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AGRICULTURAL-FOOD SUPPLY CHAIN DESIGN WITH THE CPFR APPROACH: AN APPLICATION

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ABSTRACT

Purpose- Agri-food supply chain is an important supply chain for our country in terms of both cost and food safety. In this context, the selection of suppliers, manufacturers and logistics companies that make up the chain and the relations between them are extremely important, and the quality of the companies that make up the chain must be high in order to create effective and efficient supply chains. In this study, the author aimed to conduct a research on the creation of an integrated supply chain with a collaborative approach. The framework of the study is limited to the producers, suppliers and logistics enterprises, which are the main actors in the agriculture-food value chain.
Methodology- The author proposes an integrated methodology for collaborative work in the agri-food supply chain. Within the framework of the methodology created within the framework of the CPFR method, the chains that enable the stakeholders included in the system to deliver the product to the demand points at the most affordable cost were determined by the linear programming model. In the second stage, meeting the demands created with random numbers was simulated. Finally, the suitability of the model was tested with the data of a company.
Findings- The findings show that the product moves less if the stakeholders in the chain are correctly matched within the framework of the collaborative approach. In addition, it has been seen that the needs of both demand points are met thanks to the correct match. In addition, a positive effect has been achieved in the use of the stakeholders' capacities.
Conclusion- This article is one of the first studies that looks at the agri-food supply chain in an integrated way and evaluates the processes within the framework of a collaborative approach. The study also contributes to improvement in the sector in terms of including the stakeholders involved in the collaborative process into the system according to the criteria determined.

Keywords: OR in agriculture, agri-food, agri-food supply chain, holistic design, CPFR
JEL Codes: M11, Q10, S19

1. INTRODUCTION

Agricultural products are products that have an important place in human life. They are basic foodstuffs for nutrition. Therefore, for a healthy diet, these products must be grown, collected, preserved and delivered to consumers in suitable conditions. One of the main objectives of the agricultural sector is to ensure food security. The aim of food safety is to prevent deterioration of foodstuffs and to extend their shelf life. Fresh vegetables and fruits are among the products with a short shelf life in the food industry and must be consumed within a certain period of time. Therefore, it is of great importance that the products are delivered to the consumer quickly, in sufficient quantity and with the same quality.

The agricultural sector contributes to the development of both sectors by creating demand for both its own products and industrial products. Since agricultural products are compulsory consumption products, the demand for these products will increase in parallel with the population growth in both rural and urban areas. Turkey's growing population requires more effective and efficient management of the agricultural sector. In this context, it is of great importance to deal with the agricultural sector with a supply chain management approach. Supply chain management entails planning, executing, monitoring and controlling the stages from the first material to consumption together.

Agricultural product producers are one of the most important links of the agri-food supply chain. Manufacturers can sell their products in two ways. They either harvest the product and take it to the wholesale market with their own means and sell it there through brokers, or they sell directly to retailers such as supermarkets. On the other hand, temperature changes at any level during the period from the date of harvest to consumption of fresh vegetables and fruits cause deterioration in their physical and chemical structures. Therefore, many vegetables and fruits are wasted because they are not properly stored until they reach the final customer from the field. Considering all these factors, the long product flow in the agri-food supply chain increases losses and costs.

However, developing effective strategies to meet the consumer demand for agricultural products while responding to the ever-increasing changes in lifestyle and nutritional preferences is a highly complex and challenging issue. Although the distribution of perishable products such as food is multi-stage, an integrated supply chain structure should be established as the products must be delivered to the end user as quickly as possible. An integrated agri-food supply chain should include distribution and logistics processes, along with production planning and stock control. An integrated and well-designed production schedule and delivery routes should be established in order for suppliers to supply the freshest food and meet customers' requirements in a cost-effective way (Chen & Haihong, 2013).

Within the scope of this article, first of all, literature research on the agri-food supply chain was conducted. Afterwards, a methodology for integrated supply chain design was developed within the framework of the CPFR approach. In the rest of the article, linear programming model and simulation methods were applied within the scope of the application steps of the established methodology and the model was tested on a company data. In the last part of the article, the results of the study are discussed.

2. LITERATURE REVIEW

Developing effective strategies to meet consumer demand for agricultural products, while responding to ever-increasing changes in lifestyle and dietary preferences, is a complex and challenging issue.

Aramyan et al. (2007) assessed the appropriateness of a new conceptual model formed to measure performance in agri-food supply chain in their study. The frame of an integrated performance measurement system was formed and this structure was assessed in the tomato supply chain from producer to retailer in the Netherlands and Germany.

In Ahumada and Villalobos (2009) research, literature review has been done on the studies of agri-food production and distribution. They classified the models successfully used in agri-food supply chain according to the features such as product type and plan range. They showed the literature gaps for further researchs.

Folinas et al. (2013) proposed a perspective view that uses lean thinking tools in order to support green supply chain and logistics management in agri-food supply chain. They used the Value Stream Mapping (VSM), the lean thinking technique in order to detect the activities that do not create any value in the agri-food supply chain. They showed that this model could be useful and fruitful in forming the green agri-food supply chain.

Fang and Leung (2009) proposed a Collaborative Planning Forecasting and Replenishment (CPFR) approach for a supply for agricultural products. By extending a two-tier supply chain to a multi-tier supply chain, an n-tier CPFR model was created and the concept of collaborative transportation was integrated into the model. Finally, the model was analyzed with a case study and its effectiveness was confirmed (Fang & Leung, 2009).

