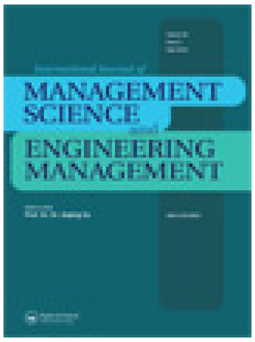

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Multi objective Fuzzy programming of remanufactured green perishable products using supply contracts

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ABSTRACT

In the recent times, remanufacturing and recycling processes have been widespread because of hard environmental legislations. The significance of green factors such as uncertainty of return rates in supply networks has been extensively acknowledged in presented studies. A revenue sharing contract improves the performance of green supply chain and has a significant role in the profitability of total supply chain. There are few quantitative studies on revenue sharing contract in green supply chains. In this study, we propose coordination subject matters of a green supply chain with recycling perishable goods, involving suppliers, manufacturers, retailers, together with collection and disposal centers, in a multi-product, multi-period and multi-level basis under Fuzzy conditions.

The consequences indicate that in dairy industries, appropriate collected returned products could be used as raw material for another product, which increases the supply chain profits and reduces waste; and also, since perishable goods have a limited shelf life, they can be reusable if they are collected before reaching to a critical time. Furthermore, the proposed revenue sharing contract can share benefits between supply network members and gain coordination of channel.

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Green supply chain; perishable goods industries; revenue sharing contract; remanufacturing; Fuzzy mathematical programming

1. Introduction

In the last few decades, remanufacturing and recycling processes have received significant consideration by supply chain managers because of hard environmental legislations to observe forward and reverse flow as a unified system which is named a closed loop supply chain (CLCS) (Guide & Van Wassenhove, 2009). In fact, designing a green closed loop network is considered as one of the most serious fields of studying the CLSCs (Yi, Huang, Guo, & Shi, 2016), which has been reduced waste and cost. In the recent era, the implication of green supply chain (GSC) management has become a crucial point all over the world and the matter of remanufacturing of returned products has paid more attention of many managers in CLSC (Giri, Mondal, & Maiti., 2018).

In perishable supply chain, retailers notice both price and freshness of products, also price decisions and freshness level play an important role in strategies of marketing, and they impress competitiveness of the market of the perishable supply chains and the various brands in it (Ren & Zhou, 2008). In perishable foods industries, consumers focus on freshness level more than price, therefore, increasing the freshness level will increase the retailer's satisfaction level and ultimately increase the demand of the retailers.

In the recent years, contracting in SC is identified as one of the crucial motivations of progression in performance of supply chain (Hou, Wei, Li, Huang, & Ashley, 2017). Fisher, Raman, and McClelland (1994) investigated a research on food industry of the US, which acknowledges need of contracting tools to prevent loss of 30 billion dollars every year between supply chain (SC) members. This study uses the RSC between members of green perishable foods supply chain to study whether RSC could make progress the perishable supply chain or coordinate the network's members. The recent literatures have focused on investigating the influence of RSC on GSCs.

In the last years, several types of uncertain cases represented that the universe is progressively unpredictable (Fahimnia, Jabbarzadeh, Ghavamifar, & Bell, 2017). Furthermore, it appears that SCs are more acute because of the multiplicity of industries (Ghomi-Avili, Naeini, Tavakkoli-Moghaddam, & Jabbarzadeh, 2018). Unpredictability in quantity and quality of product returned rates are known as one of the major central point of the management of CLSC (Vahdani, 2015). Various uncertain optimization procedures are done to attend unpredictability in GSC problems, like Fuzzy (Vahdani, Jolai, Tavakkoli-Moghaddam, & Mousavi, 2012), stochastic (Kerachian & Karamouz, 2007) and interval (Zhang, Huang, & He, 2011) method. Fuzzy programming has been extensively applied to find solutions of the problems for GSC, and CLSC networks (Tsao, Thanh, Lu, & Yu, 2018). Nevertheless, to our knowledge, no previous investigation has used Fuzzy multi-objective mixed integer linear programming (FMOMILP) in the topic of perishable SC, which perishable goods can be reusable as a raw material of another product, if they are collected before reaching a critical time.

Based on the mentioned regards, this study applied a FMOMILP method for modelling a GSC network. The problem has three objective functions: retailer's dissatisfaction minimization, manufacturer's profit maximization, and retailer's profit maximization, also the Fuzzy product return rate and reusable product return rate are considered to cope with uncertainties.

This study intends to response the following questions of research: (1) what is the role of timely collection of returned products in perishable supply chain with limited useful life? (2) How does the reuse of recycled product as a raw material

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in manufacturing another product affect the supply chain costs? (3) What is the result of contracting for sending perishable products on delivery time and retailers satisfaction level? (4) What is the performance of applicability and productiveness of the Fuzzy programming method for the presented model?

We presented a multi-period, multi-product, and multi-level closed loop SC in order to answer the questions, in which forward network contains three echelons: suppliers, manufacturers, and retailers, the reverse supply chain includes two collection and disposal centers. In this study, several third-party logistic companies conduct the task of transporting products to retailers, which the manufacturer contracts with one of the logistic companies in each period. Each logistics organization uses a type of vehicle with a level of equipment, so that, the level of equipment makes a different price and level of quality. The retailer's demand is dependent on the price and the level of product's quality. In the proposed model, returned products could be used as raw materials to produce another product. According to this issue, a part of returned products took from collection centers and also raw materials, which were given from suppliers, can be applied for the production process. As perishable goods have a limited useful life, it is practicable to reuse a part of returned products whose useful life is closely to end. Therefore, the reusable returned products are sent to collection and recycling centers, otherwise, they are sent to disposal centers. The model of this study has considered the rate of returned products and the rate of reusing returned products as Fuzzy numbers.

The major contributions of this research can be summarized as follows:

(1) Collecting perishable returned products in a timely manner and reusing them as a raw material for producing another product, reduces wastes and supply chain costs.
(2) Considering the quality of returned products for recycling and reusing them affect SC member's interest and decisions which cause a substantial benefit for the whole network.
(3) Contracting, in the offered RS mechanism, to send products in critical lifetime industries retailer's satisfaction level has been increased and lead to be executable efficiently.

The rest of the study is formed as follows: In the next section, the relevant literatures are investigated. Section 3 deals with the model notation and assumptions. Model formulation with fuzziness in the returned rate parameters and analysis applied in this article has been defined in section 4. Section 5 indicates numerical outcomes and some critical parameters of sensitivity analyses. Section 6 involves some implication for managers. Section 7 explains about conclusions and future study guidance.

2. Related literature

In this part, we revise the relevant literature across three fields: remanufacturing in CLSC, mechanisms of channel coordination for GSC, and design problem of Fuzzy SC network. Finally, importance of reviewing this study has been outlined in the section of study gap.

2.1. CLSC remanufacturing

Remanufacturing is one of the environmental and economic visions which is concentrated over the past years in CLSC (Taleizadeh, Haghighi, & Niaki, 2019). While the consumers are increased and the life-cycle of the products gets constricted, the capacity and kinds of returned product will return to expand, making manufacturers to include reverse logistics in their SC networks (Ali, Paksoy, Torğul, & Kaur, 2020). The quality, timing, and quantity of returned products also have an effect on the expenses and required capacities of reverse logistics processes (Mitra, 2012).

The returned perishable goods quality has been considered in the mathematical model which returned products can be recycled and use as a raw material of another product; and this factor is one of the evaluative capabilities of this study.

