehouse requirements in a timely and comprehensive manner. Mogalle et al. (2018) proposed a grain supply-chain network with mixed-integer nonlinear programming. They considered an integrated, multi-purpose, and multi-term mathematical model that considers the grain silo, storage capacity, and changing demand conditions [1]. This process proposed a comprehensive mathematical model that considers different target situations. Li et al. (2020) suggested production routing problems with the multiple plants and packing considerations for food products [2]. There have a short shelf life, sustainable structure aims to reach the foods to customers in new conditions, and producer firms aim to minimize waste products. Stale products are undesirable by both the manufacturer and the vendor. Allaabneh et al. considered environmental factors for perishable products; Bender's decomposition algorithm used for optimal replenishment planning and vehicle routes when maximizing the supplier's profit and minimizing costs from inventory holding [3]. Davoodi and Goi developed an integrated model for critical aid operations to prevent late arrivals of aid vehicles and used the benders decomposition algorithm [4]. Kiriolova et al. highlighted the importance of environmentally sensitive management for the dairy supply chain design [5]. They presented a mathematical model considering the factories' product portfolio and capacity status, taking the dairy portfolio together with the environmental impact assessment. Bottani et al. (2019) proposed a flexible model that ensures the continuity of business operations in case of risk situations and disruptions [6]. A mixed-integer programming approach was used in the model that maximizes profit and minimizes total delivery time. Pariazar et al. (2017) developed a pharmaceutical and food supply chain two-stage stochastic model. The strategic decisions are supplier locations with capacity and the operational decisions are transportation and inspection [7]. Bilgen and Doğan (2015) analyzed the value-added distribution integrated with production planning to reduce the cost of distribution of dairy products [8]. Eğilmez et al. (2019) applied discrete event simulation to hybris cellular manufacturing with integrated mixed integer nonlinear programming [9], and Grillo et al. (2017) considered a multi-purpose mathematical model in which different demand situations [10]. Paul et al. (2017) proposed a three-tier supply chain network [11]. It includes predictive plan management in real-time using the predictive mitigation planning approach. Gholamian et al. (2017) [12]; Bilgen & Doğan, 2015[8]; Doganis and Sarimveis (2008) [13]; Mula et al. (2010) [14]; Sel and Bilgen (2015) [15] examined the integrated some of the supply chain model planning problem. Bidhandi et al. (2009) [16], Shaw et al. (2016)[17] , Mariel and Minner (2017) used Bender's decomposition algorithm in supply chain management[18]. In our study, the dairy supply chain mathematical model has been handled in detail with the mixed integer programming approach, and Bender's decomposition algorithm has been preferred to avoid sub-optimization situations in the solution of the problem.

3. Dairy Products Supply Chain Distribution System

This study includes the structure in which the production, distribution, and consumption activities in detail. Dairy supply chain structure includes collecting, processing, and distributing the milk that constitutes the raw material of the production to the distribution centres' for the delivery of the produced product to the consumer soon as possible.

3.1 Dairy Food Products Industry

The product pricing policy of the food products depends on the homogeneity, freshness, deterioration of the original properties, and shelf life of the products. For this reason, the developed policy aims to minimize two goals: total cost and to ensure that the products meet the consumers with the minor distortion status and the average product freshness, i.e., maximizing the average shelf life. The selling price of the product may vary according to the cost of the product, shelf life, and customer demand. The speed and condition of the supply period should be adjusted by considering the connection conditions between customer demand conditions.

In the supply chain analysis, there are considerable constraints before and during production. Our main goal is to reduce the efficiency of the raw material constraints equal to or greater than the quantity required for production. At the time of production, it obtains the maximum quantity of products that meet the orders. During the production, mathematical models formed by paying attention to the constraints such as raw material, number of workers, machines, and daily labour hours. The amount of product distributed and stocked according to daily plans distributed to storage production. Much research done in the literature and various mathematical models developed. The assumptions taken into account when creating a mathematical model for our problem are;

• The demand for each product group in each city known;

• With a single source assumption, a distributor, can only receive one regional depot for all product groups;

• Each regional warehouse to open must have a storage capacity of at least 250 tons.

