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An Agri-Fresh Food Supply Chain Network Design with Routing Optimization: A Case Study of ETKA Company

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ABSTRACT

The Supply Chain Network Design (SCND) with perishability is an active research topic. The Agri-fresh Food Supply Chain (AFSC) is a relevant topic to SCND and this study aims to model a new AFSC for a real-world case study. Regarding the traditional AFSC, the geographically dispersed small farmers transport their product individually to market for selling. This leads to a higher transportation cost, which is the major cause of farmers' low profitability. This paper formulates a traditional product movement model to represent the existing AFSC. The concept of sharing economic approach is employed by the aggregate and collaborative transportation of products to minimize transportation inefficiency. This paper proposes an aggregate product movement with the vehicle routing model to re-design an AFSC for a case study in Iran based on the data of ETKA Company-the largest domestic agri-fresh food supply chain. A four-echelon, multi-period, Mixed Integer Non-Linear Programming (MINLP) approach for the proposed location-inventory-routing model is formulated for perishable products via considering the clustering of farmers to minimize the total distribution cost. According to the comparison analysis, the location-inventory-routing model is effective and leads to a reduction of 33% in total distribution cost compared to the present supply chain.

1 Introduction

Nowadays, the impact of Iran the consumption and production of food is very high in the economical growth of the developing countries [1]. Ensuring the availability of food to all the citizens and enough profitability for the farming community are the main challenges of the Islamic Republic of Iran government as a developing county. Fresh fruits and vegetables are demanded regularly to complete a balanced diet. Today's conscious customers are always trying to get these items at the lowest possible price. On the other side, suppliers of these products (farmers) are not receiving fair prices due to the

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poor design of the supply chain [2]. As reported in [3], in the range of 30-40% of total transaction cost is incurred in the transportation process. The major portion of transportation cost is borne by farmers. Thus, redesigning the supply chain to incorporate a suitable transportation strategy [4-6] is the main challenge in this paper. The supply chain of short shelf life agricultural products is a sequence of processes involved within and between different players (directly or indirectly) from production to consumption, which is defined as an Agri-fresh Food Supply Chain (AFSC) [7]. The performance of a supply chain depends on the interaction between the following drivers: transportation, facilities location, inventory, information, sourcing, and pricing [8]. Transportation moves products from one location to another location and enables farmers (customers) to supply (receive) their products with the assistance of intermediaries. Transportation decisions deal with planning, execution, and optimization of the physical movement of goods. It not only ensures the profitability of stakeholders but also ensures the less wastage of perishable items by fast delivering the items to the customers [9]. The structure of the transportation network plays a vital role in achieving the above objectives [10-11].

Recently, Patidar et al. [4] developed strategies to re-design the AFSC and suggested to design the collaborative transportation model for the collection of products from geographically dispersed small farmers. It is observed that aggregate product shipment can mitigate the effects of small farmers' supply, and it can reduce transportation cost in the chain. In this work, the concept of aggregate transportation of products from small geographically dispersed farmers is implemented in two stages. In the first stage, the products are aggregated at different central locations from nearby farmers using the clustering of farmers, followed by transportation of these aggregated products to the market using vehicle routing in the second stage. These transportation strategies enable the movement of products from Less than Truck Load (LTL) to Full Truck Load (FTL) movement hence, it will reduce transportation cost by sharing economics [2]. The purpose of this work is to re-design the AFSC considering the perishability of products, clustering of farmers, and vehicle routing such that the total distribution cost can be minimized. The rest of this paper is organized as follows: Section 2 presents a literature review on SCND optimization models. Section 3 aims to address the proposed model and problem description. Section 4 provides the computational analyses to solve our case study in ETKA Company. Section 5 summarizes the conclusion and future research directions.

2 Literature Review

The studies on the AFSC can be classified into three survives: (1) low profitability of farmers; (2) high post-harvest losses; (3) small and fragmented land-holdings. Research papers addressing these three shortcomings are presented as follows:

Authors [3, 13, 14, 15, 16]; studied the traditional AFSC and reported that farmers individually transport their products using owned or hired vehicle in LTL to market premises for selling. During the process, farmers arrange, manage, and pay the cost of transportation facilities in the range of 30-40% of the total transaction costs. Farmers observe this as a headache on every trip of the market. Due to this, they compel to sell their products to local intermediary rather than direct selling in the market. Finally, they deprive of getting the higher price of products, and the profit margin goes to intermediaries' pockets. Hence, intermediaries take benefit from this situation. Consequently, customers pay a higher price of products, and farmers get only one-third of the price paid by the customer [17]. Therefore, the traditional AFSC model is incompetent to provide an adequate profit margin to the farmers. For example, the traditional AFSC was modeled recently by Patidar et al., [6]. The second main shortcoming in AFSC is

high post-harvest losses as identified in a set of papers [18-19]; [20]; [9]. According to the papers, 15-25% of fresh products are lost due to improper storage and handling, lack of demand-supply integration, poor transportation in the chain. These losses lead to low profitability of farmers, higher prices of products, deficient nutrition level, and non-productive use of natural resources. Another cause of post-harvest losses is the perishable nature of products, and it is the primary challenge in inhibiting the reduction of food losses in the AFSC [20]. The population growth leads to family expansion, deduction in the availability of resources, and requirement of high infrastructural facilities. The population of Iran has increased from 36 million in the year 1970-71 to 75 million in the year 2010-11. Consequently, the average size of farming land-holdings per family has been reduced by half from 2.28 hectares in 1970-71 to 1.16 hectares in 2010-11. The farming in small landholdings with limited resources incurs high production and distribution costs of products. Also, the small farmers are living in geographically scattered villages. The villages are situated far away from markets (highly populated areas; demand zone) where they have to bring their products by traveling a long distance in LTL for selling [14].

As concluded in the literature review on supply chain modeling that the involvement of small and dispersed suppliers/farmers into location-inventory-routing formulation is ignored. Further, a review paper on food supply chain models [21] reported that aggregate product collection is neglected in existing researches. Moreover, if we look from the application point of view, aggregate product collection has the potential to mitigate the identified shortcomings of the AFSC. The aggregate product collection from small and fragmented farmers can reduce total transportation costs, which in turn would enhance the farmers' profitability. Therefore, it is worthwhile to develop a model for aggregation of products from small farmers and its shipment to the market. For the aggregation of products, the clustering of geographically dispersed small farmers would identify cluster centers where the products can be aggregated. Vehicle routing determines optimal paths for collaborative transportation to transport the aggregated products from these cluster centers to market. The literature indicates that the clustering of farmers and vehicle routing for the collection of agri-fresh products has not been addressed in existing supply chain models. Therefore, the main aim of this paper is to propose a novel location-inventory-routing model for aggregation, collection, and distribution of perishable products from farmers to customers through the market.

3 Model Description and Formulation

This part formulates the proposed AFSC in our case study supported by ETKA company in Iran. In this chain, the farmer grows crops and individually transports his/her products to the agricultural market for selling. During the auctioning, the wholesaler purchases these products by bidding the highest price. The wholesaler sorts and sells these items to a retailer in small amounts. Further, the retailer transports and peddles these products to customer's proximity locations [22, 3, 4]. In the literature, the researchers have given less attention to the modeling of traditional AFSC. Therefore, we develop a mathematical model for traditional AFSC, followed by proposing models for aggregate product transportation to minimize transportation inefficiency. Further, the authors perform an extensive comparison between traditional and proposed models using a case study problem to get justified results. The following product movement models are developed to transport products from farmers to market:

- Traditional Product Movement (TPM) model (M1) [6]: This is a traditional way of product shipment for distribution among markets in ETKA company. The model is available in Electronic Supplementary Materials F1.

- **Aggregate Product Movement (APM) model (M2):** In this model, the first products are aggregated at different central locations from the nearby farmers. Then these aggregated products are shipped directly to the market.
- **Aggregate Product Movement with Vehicle Routing (APMVR) model (M3):** This is an extension of model M2, where the aggregated products are picked up from the cluster centers to market using vehicle routing.

When we consider APM instead of the TPM model for the AFSC, it supports sharing economic nature since products of nearby farmers are aggregated at central locations, and the movement of these aggregated products to market will result in the transport economy. Further, extending the APM model by inclusion of vehicle routing to pick up the aggregate products from different central locations to market. It will result in added transport economy due to sharing of transportation resources. The APMVR model not only suggests a novel transportation strategy, but it is also a model of a new way of doing agri-business. In real life, this model can be easily implemented with the help of suitable information sharing applications to integrate and collaborate supply chain partners. The APMVR model is well applicable, where farmers have small quantities to supply from geographically dispersed locations to a market. The description and mathematical formulation of each of these three models are explained in the following sections.