2.2. GSC coordination mechanisms

As legislations of environmental requirements get expanded, researches are attending more consideration to the GSC. The GSC management is one of the significant approaches to get the environmental implementation better, and the improvement of GSC depends on the comprehension of GSC coordination (Falatoonitoosi, Leman, & Sorooshian, 2013). GSC contracting is obviously a crucial and significant matter in recent SC management (Shen, Choi, & Minner, 2019). Different supply contracts have been widely considered to increase profit of GSC networks (Corbett, Zhou, & Tang, 2004). Each manager uses a particular contract based on SC orientation, performance and integration (Sluis & De Giovanni, 2016).

As a significant SC contract, the revenue-sharing contract (RSC) can be noted in many literatures which denominate to find a solution for the SC coordination models (Xu & Wang, 2018). Cui, Guo, and Zhang (2020) discussed coordination subjects of the two-echelon green perishable SC, and the impact of RSC on major decisions of SC members. They presented that RSC is a preferable contract which improves the level of greenness, and shares the profits obtained between the manufacturer and the retailer.

It could be perceived from the reviewed papers that modeling an efficient method is a significant matter to comprehend GSC contracting all the time. Therefore, this study considers this literature gap, and expands optimum solution methodology for a GSC using RS.

2.3. Fuzzy SC network design problem

A serious matter of GSC is to study the model of mixed integer programing (MIP) in the field of CLSC to optimize network implementation (Prajapati, Kant, & Shankar, 2019). In the last optimization of studying on network of CLSC, the model of MIP with multi-objective goals has been substantially expanded (Shi, Liu, Tang, & Xiong, 2017).

A Fuzzy number is applied to propose imperfect, indefinite details. The linear programming parameters could also be Fuzzy numbers for the reason that they rely on many characteristics. (Pramanik, Mondal, & Haldar, 2020).

Various techniques have been improved to handle Fuzzy models including the uncertainty of the parameters and factors in the constraints and objective functions (Luhandjula & Joubert, 2010). A general method to alter the Fuzzy LP into the standard definitive LP is the approach of the Fuzzy numbers ranking. However, there is a wide literature on Fuzzy numbers ranking in triangular integer subject (Singh & Yadav, 2016; Van Hop, 2007) with various suggestion degrees, we select to apply the model of Jimenez, Arenas, Bilbao, and Victoria Rodríguez (2007).

An evaluation of the literature on the CLSC network design displays two diversities among the literature and current paper. First, current paper studies a FMOMILP model for a network of CLSC to optimize quality level and profits. Multiple products, different kinds of facilities, forward/reverse logistics aspects, and the indefiniteness of product return rates are attained in the model of MIP. Second, an efficient solving approach is proposed for the MIP model; various novel research detections and managerial suggestions are deduced by considerable investigations.

2.4. Analyzing the gap

Despite of the essential issue of uncertain return rate of reusing the returned product as a raw material of another product, many investigators pay no attention to its efficacy on the interest of SCs which is a wide imperfection of contemporary scholar works in the subject of supply chain profits. This study proposes a novel mathematical model in order to fill this gap. Also, a revenue sharing contract has been developed for aligning the profit of members of SC.

Table 1 is prepared to clarify this study contribution and to highlight the gap of study further.

3. Problem description

As it was previously mentioned in Introduction, this study considers a multi-period, multi-product, and multi-level closed loop SC, in which forward network contains three echelons: suppliers, manufacturers, and retailers, the reverse supply chain includes two: collection and disposal centers. Figure 1 shows the present supply chain model proposed in this study.

3.1. Model assumptions

Assumptions of the model, according to the definition of the problem, are as follows:

- The suggested CLSC has two networks that forward network includes three echelons: retailers, manufacturers, and suppliers and reverse network contains two echelons: collection and recycling centers with disposal centers.
- In each period, various perishable goods with fixed useful life are produced.
- Retailers demand in each period depends on the price and the quality level of products; and the lack of demand is not allowed.
- Collecting cost involves the cost of products inspection at the collection and recycling centers.
- Transportation vehicles with different equipment level and limited capacity are used for the transportation of products.
- Transportation companies transport the product between manufacturers, retailers, and collection/recycling centers.
- Transportation between suppliers and manufacturers and also between collection/recycling centers and disposal centers are conducted with self-origin vehicles.
- Reusable returned products are sent to production processes otherwise they are dispelled.

3.2. Model notation

The following notation was used for the mathematical formulation of the model.

3.2.1. Indices

p Index of products $p = 1, \dots, P$

m Index of manufacturers $m = 1, \dots, M$

i Index of raw materials $i = 1, \dots, I$

s Index of disposal centers $s = 1, \dots, S$

c Index of suppliers $c = 1, \dots, C$

d Index of retailers $d = 1, \dots, D$

r Index of collection and recycling centers $r = 1, \dots, R$

k Index of vehicles $k = 1, \dots, K$

v Index of transportation company $v = 1, \dots, V$

t Index of periods $t = 1, \dots, T$

3.2.2. Parameters

ER^t_{pd} Expected quality level of Product p ordered by Retailer d in Period t

cp^t_{pd} Unit sales price of Product p in Period t that is sold by the Retail d

scm^{tv}_{pmd} Unit transportation cost of Product p in Period t that is transported by Transportation company v from Manufacturer m to Retailer d

D^t_{pd} The demand of Retailer d in Period t for Product p

SR_m The warehousing capacity of Raw materials in Manufacturer m

fc^t_{pm} Unit production cost of Product p in Period t that is produced by Manufacturer m

scc^{tv}_{pdr} Unit transportation cost of returned Product p in Period t that is transported by Transportation company v from Retailer d to Collection and Recycling centers r

CDF_k The capacity of unusable returned products that is transported by Vehicle k from collection and recycling centers to disposal centers

dc^t_{icm} Unit purchasing cost of Raw material i in Period t that is purchased from Supplier c by Manufacturer m

mcp^t_{pd} Unit holding cost of Product p in Period t by Retailer d

mcr^t_{im} Unit holding cost of Raw material i in Period t at the Manufacturer m

vp^t_{pm} Unit wholesale price of Product p in period t that is sold by Manufacturer m

ssp^t_{pdr} Unit collecting cost of returned Product p in Period t from Retailer d to Collection and Recycling centers r

vcd^{tk}_{prs} Unit transportation cost of returned Product p in Period t that is transported by Vehicle k from Collection and Recycling centers r to Disposal center s

Table 1. A consideration between previous papers and the current paper.

	Objective function			Model feature			Costs								Competition's factor		Uncertainty					
Reference	Min (cost)	Max (profit)	Others	Multi-period	Multi-product	Multi-level	Purchase and supply	Production	Holding inventory	Transportation	Recycling	Collection and inspection	Disposal	Green issues	Quality level	Price	Demand	Returned products rate	Reusing of returned products rate	Others	Coordination contracts	Perishable goods
Luo, Lian, and Lee (2017)		●																				
Hu and Feng (2017)		●				●	●								●		●			●	●	●
Ghomi-Avili et al. (2018)	●	●	●	●			●	●	●	●	●	●	●	●	●	●	●					
Farrokh, Azar, Jandaghi, and Ahmadi (2018)	●				●		●	●	●	●	●	●	●				●			●		
Rafie-Majd, Pasandideh, and Naderi (2018)	●			●	●	●	●	●	●								●					●
Taleizadeh, Alizadeh-Basban, and Niaki (2019)		●				●		●		●	●	●		●	●	●	●					
Sahebia, Masoomib, Ghorbanic, and Uslu (2019)	●			●	●	●		●	●	●	●	●	●	●	●			●				
Long, Xu, and Li (2019)		●				●	●	●			●			●			●				●	●
Shamsi, Mahdavi, and Paydar (2019)		●		●	●	●	●	●						●			●			●		
Jalil, Hashmi, Asim, and Javaid (2019)	●		●			●	●	●		●	●	●	●	●								
Isaloo and Paydar (2020)	●		●		●	●	●	●		●				●		●	●					
Current paper		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●		●	●