• Candidate cities where regional repositories can established are certain;

•The cost of holding the total cycle inventory is not dependent on which inventory (central warehouse or regional warehouse) the inventory held in;

• All machines and jobs are ready for use at zero time,

• A machine can handle a single job at the same time,

• Once a job commenced, it should processed without division or transfer to another machine,

• A job can processed on a maximum of one machine,

• The parameters related to the job (time of operation etc.) and the number of machines are known precisely,

• There is no priority order among jobs.

3.2 Mathematıcal Programming

This section provides a detailed description of the multi-objective linear programming (MOLP) model and the notations and parameters.

The following notations used in this study to formulate the mathematical model.

e	supplier
i	plant
j	DC(Distribution Center)
k	retailer
m	product
p	period time
n	raw material
Pl_{im}	m production quantity of plant i
X_{ijm}	transportation quantity m product from plant i to DC j
pci	production cost per unit at plant i
H	holding cost
T	transportation cost
W_a	waiting penalty cost
La	lateness penalty cost
X_{jkm}	transportation quantity m product from DC j to retailer k
dem	demand
d_{isij}	Distance of node i from node j
Q	Capacity of vehicle of type z
A_{ne}	Quantity of raw material n to potential supplier e
A_{nei}	Quantity of raw material n provided by supplier e to plant i
A_{mij}	Quantity of finished product m provided by plant i to DC j
Inv_{kp}	Stored product quantity in retailer k
Inv_{jp}	Stored product quantity in distribution center j
CP_i	maximum production capacity
CDC_i	each distribution centers
CR_k	each retaler
Qs_{ne}	Upper limit on the raw material n shipped from potential supplier e
$Qp_{mi,j}$	Upper limit on the finished product m shipped from plant i to DC j
u	Arrival time
$S_{t,z}$	Average speed for vehicle tz of type of z
$Pr_{kp}(ur_{kp})$	Time windows violation penalty for retailer k
$Pdip(ud_{jp})$	Time windows violation penalty for distribution center j
L	Latest arrival time
G0	Supplier nodes
G1	Distribution centers nodes
G2	Retailers nodes
G3	Between of the plants, DCs and retailers nodes

3.3. Objective function

The objective function aims to minimize the total supply chain cost. The production cost of the basic units that make up the supply chain between Eq (1-13) consists of average holding cost, transportation cost, waiting penalty cost, and lateness penalty costs.

Costs at Plants

$$\text{Production cost}=\sum_{i=1}^{I}\sum_{m=1}^{M} P_{im}\, pc_{im} \tag{1}$$

$$\text{Average holding cost}= \sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{j=1}^{J} H_{im}\,(P_{im}-X_{ijm}) \tag{2}$$

$$\text{Transportation cost}= \sum_{j=1}^{J} \sum_{i=1}^{I} T_{ij} X_{ijm} \quad (3)$$

$$\text{Waiting penalty cost}= \sum_{i=1}^{I} \sum_{n=1}^{N} WaP_{in} X_{in} \quad (4)$$

$$\text{Lateness penalty cost}= \sum_{e=1}^{E} \sum_{n=1}^{N} LaP_{en} X_{en} \quad (5)$$

Costs at Distribution Centres (DC)

$$\text{Operating cost}= \sum_{j=1}^{J} OC_j \quad (6)$$

$$\text{Handling cost}= \sum_{j=1}^{J} \sum_{i=1}^{I} H_j X_{ij} \quad (7)$$

$$\text{Transportation cost}= \sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{m=1}^{M} T_{jkm} Y_{jkm} \quad (8)$$

$$\text{Waiting penalty cost}= \sum_{j=1}^{J} \sum_{i=1}^{I} \sum_{m=1}^{M} WaP_{jm}((Dem_{jm} - X_{ijm}) \quad (9)$$

$$\text{Lateness penalty cost}= \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{m=1}^{M} LaP_{im}(Dem_{jm} - X_{ikm}) \quad (10)$$