3.1 Aggregate Product Movement Model

In this model, we incorporate the idea of aggregation of products by identifying groups of farmers called Farmers' Cluster (FC) based on the location of neighborhood farmers. Farmers belonging to an FC bring their products to the central location that cluster named Farmers' Cluster Center (FCC). The central location within an FC is considered as any location of a farmer in the group. In this way, multiple FCs and the respective FCCs can be identified. The aggregated products at these FCCs can now be shipped efficiently to the hub. This helps in hassle-free products' movement, and it may reduce transportation cost in the delivery of fresh items. It is assumed that FCCs do not store any items and are used to manage the transshipment of products in the network to satisfy customer demand economically.

In traditional AFSC, an agent auctions and matches demand and supply for a market and play his monopoly in the pricing of products [23]. The role of this agent can be replaced with modern technology-enabled 'FCC' in the proposed supply chain to make reliable, applicable, and sustainable supply chain for the real scenario of the proposed AFSC. The modern technology includes the use of Image Processing to check quality of product, Radio-Frequency Identification (RFID) tag to recognize and track the products and Information and Communication Technologies (ICT) to share information between the partners etc. which make system dynamic and expert for changing scenario [24, 25, 4, 5, 6, 26, 27]. New assumptions in comparison with [24, 25, 4, 5, 6] are:

Assumptions:

- Each farmer can be assigned to only one FCC in each time period. Hence, the farmers cannot split their supply into multiple FCCs.
- The lower bound on FCC capacity is considered to ensure a minimum quantity of products at each FCCs.

As such, notations of the model including indices, parameters and variables are:

Index:

i index of FCCs, $i \in I \in F$

Parameters:

- Dl_{fi} distance from farmer f to FCC i (km)
 Dl_m maximum distance to be traveled by a farmer to reach any FCC (km)
 $D2_{ij}$ distance from FCC i to hub j (km)
 TC_1 unit transportation cost from a farmer to an FCC (INR/km/kg)
 TC_2 unit transportation cost from an FCC to a hub (INR/km/kg)
 LB_{ip} lower bound on the capacity of FCC i for product type p (kg)
 FCI_i the fixed cost of forming FCC i (INR)

Decision variables:

- F_i^t $\begin{cases} 1 & \text{if FCC } i \text{ is formed in period } t; \\ 0 & \text{otherwise.} \end{cases}$
 G_{fi}^t $\begin{cases} 1 & \text{if farmer } f \text{ is assigned to FCC } i \text{ in period } t; \\ 0 & \text{otherwise.} \end{cases}$
 S_{ip}^t aggregate supply availability of FCC i of product type p in period t (kg).
 Q_{ijp}^t the quantity of product type p is received by hub j from FCC i in period t (kg).

The proposed supply chain of APM is extension of TPM model and is formulated as follows:

Minimize TDC = C1 + C3 + C4 + C5 + C6 + C7 + C2' (Z2)

The costs C1, C3, C4, and C5 are the same as defined in the TPM model.

$$C1 = \sum_{t=1}^T \sum_{j=1}^J FC2_j H_j^t \quad (a)$$

$$C2 = \sum_{t=1}^T \sum_{f=1}^F \sum_{j=1}^J \sum_{p=1}^P D2_{fj} TC_2 Q_{fjp}^t \quad (b)$$

$$C3 = \sum_{t=1}^T \sum_{j=1}^J \sum_{k=1}^K \sum_{p=1}^P \sum_{\tau \geq t}^T D4_{jk} TC_4 Q_{jkp}^{\tau} \quad (c)$$

$$C4 = \sum_{t=1}^T \sum_{k=1}^K \sum_{p=1}^P HC_{kp} I_{kp}^t \quad (d)$$

$$C5 = \sum_{t=1}^T \sum_{k=1}^K \sum_{p=1}^P DC_{kp} Ex_{kp}^t \quad (e)$$

$$C6 = \sum_{t=1}^T \sum_{i=1}^I FCI_i F_i^t \quad (f)$$

$$C7 = \sum_{t=1}^T \sum_{i=1}^I \sum_{f=1}^F \sum_{p=1}^P Dl_{fi} TC_1 H_{fp}^t G_{fi}^t \quad (g)$$

$$C2' = C2' = \sum_{t=1}^T \sum_{i=1}^I \sum_{j=1}^J \sum_{p=1}^P D2_{ij} TC_2' Q_{ijp}^t \quad (b')$$