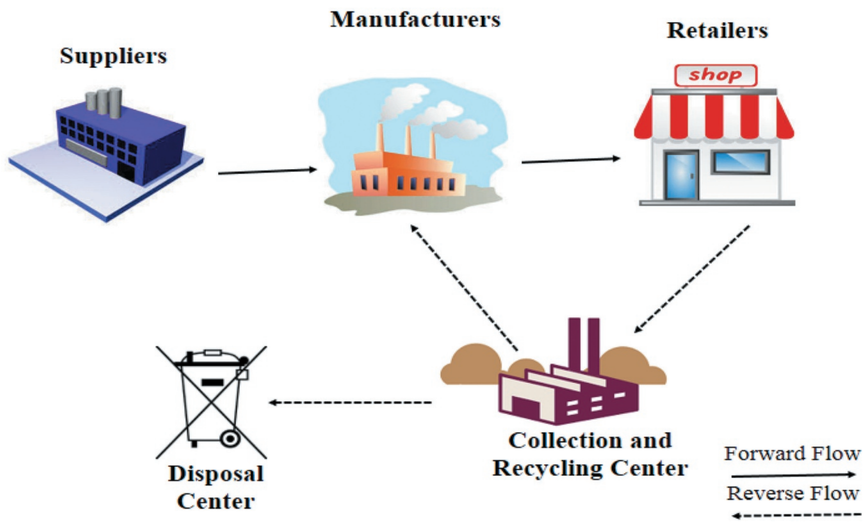


Figure 1. A schematic view of the proposed supply chain.

vcs^{tk}_{icm} Unit transportation cost of Raw material i in Period t that is transported by Vehicle k from Supplier c to Manufacturer m

bcp^{t}_{ps} Unit disposing cost of returned Product p in Period t at the Disposal center s

ac^{tv}_{pmd} Unit contracting cost of Manufacturer m in Period t with Transportation company v for transporting Product p to Retailer d

CKF_v The capacity of transporting reusable returned products from collection and recycling centers to manufacturers by Transportation company v

sck^{tv}_{prm} Unit transportation cost of returned Product p in Period t that is transported by Transportation company v from Collection and Recycling centers r to Manufacturer m

CCF_v The capacity of transporting returned products from retailers to collection and recycling centers by Transportation company v

SQ_m The capacity of Manufacturer m for production process

CSF_k The capacity of transporting raw materials from suppliers to manufacturers by Vehicle k

SK_r The capacity of Collection and Recycling centers r for collection process

CMF_v The capacity of transporting products from manufacturers to retailers by Transportation company v

Z_{ip} If returned Product p is reusable as Raw material i, it is equal to 1. Otherwise it is 0

α_p The ratio of Product p transferred to collection and recycling centers as return product ($\alpha_p = \nu_p + \mu_p$)

μ_p The ratio of Product p returned to collection and recycling centers at each order quantity

ν_p The ratio of inventory of the Product p remaining from the previous period

ϑ_{ip} The required amount of Raw material i for producing one unit of Product p

β_{pm} The ratio of reusable returned Product p, which is sent to Manufacturer m

γ^{t}_{pdv} The quality level of Product p transported to Retailer d using Transportation company v in Period t

3.2.3. Variables

Y_{mdv} If Manufacturer m contract with Transportation company v for transporting products to retailer d, it is equal 1. Otherwise it is 0.

Qp^{t}_{pd} Quantity of Product p in Period t that is ordered by Retailer d

IL^{t}_{pd} Inventory level of Product p in Period t at the Retailer d

qcr^{tk}_{icm} Quantity of Raw material i in Period t Vehicle k from Supplier c to Manufacturer m

Im^{t}_{im} Inventory level of Raw material i in Period t at the Manufacturer m

qp^{tv}_{pmd} Quantity of Product p in Period t that is transported by Transportation company v from Manufacturer m to Retailer d

$qpfm^{tv}_{prm}$ Quantity of reusable returned Product p in Period t that is transported by Transportation company v from Collection and Recycling centers r to Manufacturer m

$qpdk^{tv}_{pdr}$ Quantity of Product p in Period t that is returned by Transportation company v from Retailer d to Collection and Recycling centers r

R^{t}_{pdv} Quality level of Product p transported from Transportation company v to Retailer d in Period t

$qpvd^{tk}_{prs}$ Quantity of unusable returned Product p in Period t that is sent by Vehicle k from Collection and Recycling centers r to Disposal center s

4. Model formulation

According to the explanation of the subject, the objective functions of the problem are as follows:

$$\Pi_M = \left[\sum_{t=1}^{T}\sum_{m=1}^{M}\sum_{p=1}^{P}\sum_{d=1}^{D}\left(vp^{t}_{pm} - fc^{t}_{pm}\right)D^{t}_{pd}\right] - BC - PC - AC - MHC - VC \quad (1)$$

$$\Pi_R = \left[\sum_{t=1}^{T}\sum_{m=1}^{M}\sum_{p=1}^{P}\sum_{d=1}^{D}\left(cp^{t}_{pd} - vp^{t}_{pm}\right) \times \left(D^{t}_{pd} - \sum_{r=1}^{R}\sum_{v=1}^{V} Y_{mdv} \times qpdk^{tv}_{pdr}\right)\right] - RHC \quad (2)$$

$$BC = \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{c=1}^{C}\sum_{m=1}^{M}\sum_{k=1}^{K}\left(dc^{t}_{icm} \times qcr^{tk}_{icm}\right) \quad (3)$$

$$PC = \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{m=1}^{M}\left(fc_{pm}^{t} \times \sum_{d=1}^{D}\sum_{v=1}^{V} Y_{mdv} \times qp_{pmd}^{tv}\right) \tag{4}$$

$$AC = \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{d=1}^{D}\sum_{v=1}^{V}\sum_{m=1}^{M} Y_{mdv} \times ac_{pmd}^{tv} \times qp_{pmd}^{tv} \tag{5}$$

$$MHC = \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{m=1}^{M}\left(mcr_{im}^{t} \times \mathrm{Im}_{im}^{t}\right) \tag{6}$$

$$\begin{aligned} VC = {} & \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{c=1}^{C}\sum_{m=1}^{M}\sum_{k=1}^{K}\left(vcs_{icm}^{tk} \times qcr_{icm}^{tk}\right) \\ & + \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{m=1}^{M}\sum_{d=1}^{D}\sum_{v=1}^{V}\left(Y_{mdv} \times scm_{pmd}^{tv} \times qp_{pmd}^{tv}\right) \\ & + \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{r=1}^{R}\sum_{d=1}^{D}\sum_{v=1}^{V}\sum_{m=1}^{M}\left(Y_{mdv} \times scc_{pdr}^{tv} \times qpdk_{pdr}^{tv}\right) \\ & + \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{r=1}^{R}\sum_{d=1}^{D}\sum_{v=1}^{V}\sum_{m=1}^{M}\left(Y_{mdv} \times sck_{prm}^{tv} \times qpfm_{prm}^{tv}\right) \\ & + \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{r=1}^{R}\sum_{s=1}^{S}\sum_{k=1}^{K}\left(vcd_{prs}^{tk} \times qpvd_{prs}^{tk}\right) \end{aligned} \tag{7}$$

$$RHC = \sum_{t=1}^{T}\sum_{p=1}^{P}\sum_{d=1}^{D}\left(mcp_{pd}^{t} \times IL_{pd}^{t}\right) \tag{8}$$

$$Dissatisfaction = \sum_{t=1}^{T}\sum_{d=1}^{D}\sum_{p=1}^{P}\sum_{v=1}^{V}\sum_{m=1}^{M} Y_{mdv} \times \left(\frac{ER_{pd}^{t} - R_{pdv}^{t}}{ER_{pd}^{t}}\right) \tag{9}$$