Costs at retailer

$$\text{Average holding cost}= \sum_{k=1}^{K} H_k Dem_k \quad (11)$$

$$\text{Waiting penalty cost}= \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{M} WaP_{km} (Dem_{km} - X_{jkm}) \quad (12)$$

$$\text{Lateness penalty cost}= \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{M} LaP_{jm}(Dem_{km} - X_{jkm}) \quad (13)$$

$$\text{Min TC} = \sum_{i=1}^{I} \sum_{m=1}^{M} P_{im}\, pc_{im} + \sum_{i=1}^{I} \sum_{m=1}^{M} \sum_{j=1}^{J} H_{im} (P_{im} - X_{ijm}) + \sum_{j=1}^{J} \sum_{i=1}^{I} T_{ij} X_{ijm} + \sum_{i=1}^{I} \sum_{n=1}^{N} WaP_{in} X_{in} + \sum_{e=1}^{E} \sum_{n=1}^{N} LaP_{en} X_{en} + \sum_{j=1}^{J} OC_j + H_j X_{ij} + \sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{m=1}^{M} T_{jkm} Y_{jkm} + \sum_{j=1}^{J} \sum_{i=1}^{I} \sum_{m=1}^{M} WaP_{jm}((Dem_{jm} - X_{ijm}) + \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{m=1}^{M} LaP_{im}(Dem_{jm} - X_{ikm}) + \sum_{k=1}^{K} H_k Dem_k + \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{M} WaP_{km} (Dem_{km} - X_{jkm}) + \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{M} LaP_{jm}(Dem_{km} - X_{jkm}) \quad (14)$$

Constraints

Equality. (15 - (18) indicate the number of raw materials purchased from a particular supplier to produce the required product.

$$\sum_{n=1}^{N} \sum_{e=1}^{E} \sum_{i=1}^{i} A_{ie}^{n} - \sum_{n=1}^{N} \sum_{e=1}^{E} Qs_{e}^{n} A_{e}^{n} \leq 0 \qquad \forall\ n, e \quad (15)$$

$$\sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{i=1}^{I} A_{ij}^{m} - \sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{i=1}^{I} Qp_{ij}^{m} A_{i}^{m} \leq 0 \qquad \forall\ m, i \quad (16)$$

$$\sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{c=1}^{C} A_{jc}^{m} - \sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{i=1}^{I} Qd_{jk}^{m} A_{j}^{m} \leq 0 \qquad \forall\ m, j \quad (17)$$

$$\sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{i=1}^{I} A_{ij}^{m} - \sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{c=1}^{C} A_{jc}^{m} = 0 \qquad \forall\ m, j \quad (18)$$

Eq.(19) indicates the delivery of manufactured products from the factory to the distribution centers, and Eq. (20) refers to the delivery of the products from DC to the retailer. Eq. (21) shows the link between demand and product quantity.

$$\sum_{i=1}^{I}\sum_{m=1}^{M} P_{im} = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{m=1}^{M} X_{ijm}; \quad \forall i, j, m \tag{19}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{m=1}^{M} X_{ijm} = \sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{jkm} \quad \forall j, m \tag{20}$$

$$\sum_{j \in N_1} x_{ijp}^{t_z z} = \sum_{j \in N_1} x_{jip}^{t_z z} = q_{ip}^{t_z z} \ \forall i \in N_1, t_z \in T_z, z \in Z, p \in P \tag{21}$$

Eqs. (22-24) show product flows in line with the demand for each supplier in each time period.