Subject to:

Constraints (1) to (9) from the TPM model as can be studied in Patidar et al., [6] and can be referred to the Electronic Supplementary Materials F1.

$$\sum_{i=1}^I G_{fi}^t = 1, \forall f, \forall t \tag{10}$$

$$G_{fi}^t \leq F_i^t, \forall f, \forall t, \forall i \tag{11}$$

$$\sum_{f=1}^F H_{fp}^t G_{fi}^t = S_{ip}^t, \forall i, \forall p, \forall t \tag{12}$$

$$\sum_{j=1}^J Q_{ijp}^t = S_{ip}^t, \forall i, \forall p, \forall t \tag{13}$$

$$\sum_{j=1}^J Q_{ijp}^t \geq LB_{ip} F_i^t, \forall i, \forall p, \forall t \tag{14}$$

$$\sum_{i=1}^I Q_{ijp}^t \leq M \times H_j^t, \forall j, \forall p, \forall t \tag{15}$$

$$\sum_{k=1}^K \sum_{\tau \geq t} Q_{jkp}^{t\tau} = \sum_{i=1}^I Q_{ijp}^t, \forall j, \forall p, \forall t \tag{16}$$

$$F_i^t, G_{fi}^t = \{0, 1\} \tag{17}$$

The objective (Z2) of the APM model minimizes the TDC. Eq. (f) presents the fixed cost of forming FCCs. Eqs. (g), and (b') describe the transportation cost from farmers to FCCs and FCCs to hubs, respectively. The below constraints of the APM model are developed to present various conditions for each period. Constraints (10) and (11) identify the associated farmers of any FC based on the maximum distance to be traveled by a farmer and the respective FCC for the aggregation of products. The quantities of aggregate products at FCCs are calculated by constraint (12). Constraint (13) ensures that each product type shipped from each FCC to the hubs is equal to its availability. Constraint (14) ensures the lower bound on FCC capacity for each type of product. Constraint (15) ensures the shipment of each product type from FCCs to the opened hubs only. The product flow conservation at each hub is governed by constraint (16). Constraint (17) ensures the binary integer variables for the formation of FCC and the assignment of a farmer to the FCC.

3.2 Aggregate Product Movement with Vehicle Routing Model

APMVR model is an extension of the APM model, instead of direct transportation from each FCC to a hub, the aggregated products from multiple FCCs are picked up by a vehicle. The vehicle departs from a hub, pick up aggregated products by visiting multiple FCCs and end the route by reaching to the same hub. This will reduce transportation cost from FCCs to a hub. In this section, we incorporate vehicle routing constraints into the APM model to pick up the aggregate products from FCCs to the hub.

The proposed model simultaneously optimizes the decisions related to location-allocation of FCCs and hubs, quantities of product movement and storage, as well as vehicle routing to match demand-supply of the chain. The aggregation of small farmers' supplies at FCCs and the use of vehicle routing to pick up the aggregate products by visiting multiple FCCs will mitigate transportation inefficiency. The model combines the strategic and tactical-operational decision making in a single formulation, which

reports the optimized decisions and costs of the supply chain due to their interdependency. This section formulates a multi-period, four-echelon perishable supply chain model with considering multiple vehicles of single-mode transportation. For our final model as APMVR, new assumptions in comparison with the previous model are:

Assumptions:

- An FCC supplies all the products to a single hub. However, a CZ can receive a split supply from any hub.
- The vehicles are assumed unlimited capacity.

As such, the indices, parameters and variables of the developed APMVR are:

Indices:

m, n Index of nodes, $m, n \in N \in (I \cup J)$

v Index of vehicles, $v \in V$

Parameters:

- D_{mn} distance from node m to node n (km)
- TC_2^n unit transportation cost from an FCC to a hub via vehicle routing (INR/km/kg).
- TC_3 unit cost of vehicle running for product collection from one node to another node (INR/km).
- FC_v fixed cost for using vehicle v (INR).