Equation (1) calculates manufacturer profit from difference between income from selling all products to retailers, and total costs of purchasing, production, contracting, inventory holding in manufacturers, and transportation between facilities, which are presented by Equations (3)–(7), respectively. Equation (2) obtains retailer profit of difference between revenue from selling all products to customers, and total costs of inventory holding in retailer centers, which are presented by Equations (8). As it was previously mentioned, in this model, in addition to maximizing the profit of manufacturer and retailer, we try to maximize the satisfaction of retailers, in other words, minimize retailers' dissatisfaction. In this study, retailers' dissatisfaction is defined as the percentage of difference in the actual quality level of delivered products from their expected quality level. Equation (9) shows how to calculate retailers' dissatisfaction. Equations (10)–(27) indicate the constraints of the mathematical model.

$$\sum_{v=1}^{V} Y_{mdv} = 1 \quad \forall d, m \tag{10}$$

$$R_{pdv}^{t} = \sum_{m=1}^{M} Y_{mdv} \times \gamma_{pdv}^{t} \quad \forall p, d, t, v \tag{11}$$

$$Qp_{pd}^{t} = \sum_{m=1}^{M}\sum_{v=1}^{V} Y_{mdv} qp_{pmd}^{tv} \quad \forall p, d, t \tag{12}$$

$$\begin{aligned} \mathrm{Im}_{im}^{t} = {} & \mathrm{Im}_{im}^{t-1} + \sum_{c=1}^{C}\sum_{k=1}^{K} qcr_{icm}^{tk} \\ & + \sum_{p=1}^{P}\sum_{r=1}^{R}\sum_{d=1}^{D}\sum_{v=1}^{V} Y_{mdv} \times qpfm_{prm}^{tv} \times Z_{ip} \\ & - \sum_{p=1}^{P}\vartheta_{ip} \times \left(\sum_{d=1}^{D}\sum_{v=1}^{V} Y_{mdv} \times qp_{pmd}^{tv}\right) \quad \forall i, m, t \end{aligned} \tag{13}$$

Equation (10) guarantees that each manufacturer just contracts with one transportation company in order to transport product to retailers. Equation (11) calculates the quality level of the products, which sent to each retailer according to the selected transportation company. Equation (12) indicates that the amount of Product p in each period ordered by Retailer d is equal to the amount of Product p that is transported by transportation company. Equation (13) shows the constraint of the balance of raw materials in the manufacturers.

$$\sum_{r=1}^{R}\sum_{m=1}^{M}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} = \nu_p \times IL_{pd}^{t-1} + \mu_p \times Qp_{pd}^{t-1} \ \forall p, d, t \tag{14}$$

$$IL_{pd}^{t} = (1-\nu_p) IL_{pd}^{t-1} + (1-\mu_p) Qp_{pd}^{t} - D_{pd}^{t} \quad \forall p, d, t \tag{15}$$

$$\sum_{v=1}^{V} qpfm_{prm}^{tv} = \sum_{d=1}^{D}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} \times \beta_{pm} \quad \forall p, r, m, t \tag{16}$$

$$\sum_{k=1}^{K} qpvd_{prs}^{tk} = \left(1 - \sum_{m=1}^{M}\beta_{pm}\right) \times \sum_{d=1}^{D}\sum_{m=1}^{M}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} \quad \forall p, r, s, t \tag{17}$$

Equation (14) evaluates the amount of Product p in Period t which is returned from Retailer d to Collection center r. Equation (15) ensures the balance of inventory in retailer's centers. Equation (16) shows a fraction of reusable Product p that is returned to manufacturer from collection center. In return, Equation (17) calculates a fraction of unusable Product p that is sent to the disposal center.

$$\sum_{i=1}^{I}\sum_{c=1}^{C}\sum_{k=1}^{K} qcr_{icm}^{tk} \le SR_m \quad \forall m, t \tag{18}$$

$$\sum_{p=1}^{P}\sum_{d=1}^{D}\sum_{v=1}^{V} Y_{mdv} \times qp_{pmd}^{tv} \le SQ_m \quad \forall m, t \tag{19}$$

$$\sum_{d=1}^{D}\sum_{p=1}^{P}\sum_{m=1}^{M}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} \le SK_r \quad \forall r, t \tag{20}$$

Equation (18) and (19) indicate the constraint on the warehousing of raw materials and limitation of production at each manufacturer. Equation (20) shows that in each period the total returned products from retailers should not greater than the capacity of the collection and recycling centers.

$$\sum_{i=1}^{I} qcr_{icm}^{tk} \leq CSF_k \quad \forall c,m,k,t \tag{21}$$

$$\sum_{p=1}^{P} Y_{mdv} \times qp_{pmd}^{tv} \leq CMF_v \quad ,d,v,t \tag{22}$$

$$\sum_{p=1}^{P}\sum_{m=1}^{M} Y_{mdv} \times qpdk_{pdr}^{tv} \leq CCF_v \quad \forall d,r,v,t \tag{23}$$

$$\sum_{p=1}^{P}\sum_{d=1}^{D} Y_{mdv} \times qpfm_{prm}^{tv} \leq CKF_v \quad \forall r,m,v,t \tag{24}$$

$$\sum_{p=1}^{P} qpvd_{pkd}^{tv} \leq CDV_v \quad \forall k,d,v,t \tag{25}$$

Equations (21)–(25) show the capacity of transportation vehicles between manufacturers and suppliers, retailers and manufacturers, collection centers and retailers, manufacturers and collection centers, and collection and disposal centers, respectively.

$$R_{pdv}^{t}, qcr_{icm}^{tk}, qp_{pmd}^{tv}, Qp_{pd}^{t}, \mathrm{Im}_{im}^{t}, IL_{pd}^{t}, qpdk_{pdr}^{tv}, qpfm_{prm}^{tv}, qpvd_{prs}^{tk} \geq 0 \quad \forall i,p,m,d,r,s,t,k,v \tag{26}$$

$$Y_{mdv} \in \{0,1\} \quad \forall m,d,v \tag{27}$$

Finally, Equations (26) and (27) presents decision variables, which can have zero, one or positive values.

4.1. Fuzzy model

It is expressed in the first section that in real-world greatest parameters of reverse supply chain are inexactness and inaccuracy of detail and could be considered as Fuzzy numbers, therefore the model is presented to a Fuzzy programming (Pourjavad & Mayorga, 2019). The model of this study is considered as the rate of returned products ($\breve{\alpha}_p = \widetilde{v_p + \mu_p}$) and the rate of reusing the returned products $\left(\widetilde{\beta_{pm}}\right)$ as Fuzzy numbers. In this study, the novel method of Jimenez et al. (2007) has been applied to handle Fuzzy parameters, which is converted the presented FMILP into a same auxiliary crisp model. As it is shown in Figure 2, the following equation could be outlined if a triangular Fuzzy number is defined as $\tilde{C} = \{L, M, U\}$.

$$\mu_{\tilde{C}}(x) = \begin{cases} f_c(x) = \frac{x-L}{M-L} & if \quad L \leq x \leq M \\ 1 & if \quad x = M \\ g_c(x) = \frac{U-x}{U-M} & if \quad M \leq x \leq U \\ 0 & if \quad x \leq L \ \ or \quad x \geq U \end{cases} \tag{28}$$

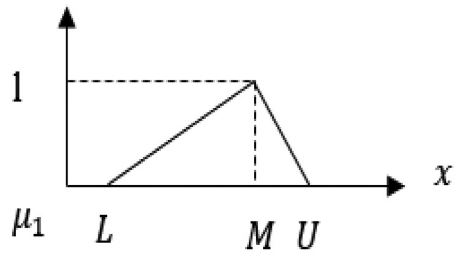


Figure 2. Membership functions of a triangular Fuzzy number.