Lamsal et al. (2016) proposed the logistic organization model from the field to the plants or to the warehouses. The two-stage solution technique was proposed in order to minimize the changes in flow of product transportation vehicles. In the first stage, the time to start yield in the field was modelled as deterministic parameters, and in the second stage, the number of required vehicles to be ready for every load was determined.

Giggler et al. (2002) proposed an optimization approach that use linear programming model (LP) aiming at the quality of the products in agri-food supply chain. The suggested LP model was developed in MATLAP program providing optimum solutions for agri-food supply chain optimization.

Chen et al. (2013) applied a supply chain simulation model on a real case with agricultural production and cooperative-centered distribution systems. Three existing models of agricultural distribution systems were created, the models were optimized quantitatively, and finally, key performance indicators of all supply chains were evaluated by simulating (Chen et al. 2016).

Sanjaya and Perdana developed a logistics model for selling local farmer-produced tomato product in a structured market. In this model, a different simulation approach is used, which is simulated by state change (Sanjaya & Perdana, 2015).

Ferreira J.O. et al. (2016) Using the system dynamics of orange production and industrial processing in Brazil, a simulation model was applied and an integrated system was created.

Ahumada and Villalobos (2011) proposed the mixed integer model for the yield and distribution planning of perishable agri-products. The proposed mixed integer model is to help producers yield, pack and distribute products in complicated and changing conditions. This model offered a sample solution based on presumptions studying tomato and pepper.

Zhong et al. have searched the needed information to be used in forming an agricultural information center that aims to meet the need of information among suppliers in vegetable supply chain. In southwest China, the survey has been carried out with agri suppliers in person. The structural equitation model that uses composite indicator variables in answering the questions has been used (Zhong et al.2015).

In the study of Behzadi et al. (2017), strategic and tactical problems in the agricultural supply chain network were discussed together. The Mixed Integer Linear Programming Model was applied in the supply chain case of the kiwi product to analyze the performance of a strong and flexible strategy for reducing the risk of harvest time and yield of agricultural products (Behzadi, et al., 2017).

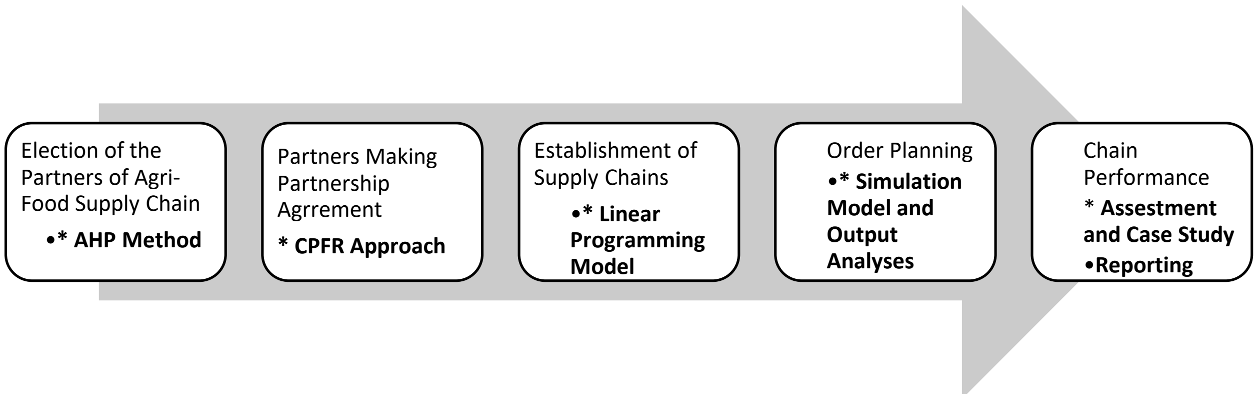
The only study that looks at the agricultural products supply chain on a holistic basis is Tsolakis et al. (Tsolakis, et al., 2014). This study is on a conceptual basis and does not includes a holistic solution. Therefore, the methodology proposed in this study has been developed to address this deficiency. In particular, a study that envisages the establishment of an effective supply chain, which includes the selection of suppliers, manufacturers and logistics companies (conformity assessment) and carries out the selection of the manufacturer and logistics companies together, with a holistic perspective is aimed.

3. DATA AND METHODOLOGY

The long flow of products in the agri-food supply chain increases losses and costs. The losses from farm-to-table could be very different depending on the development level of the countries. For this reason, the activities that do not create any added value in this process must be eliminated and short circuit supply chain must be established. In this study, a methodology was developed for the holistic solution of the problems encountered in agri-food supply chain management and an application was made on the tomato product.

In the developed model; the agri-food will be produced after inspection by the production firms, producer cooperatives and certified agri-food producers; logistic services will be carried out by certified logistics firms; the returns received by logistics firms will be turned into economic value; customers' complaints will be received through all the communication channels; and finally, those that are not suitable will be excluded from the system. In this system, which is based on standards and the provision of these standards and will work on pull, agricultural products will be delivered to customers in the fastest way and with the lowest cost. In the methodology we have created by taking all these factors into consideration, first of all, the selection of stakeholders in the agriculture-food supply chain was carried out in two stages. In the first stage of the chain members' entry process, the members of the chain were evaluated by the AHP method within the framework of the determined criteria, and those below a certain score were not included in the system. For the operation phase, it is foreseen that the orders coming to the system will be met by the manufacturer and the logistics company that provides the most suitable match. In this context, the product values of the proximity and AHP scores of the stakeholders were taken. The methodology for the design of the agri-food integrated supply chain is shown in Figure 1.