Decision variables:

$$Z_{ij}^t = \begin{cases} 1 & \text{if products are received by hub } j \\ & \text{from an FCC } i \text{ in period } t; \\ 0 & \text{otherwise.} \end{cases}$$

$$Y_{mv}^t = \begin{cases} 1 & \text{if vehicle } v \text{ is visited node} \\ & m \text{ in period } t; \\ 0 & \text{otherwise.} \end{cases}$$

$$X_{mnv}^t = \begin{cases} 1 & \text{if vehicle } v \text{ is moved from node } m \text{ to} \\ & \text{node } n \text{ to collect products in period } t; \\ 0 & \text{otherwise.} \end{cases}$$

U_{iv}^t auxiliary variable to give an ordering to all FCCs to prevent the formation of subtours

The proposed supply chain of APMVR is formulated as follows:

$$\text{Minimize TDC} = C1 + C3 + C4 + C5 + C6 + C7 + C2'' + C8 + C9 \tag{Z3}$$

Costs C1, C3, C4, C5, and C6, C7, are the same as defined in TPM and APM model, respectively.

$$C2'' = \sum_{t=1}^T \sum_{i=1}^I \sum_{j=1}^J \sum_{p=1}^P D_{ij} TC_2^n Q_{ijp}^t \tag{b''}$$

$$C8 = \sum_{t=1}^T \sum_{v=1}^V \sum_{j=1}^J FC_v Y_{jv}^t \tag{h}$$

$$C9 = \sum_{t=1}^T \sum_{v=1}^V \sum_{m=1}^N \sum_{n=1}^N D3_{mn} TC_3 X_{mnv}^t \tag{i}$$

Subject to:

Constraints (4) to (9) from the TPM model as given in Electronic Supplementary Materials F1 and constraints (10) to (17) from the APM model given in Section 3.1.

$$\sum_{p=1}^P Q_{ijp}^t \leq M \times Z_{ij}^t, \forall i, \forall j, \forall t \tag{18}$$

$$\sum_{j=1}^J Z_{ij}^t = F_i^t, \forall i, \forall t \tag{19}$$

$$\sum_{v=1}^V Y_{iv}^t = \sum_{j=1}^J Z_{ij}^t, \forall i, \forall t \tag{20}$$

$$\sum_{v=1}^V Y_{jv}^t \geq H_j^t, \forall j, \forall t \tag{21}$$

$$Y_{jv}^t \leq H_j^t, \forall j, \forall v, \forall t \tag{22}$$

$$\sum_{j=1}^J Y_{jv}^t \leq 1, \forall v, \forall t \tag{23}$$

$$Y_{iv}^t - Y_{jv}^t \leq 1 - Z_{ij}^t, \forall i, \forall j, \forall v, \forall t \tag{24}$$

$$\sum_{m=1}^N X_{mnv}^t = Y_{nv}^t, \forall n, \forall v, \forall t \tag{25}$$

$$\sum_{n=1}^N X_{mnv}^t = Y_{mv}^t, \forall m, \forall v, \forall t \tag{26}$$

$$U_{iv}^t - U_{i'v}^t + N \times X_{ii'v}^t \leq N - 1, \forall i, \forall i' (i, i' \in I, i \neq i'), \forall v, \forall t \tag{27}$$

$$Z_{ij}^t, X_{mnv}^t, Y_{mv}^t = \{0, 1\} \tag{28}$$

The objective (Z3) of the APMVR model minimizes the TDC. Eq. (b'') explains the transportation cost from FCCs to hubs. Eq. (h) presents the fixed cost of vehicles. Eq. (i) describes the cost of running vehicles in the collection of products by visiting multiple FCCs. The following constraints are formulated to represent various conditions for each period. Constraint (18) determines the assignments between FCCs and hubs for product movement. Constraint (19) restricts the split supply from any FCC to hubs. Constraint (20) ensures the assignment of a vehicle to FCC if there is a product movement from an FCC to a hub. Constraint (21) assigns at least a single vehicle to the opened hub only. assignment of a vehicle to the opened hub only is warranted by constraint (22). Constraint (23) restricts the multiple assignments of a vehicle to the hubs. Constraint (24) ensures that a vehicle is assigned to the subset of a set of FCCs that are assigned to a hub. Constraints (25) and (26) ensure that the assigned vehicle to a node arrives and departs that node. Constraint (27) prevents the formation of the subtours in the vehicle routing solution. The binary integer variables used in vehicle routing are ensured by constraint (28).

4 Computational Results

Here, we first explain the proposed case study in ETKA Company. Then, some sensitivity is analyzed to evaluate the presented models in this study. It should be noted that the developed model is nonlinear due to the assumptions of the main problem and the real case study and the algorithms are coded in GAMS software using DICOPT solution.