$$\sum_{i \in N'_1}\sum_{j \in G'_0} x_{ijp}^{t_z z} \leq |G'_0| - 1 \quad \forall t_z \in T_z, z \in Z, |G'_0| \subseteq N_1, |G'_0| \geq 2, p \in P \tag{22}$$

$$\sum_{i \in G'_1}\sum_{j \in G'_1} x_{ijp}^{m_k k} \leq |G'_1| - 1 \quad \forall t_z \in T_z, z \in Z, |G'_1| \subseteq G_1, |G'_1| \geq 2, p \in P \tag{23}$$

$$\sum_{i \in G'_2}\sum_{j \in G'_2} x_{ijp}^{m_k k} \leq |G'_2| - 1 \quad \forall t_z \in T_z, z \in Z, |G'_2| \subseteq G_2, |G'_2| \geq 2, p \in P \tag{24}$$

$$ud_{jp} = (ud_{ip} + ST_{ip}^{t_z z} + dis_{ij}/ S_{t_z z})\, x_{ijp}^{t_z z} \ \forall i, j \in G_1, t_z \in T_z, z \in Z, p \in P \tag{25}$$

$$ur_{kp} = (ur_{ip} + ST_{ip}^{t_z z} + dis_{ij}/ S_{t_z z})\, x_{ijp}^{t_z z} \ \forall i, j \in G_2, t_z \in T_z, z \in Z, p \in P \tag{26}$$

Eq. (25) and (26) show arrival and travel times of vehicles from node i to j and k nodes for distribution centres’ and retailers’. Eq. (27-29) indicates that the production amount cannot exceed the maximum capacity under ideal conditions plants, distribution centres’, and retailers’. Eq. (30) shows the top DCs product holding capacity. Eq. (31) shows the restrictions of the capacity statuses of vehicles.

$$P_i \leq CP_i; \quad \forall i \tag{27}$$

$$\sum_{i=1}^{I} X_{ij} = CD_j; \quad \forall j \tag{28}$$

$$\sum_{i=1}^{I} X_{ij} = CR_k; \quad \forall j \tag{29}$$

$$\sum_{l \in L}\sum_{i \in G_2} dem_{kp} r_{jkp}^{t_z z} \leq Q_z \quad \forall t_z \in T_z, z \in Z, p \in P \tag{30}$$

Eq. (31-32) indicates that the products produced at the factory are equal to the total quantity demanded.

$$\sum_{i=1}^{J} X_{ik} = dem_k; \quad \forall k \tag{31}$$

$$\sum_{i=1}^{I} Pl_i = \sum_{k=1}^{K} dem_k; \quad \forall j \tag{32}$$

Eq. (33) shows the condition that all variables must be greater than zero.

$$\text{All of the variables} \geq 0 \tag{33}$$

3.4 Benders’ Decomposition

The Benders' Decomposition (BD) algorithm developed by Benders, provides the optimum solution to multi-integer linear programming problems in a shorter time by reducing variables with the duality approach (Hooker, 2007)[19]. Especially in cases where the number of variables is high, the optimization process s performed by taking the dual of the problem. The algorithm consists of two parts, and the first part as the main problem defined for a subset of variables, while in the second part, variables the subset are analysed. The decision variables of x and y represent as follows: the y indicates the complex structure, x shows the non-complex variables. In the Benders-cut method, the standard optimization structure is considered. It added to the master by repeating the primal and master problems in each iteration. In this case, the reduction (maximization) depends on the main optimal solution with a lower (upper) and a Primal upper (lower) (Bidhandi et al., 2009;2017)[16,20,21]. In the Benders algorithm, while the process applied within limits in obtaining the optimum values, the problem can solved with a higher acceleration while reaching the goals that make up the Bender's cut.

The basic structure (Eq.(34)

$$\min cx+dy$$

$$Ax+By\geq b$$

$$x,y \geq 0 \tag{34}$$

After k iteration, a relationship between the main problem and the sub-problem begins with the trial where the Benders cut condition $z \geq B_{y^k}(x)$ is satisfied.

In the processing phase (second stage), the total cost of each supply point is minimized, taking into account the demand conditions, the least cost option is preferred (Mariel et al., 2017) [18]. Costs minimized, and necessary assignments are made to demand points. Delivery times unconsidered in the main problem. The problem shown below:

Main problem

Min z

$$z \geq B_{x^k}(x), i \leq k-1 \tag{35}$$

Sub problem

$$\text{Min } cz+dy \tag{36}$$

$$B_y \geq b - A_{x^k} \tag{37}$$

$$y \geq 0 \tag{38}$$

The dual solution shows the case of u^k optimality: $u^k By \geq u^k (b - Ax^k)$ assigned in the case of dy $\geq v^*$. In the case of u^kB≤d and $u^k(b - Ax^k) = v^*$, the appropriate dual solution for x also shows the weak and weak duality. At the same time, $u^k(b - Ax) \leq v$. the weak duality state can be represented more fully with $cx + u^k(b - Ax) \leq cx + v = z$.