Figure 1: Methodology



In the first stage, the partners of the chain (suppliers, manufacturers and logistics companies) were evaluated using the AHP method. The AHP method is also used for producer-logistics firm matching in operational process so that when the producer receives an order the most suitable logistics firm will be determined. The Analytic Hierarchy Process (AHP) introduced by Thomas Saaty (1970), is an effective tool for dealing with complex decision making, and to aid the decision maker to set priorities to make the best decision (Saaty 1977).

In the second stage, making collaboration agreements between the stakeholders is ensured to as the first step of Collaborative Planning Forecasting and Replenishment (CPFR) method. In the third stage, the most suitable supply chains are determined considering supply-demand balance by linear programming method and demands are integrated to the chains according to their AHP points and distance criteria.

In the third stage of the methodology, linear programming (LP) model was applied for the agri-food supply chain consisting of 3 suppliers, 3 manufacturers and 3 logistics companies. The purpose of the LP model is to maximize total AHP scores within capacity and demand limits. Thus, the model assigns orders to one of the chains based on points. It is assumed that chains that are not assigned an order will not be used.

In the last stage, the simulation model was used to create and fulfill the orders. At this stage, it is envisaged to evaluate the performance of the chain and to improve the chain. For the test of the proposed model, the data obtained from ABC company, which is the sector leader in fresh fruit and vegetables for tomato product, was used by processing.

3.1. Collaborative Planning, Forecasting and Replenishment (CPFR)

Market demand is another important issue to be dealt with the developed production model. The CPFR is an approach that integrates supply chain elements by supporting and assisting joint practices. By way of CPFR approach, all inventories throughout the supply chain can be more visible and easier to manage. The one of the important problems in agri-food sector is that the farmers are not sure about whether their product will be bought by the consumers and how to cope with the excessive / little stock problems. The CPFR approach create the structure in order to overcome these problems and to develop agri-food product supply system. From production perspective, it is vital to know what to do with surplus capacity when you make uncontrolled production.

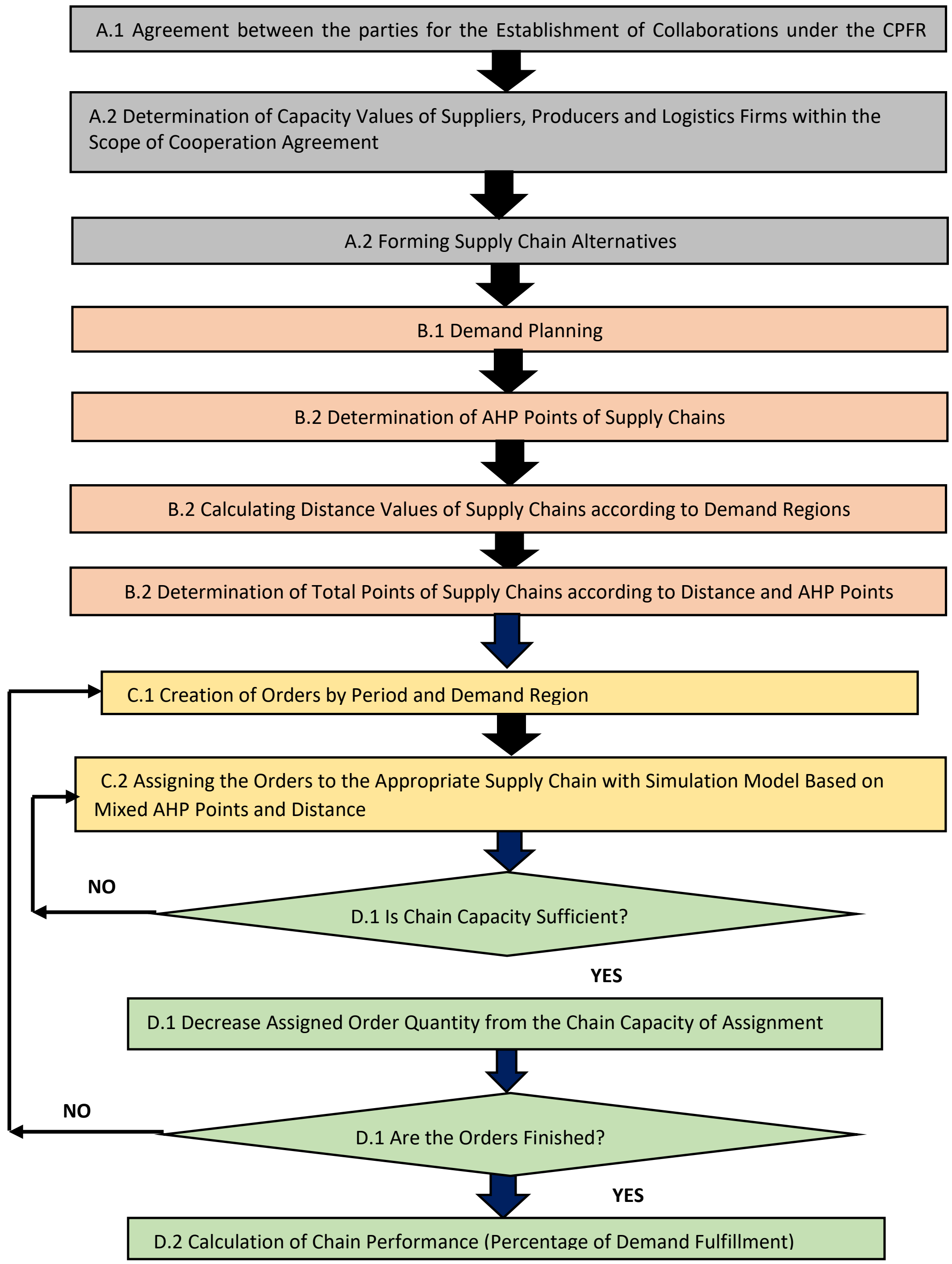
CPFR management recommends collaborative work, but considers only two phases, the seller and the buyer. Unfortunately, the agri-food value chain needs many stages or many firms with different goals. The processing steps of the CPFR method adapted for the study are shown in Figure 2.