Based on Jimenez (1996), we could consider the expected interval (EI) and expected value (EV) for $\tilde{C}$ as Equations (29) and (30).

$$EI(\tilde{C}) = \left[E_1^c, E_2^c\right] = \left[\int_0^1 f_c^{-1}(x)dx, \int_0^1 g_c^{-1}(x)dx\right] = \left[\frac{L+M}{2}, \frac{(M+U)}{2}\right] \tag{29}$$

$$EV(\tilde{C}) = \frac{E_1^c - E_2^c}{2} = \frac{L+2M+U}{4} \tag{30}$$

Based on ranking method of Fuzzy numbers of Jimenez et al. (2007), we could consider Equation (31) for a set of two Fuzzy numbers $\tilde{a}$ and $\tilde{b}$ so that the level $\tilde{b}$ is smaller than$\tilde{a}$.

$$\mu_M(\tilde{a},\tilde{b}) = \begin{cases} 1 & if \quad E_1^a - E_2^b > 0 \\ \frac{E_2^a - E_1^b}{(E_2^a - E_1^b)-(E_1^a - E_2^b)} & if \quad 0 \in \left[E_1^a - E_2^b, E_2^a - E_1^b\right] \\ 0 & if \quad E_2^a - E_1^b < 0 \end{cases} \tag{31}$$

$\mu_M(\tilde{a},\tilde{b}) \leq \alpha$ Indicates that $\tilde{a}$ is equal or smaller than $\tilde{b}$ at any rate α, which is shown as$\tilde{a} \leq_\alpha \tilde{b}$. The Fuzzy constraints in the supposed model are formulated as follows:

$$\tilde{a}x \leq \tilde{b}, x \geq 0 \tag{32}$$

According to above, crisp forms of Fuzzy constraints of Equations (14)–(17) are written as Equations (33)–(36):

$$\sum_{r=1}^{R}\sum_{m=1}^{M}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} = \left(\frac{Lv_p + 2Mv_p + Uv_p}{4}\right) \times IL_{pd}^{t-1} + \left(\frac{L\mu_p + 2M\mu_p + U\mu_p}{4}\right) \times Qp_{pd}^{t-1} \quad \forall p,d,t \tag{33}$$

$$IL_{pd}^{t} = (1 - \left(\frac{Lv_p + 2Mv_p + Uv_p}{4}\right))IL_{pd}^{t-1} + (1 - \left(\frac{L\mu_p + 2M\mu_p + U\mu_p}{4}\right))Qp_{pd}^{t} - D_{pd}^{t} \quad \forall p,d,t \tag{34}$$

$$\sum_{v=1}^{V} qpfm_{prm}^{tv} = \sum_{d=1}^{D}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} \times \left(\frac{L\beta_{pm} + 2M\beta_{pm} + U\beta_{pm}}{4}\right) \quad \forall p,r,m,t \tag{35}$$

$$\sum_{k=1}^{K} qpvd_{prs}^{tk} = \left(1 - \sum_{m=1}^{M}\left(\frac{L\beta_{pm} + 2M\beta_{pm} + U\beta_{pm}}{4}\right)\right) \times \sum_{d=1}^{D}\sum_{m=1}^{M}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv} \quad \forall p, r, s, t \tag{36}$$

4.2. Epsilon-constraint technique

As the presented model has three objectives, we have to use a method which considers all three objectives simultaneously to solve the problem and find the best solution. The constraint epsilon is one of the most widely used methods for solving multi-objective problems. In this method, for any repetition, one of the objective functions is set as main objective function of the model while the other functions are taken as constraints with suitable epsilons according to Equation (38) (Mavrotas, 2009).

$$\begin{aligned} &\min f_1(x) \\ &subject\ to \\ &f_2(x) \le \varepsilon_2 \\ &f_3(x) \le \varepsilon_3 \\ &\ldots \\ &f_p(x) \le \varepsilon_p \\ &x \in S. \end{aligned} \tag{38}$$

The modelled epsilon constraint problem of this study is shown as follows: Equations (39)–(41)

$$MOP: Min\,Dissatisfaction = \sum_{t=1}^{T}\sum_{d=1}^{D}\sum_{p=1}^{P}\sum_{v=1}^{V}\sum_{m=1}^{M} Y_{mdv} \times \left(\frac{ER_{pd}^{t} - R_{pdv}^{t}}{ER_{pd}^{t}}\right) \tag{39}$$

$$\Pi_M = \left[\sum_{t=1}^{T}\sum_{m=1}^{M}\sum_{p=1}^{P}\sum_{d=1}^{D}\left(vp_{pm}^{t} - fc_{pm}^{t}\right)D_{pd}^{t}\right] - BC - PC - AC - MHC - VC \ge \varepsilon_1 \tag{40}$$

$$\Pi_R = \left[\sum_{t=1}^{T}\sum_{m=1}^{M}\sum_{p=1}^{P}\sum_{d=1}^{D}\left(cp_{pd}^{t} - vp_{pm}^{t}\right) \times \left(D_{pd}^{t} - \sum_{r=1}^{R}\sum_{v=1}^{V} Y_{mdv} \times qpdk_{pdr}^{tv}\right)\right] - RHC \ge \varepsilon_2 \tag{41}$$

5. Numerical outcomes and sensitivity analyze

ARIANA Dairy Industry Company was established in 1989, it is a reputable Iranian dairy industry group with the slogan 'Healthy Diet leads to Healthy Society'. Remanufacturing the considerable amount of returned goods is a significant anxiety for the senior management. Considering the recycling center in designing process of a supply chain keeps from enormous disposal expenses and causes profits through the entire network. This issue shows signs of being practical in ARIANA, because there is no dissimilarity in putting up for sale between the goods which are produced from recycled or usual raw material. For this purpose, an investigation started on a cream and butter production network in ARIANA's supply chain. The investigation was executed in a supply chain which includes a manufacturer, two suppliers, a disposal center, a collection and recycling center and four retailers in three periods. The production of one-unit cream needs one unit of full-fat milk (1st Raw material), while one unit of yogurt (2nd raw material) and two units of full-fat milk are used to produce one-unit butter. In addition, only the cream could be reused in the manufacturer as the raw material of butter. The expected value of return rate of cream is 0.3 ((EV $(\alpha_p) = 0.3$), provided that only the expected value 0.6 of returned cream is appropriate for recycling ((EV $(\beta_{pm}) = 0.6$). Three 3rd party logistic companies conduct the task of transporting products to retailers that the manufacturer contracts with one of the logistic companies in each period. Each logistics organization uses a type of vehicle with a level of equipment, so that, the level of equipment leads to a different price and level of quality. As the retailer's demand depends on the price and the level of product's quality, the manufacturer considers the demand of all retailers, and contracts with the logistic company which leads to the most satisfaction level of retailers. The mathematical model was designed according to Equations (1)–(32) as it has been indicated in section 4 and the optimal solution is calculated using the GAMS software. Table 2 shows the cost of producing, wholesales, sales price, retailer's demand and expected quality level for each of the products.

Table 3 shows the cost of transporting each of the raw materials.

Table 4 shows the cost of transporting each of the returned product between different levels.

Finally, related values of each of the products for various transportation companies are indicated in Tables 5–7.

Optimal solution was reached from solving the model in GAMS software and also values of each of the goal functions have been reported in Table 8.

As it is shown in Table 8, the manufacturer should contract with the transportation company, which offer highest

Table 2. The cost of producing, wholesales and sales price, retailer's demand and expected quality level for each of the products.