Benders' cutting algorithm is developed based on the above model structure:

Step 1 (Initiation): An appropriate starting point for Y is chosen and is called Y¯. As upper and lower boundaries, under the Z u = + ∞, Z l =-∞, $U_k \leftarrow U$, are taken into account to create the primary constraint.

Step 2 (Linear programming phase): To obtain the extreme points, the Benders solve the sub-problem and then consider the top problem Zu = μινα {Zu, U_0 + cY¯.

Step 3 (Integer programming phase): Based on the sub-problem solution is in Step 2, new constraints add to the main problem, and by solving the main problem (IP), Y obtained. Then {Zu = μινα {Zu, U_0 + cY¯} state is updated by considering Z l =min Z.

Step 4 (Termination): If the upper and lower bounds are not close enough, i.e., Zu-Zl > ε, go to step 2. Otherwise, Y¯ is the ultimate optimal value of Y. In order to get X¯, the fundamental problem for Y = Y¯ obtained [18-20].

4. Case Study

The main problem phase determines which products shipped to which demand points before sourcing from suppliers. If the quantity sent to each assignment point known, a sub-problem created. Demand-based sub-problem finds the allocation quantities and durations and minimizes the procurement production time. On each iteration, the following sub-problem solved and logical breaks related to assignments created.

Since the purpose function of MP is the attenuation of the equivalent Benders-reformulation, it gives a reasonable low limit for optimum cost. In addition, combining the objective value of the subproblem with the solution, which is equivalent to fixing the expression in the original formulation, imposes a valid upper bound for optimum cost. It has the feature of reduction, gives a reasonable lower limit for optimum cost. Furthermore, the objective value of the sub-problem is equivalent to fixing the expression in the original formulation. Combining the Y-optimal solution sets a reasonable upper limit for the optimum cost (Shaw et al.)[17, 21].

Simultaneously, the company carries out the procurement, production, and distribution processes by applying the following steps in the production processes and supply chain model. Company's existing storage system is scattered; there are nine regional warehouses opened in different cities in order to meet customers' urgent orders in factory production facilities, but the stock quantity of these warehouses is usually deficient, so there are not many stocks for many products in many days of the month. Therefore, the necessity and efficiency of these deposits can questioned (Fig.1).