Figure 2: Application of CPFR Process Steps

A. STRATEGY and PLANNING	•**A.1.** Arranging Cooperation •**A.2.** Joint Business Plan
B. DEMAND and SUPPLY MANAGEMENT	•**B.1.** Creating Sales Forecast •**B.2.** Planning Order Forecast
C. EXECUTION	•**C.1.** Forming Orders •**C.2.** Generating Orders
D. ANALYSIS	•**D.1.** Identifying Exceptions •**D.2.** Performance Assessment

The CPFR Methodology of the Agri-Food Supply Chain is shown in Figure 3. Process steps A and B represent the planning and estimation function of the CPFR determined by the linear modeling program that evaluates the distance of each chain and the AHP points. Stages C and D make up the CPFR feed function. In this context, with the simulation model, which customer order will be fulfilled by which supply chain has been determined.

Figure 3: CPFR Methodology of Agri-Food Supply Chain



3.2. Linear Programming Model of Agri-Food Supply Chain

In the linear programming model to be used for phases A and B of the methodology. It is assumed that there will be 3 suppliers, 3 producers, 3 logistics companies, 3 different demand regions and 4 planning periods within the CPFR approach for the agri-food supply chain.

The linear programming model is as shown below:

Index

Planning Period t= 1,2,3,4

Demand Zone d= 1,2,3

Supplier s= 1,2,3

Producer p= 1,2,3

Logistics Firm n= 1,2,3

Decision Variable

X s, p, n, t, d: The amount sent to the (d) zone by the chain formed by (s) supplier (p) producer and (n) logistics firm during the (t) period.

Parameters

P s, p, n, t, d: The point which is gained after the supplier send the producer via logistics firm chain during the period.

SCs,t : production capacity of s supplier in the t period

PCp,t : production capacity of p producer in t period

NCn,t : transport capacity of n logistics firm in t period

Dd,t : demand amount of d zone in t period

Objective Function is the maximization of Total Supply Chain score (point).

$$\max z = \sum_{s=1}^{S}\sum_{p=1}^{P}\sum_{n=1}^{N}\sum_{t=1}^{T}\sum_{d=1}^{D} X_{s,p,n,t,d}\, P_{s,p,n,t,d}$$

Constraints

Supplier Constraints:

$$\sum_{n=1}^{N}\sum_{p=1}^{P}\sum_{d=1}^{D} X_{s,p,n,t,d} \leq \mathrm{SC}_{s,t} \qquad ,\forall \quad t \in T, \qquad s \in S$$

Producer Constraints:

$$\sum_{s=1}^{S}\sum_{n=1}^{N}\sum_{d=1}^{D} X_{s,p,n,t,d} \leq \mathrm{PC}_{p,t} \qquad ,\forall \quad t \in T, \qquad p \in P$$

Logistics Firm Constraints:

$$\sum_{s=1}^{S}\sum_{p=1}^{P}\sum_{d=1}^{D} X_{s,p,n,t,d} \leq \mathrm{NC}_{n,t} \qquad ,\forall \quad n \in N, \qquad t \in T$$

Demand Constraints:

$$\sum_{s=1}^{S}\sum_{p=1}^{P}\sum_{n=1}^{N} X_{s,p,n,t,d} \geq \mathrm{D}_{d,t} \qquad ,\forall \quad d \in D, \qquad t \in T$$

Non-negative Constraints: Every decision variable must not be negative.

$$\mathrm{X}_{\mathrm{s,p,n,t,d}} \geq 0$$

First criteria to consider in the calculation of the chain value is the customer-producer distance and the producer-demand zone distance. These values are normalized to determine the total distance. Then this value will be multiplied with the AHP points of each chain consisting of the producer, logistics firm to determine the total point.

P_(s,p,n,t,d)= The point got by the AHP and distance points when the product is sent to the zone via the chain including the supplier, producer and logistics firm.

$$s,p,n,t,d \qquad\qquad s \in S\,, p \in P, n \in N, t \in T, d \in D$$

In this sense the distance of the supplier to the producer is called FD and the matrix is shown in Figure 4.