		Product $p = 1$			Product $p = 2$		
Parameter	Retailer	$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
fc_{pm}^{t}	-	2000	2200	2300	1800	2000	2100
vp_{pm}^{t}	-	25000	26000	26000	21000	24000	25000
cp_{pd}^{t}	$d = 1$	3000	3000	3000	2800	3000	3000
	$d = 2$	3200	3200	3200	3000	3200	3200
	$d = 3$	3500	3500	3500	3400	3600	3600
	$d = 4$	4000	4000	4000	3600	3800	4000
D_{pd}^{t}	$d = 1$	1000	1200	1500	500	550	600
	$d = 2$	800	900	1100	400	450	500
	$d = 3$	500	800	1000	450	500	550
	$d = 4$	800	1000	1300	600	650	700
ER_{pd}^{t}	$d = 1$	80	80	80	75	75	75
	$d = 2$	75	75	75	80	80	80
	$d = 3$	65	65	65	85	85	85
	$d = 4$	70	70	70	80	80	80

Table 3. The cost of transporting each of the raw materials.

		Raw material $r = 1$			Raw material $r = 2$		
Parameter	Supplier	$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
vcs_{icm}^{tk}	$c = 1$	10	10	10	10	10	10
	$c = 2$	10	10	10	10	10	10

Table 4. The cost of transporting each of the returned products between different levels.

Parameter	Retailer	Returned Product $p = 1$		
		$t = 1$	$t = 2$	$t = 3$
scc_{pdr}^{tv}	$d = 1$	10	15	20
	$d = 2$	10	15	20
	$d = 3$	10	15	20
	$d = 4$	10	15	20
sck_{prm}^{tv}	-	10	15	20
vcd_{prs}^{tk}	-	10	10	10

Table 5. The cost of transporting each of the products for various transportation companies.

Parameter	Transportation company	Retailer	Product $p = 1$			Product $p = 2$		
			$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
scm_{pmd}^{tv}	$v = 1$	$d = 1$	15	15	15	5	5	5
		$d = 2$	10	10	10	10	10	10
		$d = 3$	5	5	5	15	15	15
		$d = 4$	8	8	8	8	8	8
scm_{pmd}^{tv}	$v = 2$	$d = 1$	20	20	20	8	8	8
		$d = 2$	15	15	15	15	15	15
		$d = 3$	8	8	8	20	20	20
		$d = 4$	10	10	10	10	10	10
scm_{pmd}^{tv}	$v = 3$	$d = 1$	30	30	30	12	12	12
		$d = 2$	20	20	20	20	20	20
		$d = 3$	12	12	12	30	30	30
		$d = 4$	15	15	15	15	15	15

Table 6. The cost of contracting each of the products for various transportation companies.

Parameter	Transportation company	Retailer	Product $p = 1$			Product $p = 2$		
			$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
ac_{pmd}^{tv}	$v = 1$	$d = 1$	18	18	18	6	6	6
		$d = 2$	14	14	14	14	14	14
		$d = 3$	6	6	6	18	18	18
		$d = 4$	10	10	10	10	10	10
ac_{pmd}^{tv}	$v = 2$	$d = 1$	20	20	20	8	8	8
		$d = 2$	16	16	16	16	16	16
		$d = 3$	8	8	8	20	20	20
		$d = 4$	12	12	12	12	12	12
ac_{pmd}^{tv}	$v = 3$	$d = 1$	22	22	22	10	10	10
		$d = 2$	18	18	18	18	18	18
		$d = 3$	10	10	10	22	22	22
		$d = 4$	14	14	14	14	14	14

Table 7. The quality level of each of the products for various transportation companies.

Parameter	Transportation company	Retailer	Product $p = 1$			Product $p = 2$		
			$t = 1$	$t = 2$	$t = 3$	$t = 1$	$t = 2$	$t = 3$
γ_{pdv}^{t}	$v = 1$	$d = 1$	50	50	50	45	45	45
		$d = 2$	45	45	45	50	50	50
		$d = 3$	35	35	35	55	55	55
		$d = 4$	40	40	40	50	50	50
γ_{pdv}^{t}	$v = 2$	$d = 1$	65	65	65	60	60	60
		$d = 2$	60	60	60	65	65	65
		$d = 3$	50	50	50	70	70	70
		$d = 4$	55	55	55	65	65	65
γ_{pdv}^{t}	$v = 3$	$d = 1$	80	80	80	75	75	75
		$d = 2$	75	75	75	80	80	80
		$d = 3$	65	65	65	85	85	85
		$d = 4$	70	70	70	80	80	80

Table 8. Values of each of the objective functions.

Objective Function	Value
Retailer profit	14317360
Manufacturer profit	453806.4
Raw material purchase cost	527185
Production cost	541070
Raw material holding cost	78900
Production holding cost	43455
Contracting cost	403538
Cost of transportation between centers	995945
Dissatisfaction	1.2

quality level and cost value for the retailer's satisfaction. Finally, Table 9 shows how the manufacturer can contract with the transportation companies.

Also, Figure 3 shows the Pareto solutions of three-goal proposed model by epsilon-constraint method and their distributions.

In this part, performance and validity of the presented mathematical model and the impressible parameters were evaluated in

Table 9. Manufacturer contract with transportation companies.

		Transportation company		
Manufacturer	Retailer	$v = 1$	$v = 2$	$v = 3$
$m = 1$	$d = 1$			✓
	$d = 2$			✓
	$d = 3$			✓
	$d = 4$		✓	

the model. Therefore, the values of two significant parameters, include EV (βpm) (expected value of the proportion of returned products reusable for production) and also EV (αp) (expected value of the product return rate), were changed, and their analysis on the objective functions were reported. Figure 4 shows the variation effect of these parameters on the three objective functions.

As it has been represented in Figure 4, manufacturer and retailer profit have regular reduction trend while retailer dissatisfaction doesn't have this procedure. Table 10 shows the effect of variation in the parameters on the costs and there is almost an increasing trend, while holding costs of products have reverse procedure

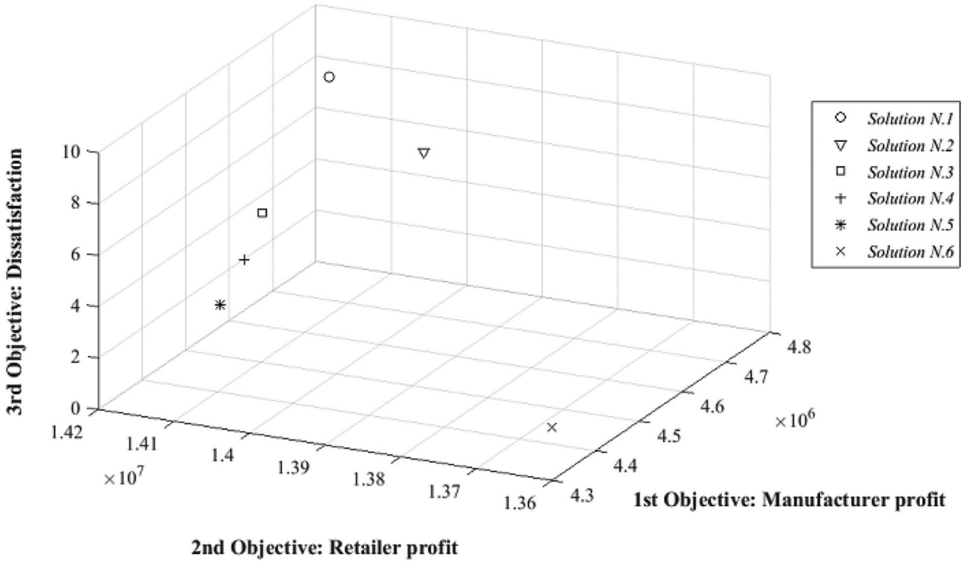


Figure 3. Pareto solutions of exact of three-objective proposed model.