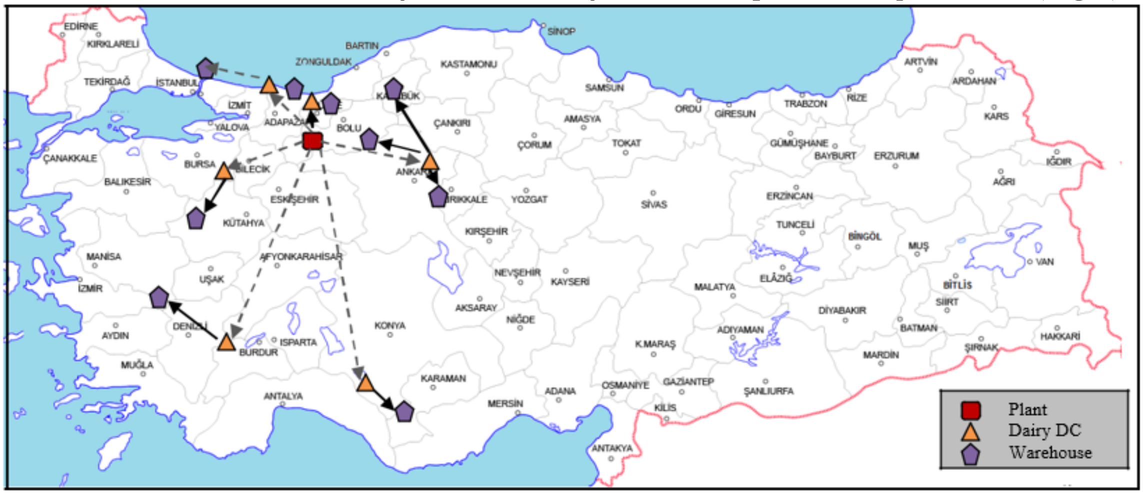

Figure 1: Factory and distribution points

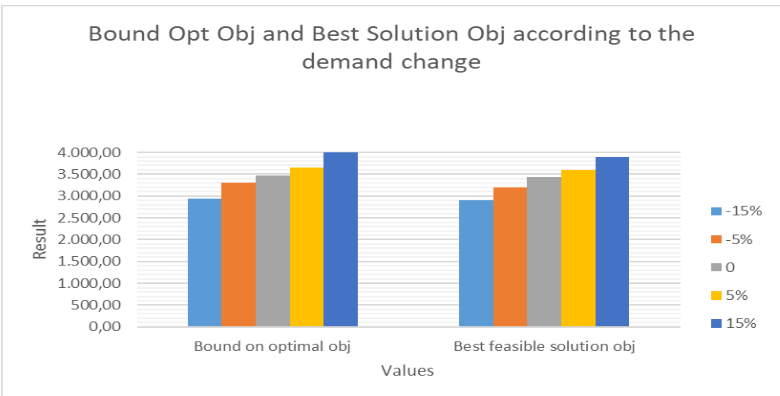

Figure 2: Bound and best optimal solution result

As a result, in the current distribution system, the logistics durations cannot reduced, as the company cannot get the desired level of service in the storage distribution of the products. In light of these symptoms arising from the analysis of the distribution part of the firm's supply chain, the problem defined as an efficient and inefficient logistics system for the distribution of products. Table 1 and Fig. 2 show the profit/unit values between supply centres and product's respect of the distances.

Table 1: Distances between supply centres, dairies, markets, and respective transportation costs.

	D1	D2	D3	D4	D5	D6	D7	D8	D9
P1	16	12	11	14	14	29	23	24	27
P2	11	18	26	13	13	19	25	22	24
P3	12	14	15	14	15	16	13	13	37
P4	12	12	19	19	15	17	13	13	27
P5	12	14	13	18	15	14	21	19	22
P6	12	11	14	15	12	13	20	10	10
P7	10	10	12	17	14	13	10	20	10
P8	10	12	12	13	15	15	17	12	20
P9	9	9	9	11	16	18	12	19	12
P10	10	14	15	11	14	12	17	16	18

Then, the values of 15% and -15% for the bound optimal objective almost equally affected (in Table 2 and Fig.3). As in product, quantity values, 15% are the most affected values in best solution and objective values. As the demand values increased, the solution increased at the same rate and decreased at the same rate.

Table 2: Products and quantity sensitivity values in -15% to 15%

Item / Variable Quantity	-15%	-5%	0	5%	15%
Cheddar cheese	46,33	50,02	64,83	59,65	53,43
Buttermilk	57,53	92,51	101,37	95,18	142,3
Yoghurt	47,83	56	60,72	57,75	70,53
Butter	0.00	0.00	0.00	0.00	0.00
Curd Cheese	5,48	68,64	81,18	78,94	58,34
Cream cheese	45,88	33,55	19,23	0.00	0,26
Pasteurized Milk	102,77	31,16	39,07	87,05	98,44
Strained Yoghurt	0.00	0.00	0.00	0.00	0.00
String Cheese	0.00	0.00	0.00	0.00	0.00
Knitted Cheese	0.00	0.00	0.00	0.00	0.00
Bound on optimal obj	2948,04	3303,76	3474,58	3647,21	4004,63
Best feasible solution obj	2899,41	3199,27	3429,02	3599,03	3894,53
Objective Function	6875,13	7513,67	8192,2	8520,36	9397,52