Figure 4: The (S) Supplier-(P) Producer Distance Matrix

Distance (S-P) =FD The Normalized Form of Distance Between

$$\mathrm{S-P} \quad \begin{array}{c|ccccc} \cdot & \mathrm{P}_1 & \mathrm{P}_2 & \mathrm{P}_3 & \dots & \mathrm{P}_n \\ \hline \mathrm{S}_1 & \mathrm{FD}_{11} & \mathrm{FD}_{12} & FD_{13} & .. & FD_n \\ \mathrm{S}_2 & \mathrm{FD}_{21} & \mathrm{FD}_{22} & \mathrm{FD}_{23} & .. & .. \\ \mathrm{S}_3 & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \mathrm{S}_n & \mathrm{FD}_n & .. & .. & .. & .. \end{array} \rightarrow \begin{pmatrix} FD_{11}/FD_{max} & \mathrm{FD}_{12}/FD_{max} & \dots & FD_n \\ FD_{21}/\mathrm{FD}_{max} & .. & .. & .. \\ FD_{31}/FD_{max} & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \end{pmatrix}$$

The second step in calculating the chain value is to determine producer-demand zone distance. This distance is named as SD and matrix has been shown in Figure 5.

Figure 5: The (P) Producer- (D) Demand Zone Matrix

Distance (P-D)=SD The Normalized Form Distance Between PD

$$\begin{array}{c|ccccc} \cdot & \mathrm{D}_1 & \mathrm{D}_2 & \mathrm{D}_3 & \dots & \mathrm{D}_n \\ \hline \mathrm{P}_1 & \mathrm{SD}_{11} & \mathrm{SD}_{12} & SD_{13} & .. & SD_n \\ \mathrm{P}_2 & \mathrm{SD}_{21} & \mathrm{SD}_{22} & \mathrm{SD}_{23} & .. & .. \\ \mathrm{P}_3 & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \dots & .. & .. & .. & .. & .. \\ \mathrm{P}_n & .. & .. & .. & .. & .. \end{array} \rightarrow \begin{pmatrix} \mathrm{SD}_{11}/SD_{max} & \mathrm{SD}_{12}/SD_{max} & \dots & SD_n \\ \mathrm{SD}_{21}/SD_{max} & .. & .. & .. \\ \mathrm{SD}_{31}/SD_{max} & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \end{pmatrix}$$

Finally, the total distance is calculated by the multiplication of the normalized distances. The total distance is named as TDV Figure 6.

Figure 6: Total Distance Matrix

$$\begin{pmatrix} FD_{11}.SD_{11} & FD_{12}.SD_{12} & \dots & TDV_n \\ FD_{21}.SD_{21} & .. & .. & .. \\ FD_{31}.SD_{31} & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ .. & .. & .. & .. \end{pmatrix}$$

As an example, when we have 3 demand zones, 3 suppliers and 3 producers there will be 27 chains. Since distance is a positive factor in evaluating chains, the total distance value will be extracted from '1' value. In order to calculate the value of every chain; 0,5 of the AHP points multiplication of the supplier, producer and logistics firm and 0,5 of the 1-total distance values are summed (Figure 7). In this sense AHP points and TDV have equal weights. Yet, if needed, these weights can be changed.

Figure 7: Calculation Matrix of Total Gained Point

$$\left(\begin{array}{c|cc} & \textbf{AHP POINT} & \textbf{TOTAL DISTANCE} \\ Z_{111} & W_{111} & TDV_{111} \\ Z_{112} & W_{112} & TDV_{112} \\ Z_{113} & .. & .. \\ Z_{211} & .. & .. \\ \dots & .. & .. \\ \dots & .. & .. \\ \dots & .. & .. \\ \dots & .. & .. \\ Z_{nnn} & .. & .. \end{array}\right) \rightarrow \begin{pmatrix} \textbf{CHAIN POINT} \\ 0{,}5.W_{111} + 0{,}5(1 - TDV_{111}) \\ 0{,}5.W_{112} + 0.5\,(1 - TDV_{112}) \\ .. \\ .. \\ .. \\ .. \\ .. \\ .. \end{pmatrix}$$

4. FINDINGS AND DISCUSSIONS

4.1. Application of Linear Programming Model

The LP model created above is built for three suppliers, three manufacturers, and three demand regions. Within the scope of calculating each chain value to be determined for the first two steps of the CPFR method, firstly, the distances of the suppliers to the manufacturers were determined and normalized. AHP scores of suppliers, manufacturers and logistics companies were calculated separately and the scores of the stakeholders in the chain were multiplied to form 27 supply chains. In the next step, the total score values of the supply chains on the basis of AHP and proximity (distance) were calculated separately for the three demand regions, and the chains Z111 for the 1st period, Z112 for the 2nd period and Z113 for the 3rd period have the highest scores (Appendix- 1).

The data used in the model for the demands of three different regions for four different periods, which will be used in the linear programming model for the next process, and the capacities of the suppliers, manufacturers and logistics enterprises that make up the chain were evaluated as seasonally quarterly periods (Appendix-2).

At the last stage, in the mathematical model we created for the agri-food supply chain, the data in Appendix 2 was transferred to the AIMS program and the most appropriate solution found is given in Table 1. It is assigned to the most suitable chains for each period from three different regions. For example, the first period demand of the first region is 1,084 units, and this demand was met by the chains Z311, Z221 and Z133. Likewise, in the fourth period, it is seen that the demand of the second region is 833 units and the Z231 chain alone meets the demand. In this way, we can say that all demands are met, considering capacity constraints.