4.1 Case Study

To show the applicability of the proposed APMVR, a case study in Tehran from ETKA company, is provided. In our case study for Tehran, we considered 22 villages and each village as a farmer unit and its location as a farmer's location. Tehran city was considered as demand area, which consists of several wards, and each ward was assumed as a CZ. We considered three potential locations of hubs in the city. Since there is a cost involved in opening each hub, the optimal location of hubs in each period will be decided based on the number of hubs to be opened as given in the constraint (8).

The fixed cost of the vehicles for the transportation is around 1000 \$. The rate of transportation is between 3 to 8 per unit of distance. The FCC capacity for each product is about 1,000 Kg. Table 1 presents the sizes of nine problems categorised in two groups of large and small sizes in terms of the number of FCCs, the number of demand zones, and the number of vehicles. Then, these problems will be utilized for demonstrating the complexity of the problem at hand and the way the solution algorithms handle them.

Table 1: The Sizes of the Problems

Complexity level	Test problem	Number of FCCs	Number of hubs	Number of vehicles	Number of demand zones
Small	P1	10	2	4	20
	P2	12	2	6	30
	P3	14	2	8	40
	P4	18	3	10	50
	P5	20	3	12	60
	P6	22	3	12	60
Large	P7	24	5	12	80
	P8	36	7	16	100
	P9	50	10	20	110

4.2 Sensitivity Analysis

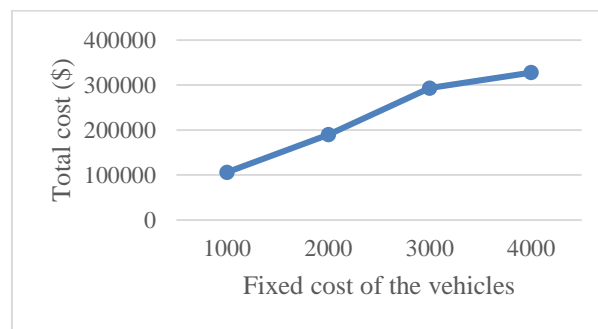
Here, we firstly compare the optimal solutions for the models in 2 group of complexity level considering changes in the number of hubs, FCCs and vehicles and next, to show the impact of the parameters on the total cost, some sensitivity analyses are done. Our case study in Iran is selected and for our case study, the optimal solution from model M1, M2 and M3, is compared as given in Table 1.

The gaps between the solution of M3 and other models are also noted in this table. These results show that although the proposed model has a higher total cost in comparison with other models, it covers all the tactical and operational decisions from inventory and routing decisions for the AFSC network design problem

Table 2: Comparison of the Models

Total cost of M1 model	Total cost of M2 model	Total cost of M3 model	Gap between M1 and M3	Gap between M2 and M3
89731.3559	79611.278	105883	33%	18%

We also analyze the impact of the fixed cost of the vehicles. This factor is only for M3 model and it is relative important for the real-world decision-making. Fig 1 shows the changes of this parameter from 1000 to 4000 \$. The results show a significant increase in the value of the total cost in our model.

**Fig. 1:** Sensitivity Analysis on the Fixed Cost of the Vehicles

5 Conclusion and Future Research

In this paper, an extension to the traditional Agri-fresh Food Supply Chain (AFSC) geographically dispersed small farmers transport their product individually to market for selling was proposed. The main demerits of the traditional AFSC is a higher transportation cost, which is the major cause of farmers' low profitability. In this regard, the concept of sharing economic approach was employed by the aggregate and collaborative transportation of products to minimize transportation inefficiency. This paper proposed an aggregate product movement with the vehicle routing model to re-design an AFSC for a case study in Iran based on the data of ETKA Company. A four-echelon and multi-period MINLP approach for the proposed location-inventory-routing model was developed. The purpose of this work was to re-design the AFSC considering the perishability of products, clustering of farmers, and vehicle routing such that the total distribution cost can be minimized.

The results confirm the high efficiency of the proposed math-heuristic and the performance of the developed location-inventory-routing AFSC in practice. Although the proposed AFSC was much complex than majority of the traditional AFSC frameworks, it is still so general and many new suppositions can be added. First of all, an introduction to the sustainable AFSC with the goals of environmental protections and consumers' satisfaction in addition to the total cost, is an interesting addition. The quality of agri-fresh food delivered to customers and customer demand uncertainty can also be considered in modeling. The use of an approximated method like metaheuristic is very important recommendation for further research [27-29]. At last but not least, more sensitivity analyses and the extra large-scale test studies can be evaluated for the continuation of this work.

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