When we look at the product values, four products attract attention at the -15%, -5%, 0%, 5%, and 15% values that occur in the demand change, and in each case, the product value is 0 (Table 2). Keeping stock for butter, strained yogurt, string cheese, and braided cheese because unnecessary stock respect from the holding costs and the shelf life of these products in the perishable food class before they sold. Therefore, it seems more appropriate to produce according to order in these products. When we examine it as a product, the most different change in the product value on all the demand changes observed in the -15% change in the pasteurized milk value (Fig. 4). The most significant change in product value occurred at -15% (Fig.4). The most sensitive product according to the changes in demand from the percentage changes that occur in the demand changes is pasteurized milk. Buttermilk and yogurt less affected than other products. In this case, the best interpretation is that ayran and yogurt are the most suitable products to keep stock in.

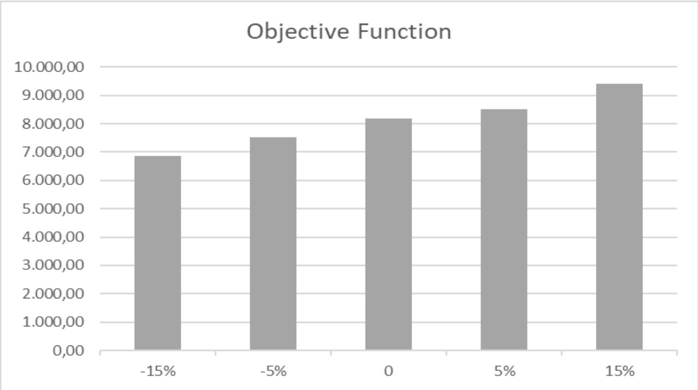

Figure 3: Objective Function value in sensitivity degrees in -15% to 15%

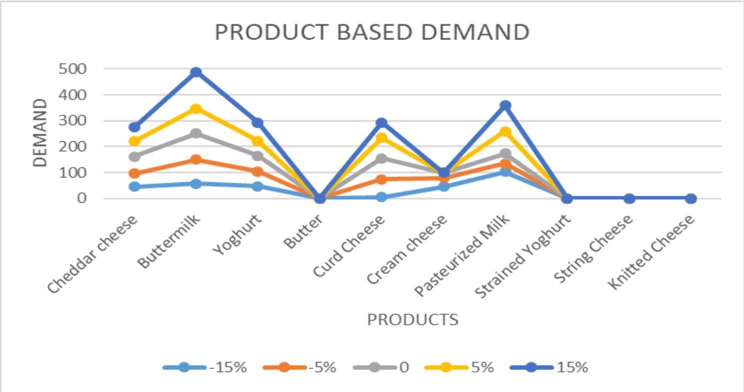

Figure 4: Product amounts and demand changes in sensitivity

Thanks to Bender's cutting, in the solution of multivariate and multipurpose problems, more solutions that are balanced obtained by overcoming more than one conflicting target. It is possible to obtain the optimal solution because of evaluating the different demand conditions obtained. Thanks to the information obtained from this study, it is possible to determine production strategies by evaluating different demand situations.

5. Conclusion

Bender's decomposition management applied to the dairy supply-chain management model in this study. The dairy products factory operations of the supply chain model analysed by Bender's decomposition approach. Work carried out on the optimum management strategies with the available real data. The study consists of a three-layer supply-chain management model that includes raw material procurement, product manufacturing, and distribution of manufactured products. The proposed approach proven in actual case studies from Turkey dairy industry. Finally, the successful implementation of the proposed approach is such that it exemplifies not only the entire range of dairy products, but also supply chain management models of a similar nature.

The main contributions that the dairy supply chain model was developed and the optimal production quantities found for different demand situations by applying the Benders decomposition algorithm.

References

[1] Mogale D.G., Kumar M., Kumar S.K. & Tiwari M.K. (2018). Grain Silo location-allocation problem with dwell time for optimization of food grain supply chain network, Transportation Research Part E, 111, 40-69.