Table 1: Linear Programming Solution

Supply Chains	**Demand Zone -1**				**Demand Zone -2**				**Deand Zone -3**			
	Periods				**Periods**				**Periods**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Z_{111}	0	0	0	0	0	0	0	0	0	**232**	0	0
Z_{112}	0	**490**	0	0	0	0	**659**	0	**527,5**	0	0	0
Z_{113}	0	0	0	0	0	0	0	0	0	0	0	**616**
Z_{213}	0	**39**	0	0	0	0	0	0	0	0	0	0
Z_{311}	**129,5**	0	0	**15**	0	0	0	0	0	0	0	0
Z_{313}	0	0	0	0	0	0	0	0	0	0	**446**	0
Z_{123}	0	0	0	0	0	**192**	0	0	0	0	0	0
Z_{221}	**526**	0	0	**348**	0	**106**	0	0	0	0	**506**	0
Z_{222}	0	0	0	0	**528,5**	0	0	0	0	0	0	0
Z_{321}	0	0	0	0	0	**506**	0	0	0	0	0	0
Z_{323}	0	0	0	0	0	0	**340**	0	**313,5**	0	0	0
Z_{132}	0	0	0	416	0	0	0	0	0	0	0	0
Z_{133}	**428,5**	0	0	0	0	0	0	0	0	0	0	0
Z_{231}	0	0	0	0	**226,5**	0	0	**833**	0	0	0	0
Z_{232}	0	**541**	**230**	0	0	0	0	0	0	0	0	0
Z_{233}	0	0	0	0	**90**	0	0	0	0	**558**	0	0
Z_{331}	0	0	**478**	0	0	0	0	0	0	0	0	0
Total	**1.084**	**1.070**	**708**	**779**	**845**	**804**	**999**	**833**	**841**	**790**	**952**	**616**

4.2.

Simulation Application

The second phase of the CPFR model in the agri-food supply chain consists of steps C and D in Figure 2. This stage determines which chain can meet the order demand by comparing their capacities. The distance of the demand region and the AHP point of the chain are important in allocating the demands to the appropriate chains. Unlike the linear programming model, the AHP point of the manufacturer-logistics company partner selection and the AHP point of the chain, supplier, manufacturer and logistics company are considered. The distances and weights of the AHP points are equal. The values of chains consisting of 50% distance and 50% mixed AHP points are calculated (Appendix-3)

Chain capacity is the capacity of the firm at the bottleneck stage of the chain. For example; In the first demand period in Z111, the chain supplier capacity is 956, the producer capacity is 1,213 and the logistics company capacity is 1,054 tons. In this context, the capacity of the Z111 chain was taken as 956 tons. Chain capacity according to demand periods is shown in Appendix-4. When orders are allocated to chains, they are subtracted from chain capacity. The model runs until all demands are met.

The simulation model allocates orders to chains on a weekly basis according to their capacity. There are two different data types for orders; one for the number of orders per week and the other for the amount of each order. Uniform distribution is used to keep random numbers at least 5:15, maximum 16:55 based on 16 weeks (4 months x 4 weeks) for the number of orders in 4 periods from 3 different demand regions. In this context, randomly generated numbers are processed into the SQL database. Finally, the C# program is used to decide which chain will meet which demand. The results of the simulation program run with the data from the SQL database are shown in Table 2.

Demand met/backlog demand ratio is 6,44% in Demand Zone 1; 24,50% in Demand Zone 2; and 26,53% in Demand Zone 3. The average ratio is 19,61%. In the last stage. In order to test the validity of simulation model, 52 different tests were done to check the validity. In each test, different order numbers and amounts were used to determine the demand met and the backlog demand for each zone in each period. Following 52 tests, the relationship between the number of demand and the amount of demand was analyzed and 0,76 R2 value was obtained on periodical basis. This shows that simulation model yields similar results in similar values.

Table 2: Simulation Results

								Demand Zone – 1								
Supply Chains	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Z_{112}					43		118									
Z_{311}	28	21	28	17												
Z_{221}	120	119	126	129									84	86	73	80
Z_{132}													51	75	95	84
Z_{133}	27	61	79	100												
Z_{232}					124	73	128	83	27		45					
Z_{331}									119	113	108	19				
BD				**56**			**23**				**81**					
								Demand Zone – 2								
Supply Chains	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Z_{112}									164	154	116	163				
Z_{123}					40	27	47	42								
Z_{221}					25	24	14	20								
Z_{222}	129	119	126	131												
Z_{321}					17	122	103	113								
Z_{323}									79	19		44				
Z_{231}	38		54	49									125	179	191	188
Z_{233}	16		21	14												
BD	**24**		**54**	**159**		**49**		**119**	**248**						**45**	
								Demand Zone – 3								
Supply Chains	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Z_{111}					44	55	13	54								
Z_{112}	128	87	121	83												
Z_{113}													103	143	138	149
Z_{313}									107	108	108	40				
Z_{221}									43	121	125					
Z_{323}	75	78	64	75												
Z_{233}					120	135	128	133								
BD	**97**		**121**		**25**	**56**		**121**		**14**	**173**				**17**	**96**
BD: Backlog Demand																