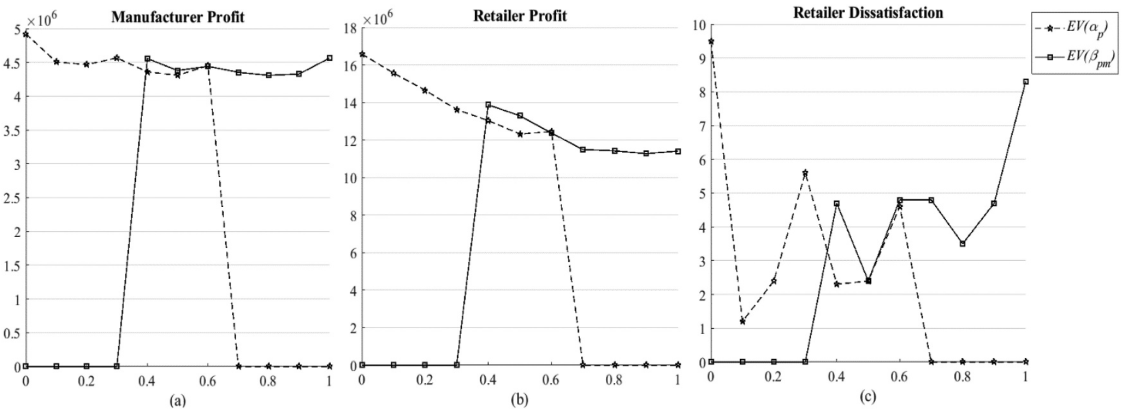


Figure 4. Effect of variation in the parameters on the three objective functions.

Table 10. Effect of variation in the parameters on the costs.

	Purchase cost		Contract cost		Production cost		Raw material maintenance cost		Products maintenance cost		Transportation cost	
	EV(α_p)	EV(β_{pm})	EV(α_p)	EV(β_{pm})	EV(α_p)	EV(β_{pm})	EV(α_p)	EV(β_{pm})	EV(α_p)	EV(β_{pm}	EV(α_p)	EV(β_{pm})
0	0	529450	0	294488	0	507093	0	42768	0	100258	0	667902
0.1	0	534233	0	402862	0	542915	0	36448	0	114354	0	941208
0.2	0	535057	0	400970	0	555490	0	38652	0	105381	0	966022
0.3	0	537346	0	373534	0	575474	0	40098	0	99241	0	872733
0.4	532141	536240	376499	415052	554114	574793	50207	41903	40716	80421	894012	1034484
0.5	532619	536756	405821	420996	562704	585524	48967	46423	43461	69690	1034052	1065141
0.6	535243	535038	393880	392016	581999	581153	48975	49143	51468	51193	961599	954197
0.7	537673	0	406458	0	603111	0	57850	0	60142	0	1005326	0
0.8	537162	0	415740	0	603328	0	62177	0	60300	0	1036860	0
0.9	537412	0	407015	0	605912	0	72056	0	61513	0	1013650	0
1	537905	0	363926	0	602043	0	50965	0	59519	0	846588	0

It is obvious that, if the expected value of α_p exceeds a specified magnitude, the model becomes infeasible and production of the product won't be economically valuable. Also, it is obvious that the product return rate should not be greater than the proportion of usable returned product; therefore, the model is feasible more than 30% for EV (β_{pm}).

This study creates a substantial allotment to acquiring a profound comprehension on the designation of reusing perishable goods, which their expiration date is close, through giving assistance to administrators and decision-making executives to expand a more powerful, inconsiderable expenditure and SCLSC methodologies as stated in ARIANA supply chain.

5.1. Approach for testing the Fuzzy model

As multi-objective models, have a set of responses which are called the Pareto solutions, instead of having a single response, different efficiency indices have been provided to determine the state of set of Pareto-Optimal (Kaur, Sidhu, Awasthi, & Srivastava, 2019). In expression of 4 indices defined in the following, the effectuation of the FMOMILP applied for solving the presented model is evaluated.

5.1.1. Mean ideal distance (MID)

This index which is determined in Equation (42) has been used to calculate the proximity of ideal point and Pareto fronts (Karimi, Zandieh, & Karamooz, 2010).

$$MID = \frac{\sum_{i=1}^{|Q|}\left(\sqrt{\sum_{j=1}^{n_{obj}}\left(\frac{f_i^j - f_{best}^j}{f_{\max}^j - f_{\min}^j}\right)^2}\right)}{|Q|} \tag{42}$$

In Equation (42), $|Q|$ and n_{obj}represent the number of non-dominated solutions and number of objective functions. f_i^j is solution i of objective function j and f_{best}^j is ideal point of objective function j and also f_{max}^j and f_{min}^j are the maximum and minimum values of objective function j among all of Pareto solutions. This metric in problems with a smaller size, has a better efficiency.

5.1.2. Number of Pareto Solutions (NPS)

This index is measured the number of non-dominated solutions which are found by a proposed model to solve the multi-objective problems. (Habibi, Barzinpour, & Sadjadi, 2017).

5.1.3. Spread of Non-dominance Solution (SNS)

This index which is determined in Equation (43) is used to gage the variety of obtaining of Pareto solutions (Maghsoudlou, Kahag, Niaki, & Pourvaziri, 2016).

$$SNS = \sqrt{\frac{\sum_{i=1}^{|Q|}\left(MID - \sum_{j=1}^{n_{obj}} f_i^j\right)^2}{|Q| - 1}} \tag{43}$$

Table 11. *The numerical examples for small size problems.*

Problem number	Raw materials	Products	Suppliers	Manufacturers	Retailers	Collection centers	Disposal centers	Vehicles	Transportation companies	Period times
1	3	5	2	3	2	2	2	2	2	2
2	3	6	2	3	3	2	2	2	2	2
3	4	7	3	3	4	3	2	3	2	2
4	5	8	3	2	5	3	2	3	2	2
5	5	9	3	2	5	3	2	3	2	2