[2] Li Y., Chu F., Cote, J.F, Leandro C. C. & Chu C. (2020). The multi-plant perishable food production routing with packaging consideration, International Journal of Production Economics, 221, 107472.
[3] Alkaabneh F., Diabat A. & Gao H.O. (January 2020). Benders decomposition for the inventory vehicle routing problem with perishable products and environmental costs, Computers & Operations Research, 113, 104751.
[4] Davoodi S.M.R. & Goli A. (April 2019) An integrated disaster relief model based on covering tour using hybrid Benders decomposition and variable neighborhood search: Application in the Iranian context, Computers & Industrial Engineering, 130, 370-380.
[5] Kirilova E.G. & Vaklieva-Bancheva N.G. (2017). Environmently friendly management of dairy supply chain for designing a green products' portfolio, Journal of Cleaner Production, 107, 493-504.
[6] Bottani E., Murion T., Schiavo M. & Akkerman R. (2019). Resilient food supply chain design: Modelling framework and metaheuristic solution approach, Computers & Industrial Engineering, 135,177-198.
[7] Pariazar M., Root S. & Sir M.Y. (2017). Supply chain design considering correlated failures and inspection in pharmaceutical and food supply chain, Computers & Industrial Engineering, 111, 123-138.
[8] Bilgen B. & Dogan K. (2015). Multistage Production Planning in the Dairy Industry: A Mixed Integer Programming Approach, Industrial & Engineering Chemistry Research, 54(46), 11709–11719.
[9] Egilmez G., Erenay B. & Süer G.A. (2019). Hybrid cellular manufacturing system design with cellularisation ratio: an integrated mixed integer nonlinear programming and discrete event simulation approach, International Journal of Services and Operations Management, 32, 1.
[10] Grillo H., Alemany M.M.E. & Ortiz A. (2017). FuertesMiquel, V.S. Mathematical modelling of the order-promising process for fruit supply chains considering the perishability and subtypes of products, Applied Mathematical Modelling, 49, 255-278.
[11] Paul S.K., Sarker R. & Essam D. (2017) A quantitative model for disruption mitigation in a supply chain, European Journal of Operational Research, 257, 881-895.
[12] Gholamian M.R. & Taghanzadeh A.H. (2017). Integrated network design of wheat supply chain: A real case of Iran, Computers and Electronics in Agriculture, 140, 139-147.
[13] Doganis P. & Sarimveis H. (2008). Mixed Integer Linear Programming Scheduling in the Food Industry. Optimization in Food Engineering, 80, (2), 445-453
[14] Mula J., Peidro D., DíazMadroñero M. & Vicens E. (2010). Mathematical programming models for supply chain production and transport planning, European Journal of Operational Research, 204(3), 377-390.
[15] Sel C., Bilgen B., Bloemhof-Ruwaard J.M. & Vorst J.G.A.J. van der (June 2015). Multi-bucket optimization for integrated planning and scheduling in the perishable dairy supply chain, Computers & Chemical Engineering, 77(9), 59-73.
[16] Bidhandi H.M., Yusuff R.M., Hamdan M.M., Ahmad H.M. & Abu Bakar M.R. (October 2009) Development of a new approach for deterministic supply chain network, European Journal of Operational Research, 198(1), 121-128.
[17] Shaw K., Irfan M., Shankar R. & Yadav S.S. (2016). Low carbon chance constrained supply chain network design problem: a Benders decomposition based approach, Computers & Industrial Engineering, 98 483–497.
[18] Mariel K. & Minner S. (April 2017) Benders decomposition for a strategic network design problem under NAFTA local content requirements, Omega, 68, 62-75.
[19] Hooker J.N. (2007). Planning and Scheduling by Logic-Based Benders Decomposition, Operations Research, 55, 3.
[20] Bidhandi H. & Patrick J. (January 2017). Accelerated sample average approximation method for two-stage stochastic prograamming with binary first-stage variables, Applied Mathematical Modelling, 41, Pages 582-595.
[21] Turgay S., Yaşar Ö., Tutar A.C., A Multi-objective Framework for Sustainable Dairy Products Supply Chain Distribution System Proceedings of 10th International Symposium on Intelligent Manufacturing and Service Systems Pages, 1481-1490. (2019)