4.3. Tomato Application

ABC firm data was used for tomato supply chain. The ABC firm owns 5 agriculture farms in 5 different regions of Turkey and produces 12 kinds of vegetables, and 35 kinds of fruit in agricultural farms. It also makes production with contracted farmers. The products grown in agricultural farms are packaged in the factories with 110.000 square meters- closed space in 5 different regions with sophisticated technology machine park according to first-in first-out (FIFO) and cold chain rule. The firm using ERP software has established 5 factories for the alternative customers at different points of the country so that they could minimize the risks that may result from negative conditions and ensure that the fruit and vegetables are delivered fresh at minimum time. The firm ensures that fruit and vegetables could reach the customers as soon as possible by 180 refrigerating trucks. Tomato is packaged in 3 factories owned by the firm. Although different products are packed in the factory, the tomato packaging capacities of the factories were used for this study.

Linear programming model was used to create the most suitable chains by determining the AHP scores of the relevant parties with the data received from the company. Since the main aim of the model is to maximize the total AHP and distance points, the capacity is determined more than the demand. The most suitable solution created with AIMS is shown in Table 3.

Table 3: L Tomato app linear programming solution

Supply Chain	Demand Zone - 1				Demand Zone - 2				Demand Zone - 3			
	Period 1	Period 2	Period 3	Period 4	Period 1	Period 2	Period 3	Period 4	Period 1	Period 2	Period 3	Period 4
Z_{112}	0	0	0	0	**20**	**50**	0	20	230	150	170	200
Z_{131}	**500**	**560**	**540**	**500**	0	**40**	**60**	0	0	0	0	0
Z_{132}	0	0	0	0	**150**	**50**	50	150	0	0	0	0
Z_{223}	**50**	0	0	0	0	0	0	0	0	0	0	0
Z_{312}	0	0	0	0	**50**	**100**	**130**	**80**	0	0	0	0
Z_{322}	0	0	0	0	**50**	0	0	**50**	0	**100**	**50**	0
Z_{323}	**50**	0	0	140	0	0	0	0	**200**	**250**	**300**	**160**
Total	**600**	**560**	**540**	**640**	**270**	**240**	**240**	**300**	**430**	**500**	**520**	**360**

As a result, it is seen that linear programming model enables to allocate the demands of 3 different zones for every period to the most suitable chains. In the data asked from ABC firm, the quality order of supplier, factory and logistics firm and in AHP done for supplier, factory and the logistics firm, the same quality was obtained. In AHP done for the choice of factory and logistics firm jointly, Istanbul factory and self-owned vehicles proved to be the best match. For example; in Table 7, the demand of the first zone for the first period is 600 units and this demand is met from Z_{131}, Z_{223}, and Z_{323} chains. Similarly, the demand of the second zone for the 3rd period is 240 units and this demand is met by Z_{131}, Z_{132} and Z_{312} chains. In this way taking the capacity constraints into consideration it could be said that all the demands are met and suitable solutions are obtained. It is also obvious that the demand of the third zone is met in all the periods with surplus capacity. The reason for this is that the objective of linear programming is to maximize the total point.

5. CONCLUSION

Agricultural product producers are one of the most important parties in agri-food supply chain. Producers sell their products in two ways. They either yield the product by themselves and take it to wholesale markets and sell them via middleman, or directly sell to the retailers such as markets or supermarkets. On the other hand, any level of heat change from harvest period till consumption of fresh fruit and vegetables causes chemical and physical deterioration in their structure. So, because fruit and vegetables are not preserved suitably until they reach the consumer, there is too much loss. In this sense, agri-food supply chain should be shortened by eliminating the activities that do not create added-value. In this sense, activities that do not create added value should be eliminated and the agri-food supply chain should be shortened. In this article, it is aimed to create a short-term supply chain and to provide communication between the producer and the consumer.

As a result, if the methodology described above is applied on a national basis in the existing agri-food supply chain, a pull-based system will be adopted, artificial price fluctuations will be prevented by providing sufficient supply, it will be possible to deliver the products to the consumers in the fastest way with the least loss through cold chain transportation, and in accordance with the standards. Agricultural production in our country will be planned more healthily with the database to be created and distribution will be ensured together with the production of high-quality products.

In future studies, mapping the production and shooting locations of Turkey's agricultural products by taking into account seasonal characteristics, establishing product, packaging and logistics standards, determining the features of the website, determining the location, size and characteristics of the transfer centers, determining the transportation system according to the product, season and packaging criteria, Entry of suppliers with a certain level into the system by creating models for the supplier selection of manufacturers, considering the use of suppliers in the system as a new criterion in the evaluation of producers, determining the methods of removing enterprises from the system, expanding the scope of the supply chain, and the implementation of the digitalization action plan (blockchain, big data) in agriculture. , internet of things etc.) can be suggested.