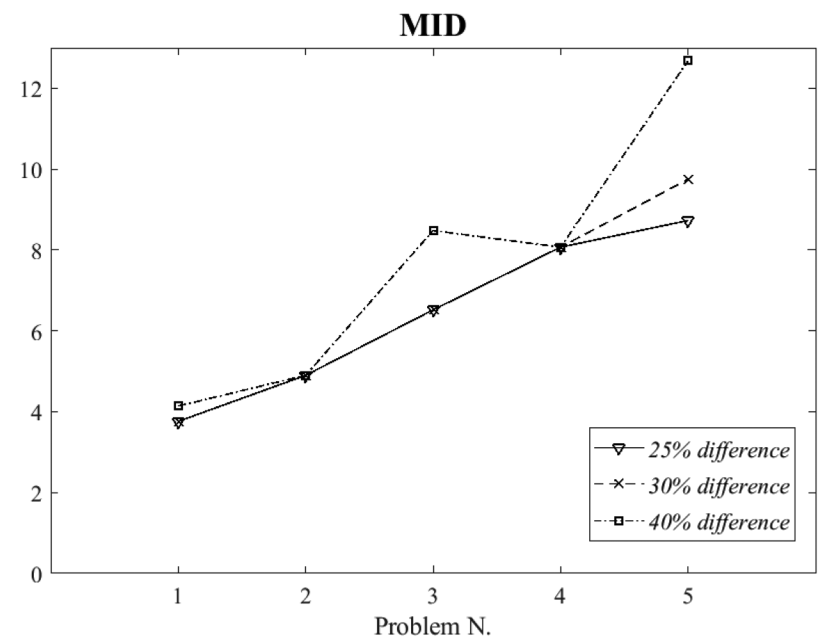
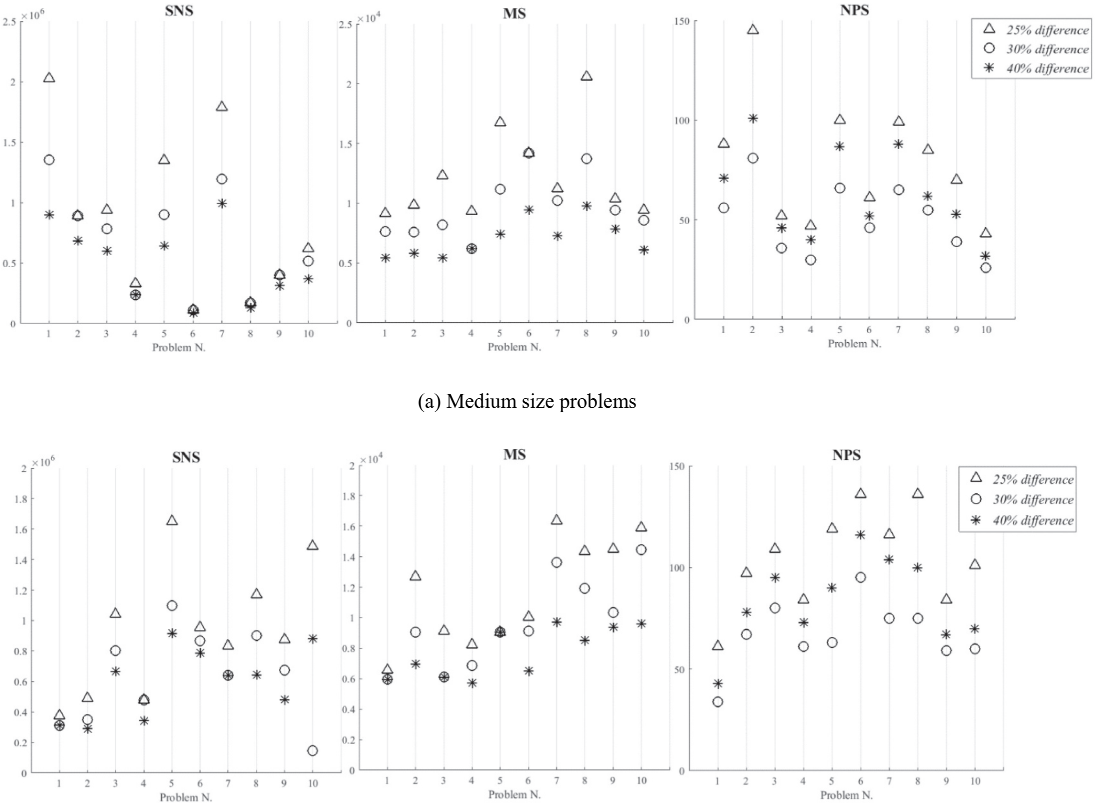


Figure 5. Changes of MID for different values of uncertainty



(a) Medium size problems

(b) Large size problems

Figure 6. Changes of SNS, MS and NPS for different values of uncertainty.

5.1.4. Maximum spread (MS)

This index which is determined in Equation (44) is used to gage the expansion of Pareto solutions (Sahebjamnia, Mohammad Fathollahi-Fard, & Hajiaghaei-Keshteli, 2018).

$$MS = \sqrt{\sum_{j=1}^{n_{obj}} \left(f_{\max}^{j} - f_{\min}^{j}\right)^2} \tag{44}$$

In the following, 5 problem numbers are presented in Table 11 which is evaluated with MID index.

The difference between lower, medium and upper levels are considered in different intervals of 25, 30 and 40% in order to investigate the effect of uncertainty. In fact, the 25% difference indicates that the lower limit is 25% lower than the average and the upper limit is 25% higher than the average. There is a similar explanation for 30% and 40% that the results are shown in Figure 5.

10 numerical examples were generated and evaluated with SNS, MS and NPS indicators in order to evaluate the model's efficiency for medium and large size problems, which are shown in Figure 6.

As Figure 6 shows, in a difference of 25%, larger amounts of SNS, MS and NPS criteria are obtained, which indicates a higher performance of the model in lower uncertainty

6. Managerial significance

However, previous studies in this issue prepare many beneficial intuitions toward optimal performance in GSC, scholars do not prepare a suitable regard to administrators when the quality of the returned goods leads to a decision on whether it can be used as a raw material in the production of another product. Our study enables such viewpoint which could assist decision-making managers as follows:

(1) The result shows that collecting perishable returned products in a timely manner and reusing them as a raw material for producing another product reduces wastes and supply chain costs. Therefore, a manager needs to make the best decision in these conditions to maximize interests, which this model suggests, the best solution to the managers.
(2) Considering the quality of returned products for recycling and reusing them effects on SC member's interest and decisions which cause a substantial benefit for the whole network. Therefore, the presented coordination contract can be applicable to share profit in SC.
(3) Considering in the offered RS mechanism, the level of retailer satisfaction increases and leads to be executable efficiently, to send products in critical lifetime industries.
(4) The analyses of numerical problems specify that the presented method is an extremely hopeful multi-objective model under uncertainty decision situations which could prepare asymmetric and symmetric effective solutions for managers with settlement of the opposite objectives. Choosing the triangular membership function to indicate the parameters of Fuzzy constraints for modeling the network of Fuzzy multi-objective GSC problems demonstrate that the suggested FMOMILP

model is more productive and flexible in terms of computing (Zimmermann, 1996).

In this study, we presume an ordinary communication between returned product rate and allowable quality level whereas discussing on intricate real information could be examined as amplification to this study. Moreover, the reusing and recycling unit cost could be investigated as an objective on retailer's satisfaction which is not studied in our research and stays as a space for subsequent studies. In addition, thinking about a reward for sending critical lifetime products with more quality can be applicable in certain conditions and may be studied as further fascinating orientation for the next researches.

7. Concluding remarks and future research guidance

This study converse about the contracting mechanism in a new Fuzzy mathematical model for multi-period and multi-product CLCS, especially in industries which, time plays a crucial role to maximize the profit of SC. In addition, design of GSC networks could be difficult by uncertain parameters of decision making like customer return rates. For this reason, in the presented FMOMILP model, the return rate and reusable return rate is considered uncertain for designing a network of GSC. This study shows that there is a research gap in the perishable supply chain networks about subject matters such as how returned products can be collected and recycled, and methods for reusing returned products from the perishable goods production processes. The model of research is formularized in the dairy cases where the returned cream was reused as a raw material for butter. AS the retailer's satisfaction is an essential element in the profit of perishable supply chain network, in this model the revenue sharing contract is considered for coordination between SC members. It is acknowledged that it is financially beneficial for SC members to use coordination tools in terms of maximize the whole interest of the GSC which the returned product can be used as a raw material of another product by analyzing the consequences. Eventually, an explanatory numerical example is provided to present the extended mathematical model. The result of analyzing the numerical sensitivity shows the definite influence of cooperation mechanism between perishable industries on the overall benefit of each member of the SC.

There are some methods to develop this study. Allegorically, stochastic or Fuzzy demand of retailers could be investigated in next studies. Moreover, various kinds of coordination contracts can be assumed in order to how they affect the profit of the whole supply chain. In this study, we presume an ordinary communication between returned product rate and allowable quality level whereas discussing on intricate real information could be examined as amplification to this study. Moreover, the reusing and recycling unit cost could be investigated as an objective on retailer's satisfaction which is not studied in our research and stays as a space for subsequent studies. In addition, thinking about a reward for sending critical lifetime products with more quality can be applicable in certain conditions and may be studied as further fascinating orientation for the next researches.

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