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Appendix 1: Total Points of Supply Chains

SUPPLY CHAIN	DEMAND ZONE - 1	DEMAND ZONE- 2	DEMAND ZONE- 3
Z_{111}	**0,4762**	0,1191	0,3191
Z_{112}	0,3517	**0,5232**	0,4160
Z_{113}	0,3181	0,5110	**0,5324**
Z_{211}	0,4430	0,0858	0,2858
Z_{212}	0,3057	0,4771	0,3700
Z_{213}	0,2706	0,4635	0,4849
Z_{311}	0,4368	0,0797	0,2797
Z_{312}	0,2972	0,4686	0,3615
Z_{313}	0,2618	0,4547	0,4761
Z_{121}	0,4536	0,0965	0,2965
Z_{122}	0,3204	0,4919	0,3847
Z_{123}	0,2858	0,4787	0,5001
Z_{221}	0,4362	0,0790	0,2790
Z_{222}	0,2962	0,4677	0,3605
Z_{223}	0,2608	0,4537	0,4751
Z_{321}	0,4329	0,0758	0,2758
Z_{322}	0,2917	0,4632	0,3560
Z_{323}	0,2562	0,4491	0,4705
Z_{131}	0,4451	0,0879	0,2879
Z_{132}	0,3086	0,4800	0,3729
Z_{133}	0,2736	0,4664	0,4879
Z_{231}	0,4336	0,0764	0,2764
Z_{232}	0,2926	0,4641	0,3569
Z_{233}	0,2571	0,4500	0,4714
Z_{331}	0,4314	0,0743	0,2743
Z_{332}	0,2897	0,4611	0,3540
Z_{333}	0,2541	0,4470	0,4684

Appendix 2: Linear Programming Model Data

	Period -1	Period -2	Period -3	Period -4
Demand Zone-1	1.084	1.070	708	779
Demand Zone-2	845	804	999	833
Demand Zone-3	841	790	952	616
	2.770	**2.664**	**2.659**	**2.228**
	Period -1	**Period -2**	**Period -3**	**Period -4**
Producer- 1	1.213	1.047	1.253	1.455
Producer- 2	1.368	863	846	1.336
Producer- 3	899	1.099	1.004	1.493
	3. 480	**3.009**	**3.103**	**4.284**
	Period -1	**Period -2**	**Period -3**	**Period -4**
Logistics Firm-1	1.054	844	984	1.232
Logistics Firm-2	1.056	1.031	889	1.018
Logistics Firm-3	832	1.045	847	1.319
	2.942	**2.920**	**2.720**	**3.569**
	Period -1	**Period -2**	**Period -3**	**Period -4**
Supplier-1	956	914	900	1.032
Supplier-2	1.371	1.244	1.088	1.181
Supplier-3	1.264	1.325	1.281	941
	3.591	**3.483**	**3.269**	**3.154**

Appendix 3: Values of Chains Calculated with Distance and Mixed AHP Points According to Zones

Supply Chains	Demand Zone -1	Demand Zone -2	Demand Zone -3
Z_{111}	0,4340	0,0760	0,2760
Z_{112}	0,2950	0,4670	0,3590
Z_{113}	0,2550	0,4480	0,4690
Z_{211}	0,4380	0,0800	0,2800
Z_{212}	0,3030	0,4740	0,3670
Z_{213}	0,2580	0,4510	0,4730
Z_{311}	0,4340	0,0760	0,2760
Z_{312}	0,2950	0,4670	0,3590
Z_{313}	0,2550	0,4480	0,4690
Z_{121}	0,4410	0,0830	0,2830
Z_{122}	0,2900	0,4620	0,3550
Z_{123}	0,2550	0,4480	0,4690
Z_{221}	0,4500	0,0930	0,2930
Z_{222}	0,2940	0,4650	0,3580
Z_{223}	0,2590	0,4520	0,4730
Z_{321}	0,4410	0,0830	0,2830
Z_{322}	0,2900	0,4620	0,3550
Z_{323}	0,2550	0,4480	0,4690
Z_{131}	0,4360	0,0780	0,2780
Z_{132}	0,2880	0,4590	0,3520
Z_{133}	0,2560	0,4490	0,4700
Z_{231}	0,4410	0,0840	0,2840
Z_{232}	0,2890	0,4610	0,3540
Z_{233}	0,2610	0,4540	0,4750
Z_{331}	0,4360	0,0780	0,2780
Z_{332}	0,2880	0,4590	0,3520
Z_{333}	0,2560	0,4490	0,4700

Appendix 4: Capacity of the Chains According to Demand Periods

Supply Chains	Demand Period-1	Demand Period -2	Demand Period -3	Demand Period-4
Z_{111}	956	844	900	1032
Z_{112}	956	914	900	1032
Z_{113}	832	914	847	1032
Z_{211}	1054	844	984	1181
Z_{212}	1056	1031	889	1181
Z_{213}	832	1045	847	1181
Z_{311}	1054	844	984	941
Z_{312}	1056	1031	889	941
Z_{313}	832	1045	984	941
Z_{121}	956	863	846	1032
Z_{122}	956	863	846	1018
Z_{123}	832	863	846	1018
Z_{221}	1054	844	846	1181
Z_{222}	1056	863	846	1018
Z_{223}	832	863	846	1018
Z_{321}	1054	844	846	941
Z_{322}	1056	863	846	941
Z_{323}	832	863	846	941
Z_{131}	899	844	900	1032

Z_{132}	899	914	889	1018
Z_{133}	832	914	847	1032
Z_{231}	899	844	984	1181
Z_{232}	899	1031	889	1081
Z_{233}	832	1045	847	1181
Z_{331}	899	844	984	941
Z_{332}	899	1031	889	941
Z_{333}	832	1045	847	941