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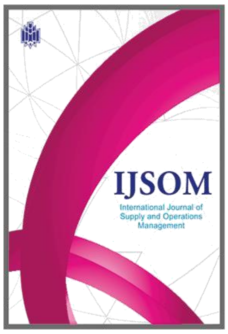

A Multi-objective Closed Loop Supply Chain Design: A Case Study in Iran

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Abstract
This paper presents a closed loop supply chain. The proposed model involves several parts including market zone, disposal, collection, recycling, supply, and manufacturing and distribution centers. Establishments of supply chain ingredients are considered as decision variables. Two objective functions are taken into consideration. The first objective desires to minimize the economic charges of the supply chain management in terms of establishment, transportation and market lost while the second one aims to maximize the attained market share. Any unmet demand will impose lost market charge on the system. A real case study has evaluated the outcomes of the proposed model. The results depict a novel way to provide a tradeoff between the objective functions values.

Keywords: Closed loop supply chain; Multi-objective models; Market-share.

1. Introduction

Nowadays, reverse logistic constitutes a considerable portion of supply chain models. Reverse logistic processes all types of returns, from late to early stages of supply chain (Coronado Mondragon et al., 2011). Reverse logistic network includes adding the backward flow of materials in a way that both the forward and reverse flows are coordinated (Akçalı et al., 2009). Such returns appear due to consumer rights, end of shelf-life, defective product etc. Returns can occur at any stage such as purchasing, production, distribution, or consumer. It is of interest that the returned products be disposed or recycled in a way that the minimum charges are imposed on the supply chain. Manufacturers take advantage of return of defective or expired materials both economically and environmentally (Huang and Wang, 2017). Reverse logistics are known to be the principal component of product recovery (Jayant et al., 2012). Return types determine reverse logistics operations, and make goods reenter in the forward supply chain (Guide Jr et al., 2003). Remanufacturing is called the process of disassembling the product and replacing the required components for repair or upgrade of the product. Basically, reverse logistic decisions are related to supplier, manufacturer, distribution and transportation partners for both new and remanufactured products. These strategic decisions should be made in a way that the overall desired objective is optimized. Remanufacturing has been an effective marketing strategy for many manufacturers to protect their market share or even improve their profit margin (Wu, 2015) (Chen and Chang, 2013). In this study, Market share protection or improvement is considered as a major objective. The key objectives of this study are: (a) to present an integrated reverse logistic optimization model for products with competitors in which market share is one of the key decision variables; (b) to do a real-world case study and to provide the values which could depict the applicability of the model.

2. Literature Review

Over the course of time, reverse logistic has been an interesting subject for researchers. As the desire of decision makers mount to attain better performance in supply chains, the need for a high-performance modeling framework rises. Reverse logistic constitutes a major stream of supply chain studies. The main goal of decision makers in reverse logistic is to design a supply chain considering return flows. The related literature includes a variety of studies. Fuente et al. (2008) integrated forward and the reverse operations of a supply chain in a way to redefine the firm's management procedures.

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Torabi and Hassini (2008) presented a multi-objective probabilistic mixed-integer linear programming model for a closed loop model. Two-conflicting objectives were simultaneously taken into account. Xu and Liu (2017) evaluated effect of reference price on a reverse logistic. Shaharudin et al. (2017) evaluated product returns importance in a closed-loop supply chain activity and realized its effectiveness in cost savings, relationship with consumers, production capacity improvement and less consumed raw material. Vahdani et al. (2012) presented a reliable network design for plants in closed loop supply chains with uncertainty for iron and steel industry. They proposed a solution, a novel methodology, for the problem. The numerical experiments showed significance of the solution approach for the related industry.

Zeballos et al. (2014) proposed a multi-layer, multi-period, multi-product reverse logistic network to minimize the overall expenses including network design, raw material, inventory holding, and transportation. Liu et al. (2017) proposed dual recycling channels for returned products and determined the best reverse channel. Wang and Wang (2013) evaluated discount in a closed-loop supply chain with disruptions. Schultmann et al. (2006) considered a closed loop with objective of increasing the recycling ratio by reprocessing materials and reintegrating these materials into their authentic supply chains.

Salema et al. (2007) proposed a mixed-integer mathematical formulation for a supply chain with reverse flow which desires to minimize the overall charges. The main characteristics of the model include limitation on capacity, dealing with multiple products and demand uncertainty. Qu and Williams (2008) developed a non-linear model which addresses automotive reverse production planning besides pricing issues. Östlin et al. (2008) evaluated return types for a reverse logistic. Amin and Zhang (2013) optimally chose suppliers and refurbishing sites besides determining manufacturing units under demand uncertainty. Amin and Zhang (2014) specified location of new facilities, and flow of products for a closed loop supply chain. One of the main goals was to minimize rate of defected products besides operational times spent at the collection centers. Sasikumar and Haq (2010) presented a multi-echelon reverse logistic network and developed a mixed-integer non-linear programming model which aimed to maximize overall profit. The model was applied in a truck tire for automotive industry. Sensitivity analysis revealed allowable distance among available centers. Ramezani et al. (2014) designed a multi-product, multi-period closed loop supply chain which maximized profit and quality while minimizing delivery time beside uncertainty.

Zhou et al. (2013) presented a reverse logistic for both centralized and decentralized control mode for plant’s manufacturing and remanufacturing activities. Abdulrahman et al. (2014) evaluated impact of governmental issues on reverse logistics and manufacturing sectors performance. Francas and Minner (2009) concluded that an integrated model is useful for whole-market fulfilment and a non-integrated one is beneficial in local markets. Jayaraman (2006) optimized the number of disassembled, disposed, and remanufactured units for a specific period of time. Salema et al. (2010) designed a closed loop model which encounters both strategic and tactical decisions. The major strategic decision includes network design and tactical decisions such as production, storage, and distribution issues. Panda et al. (2017) investigated a socially responsible reverse logistic with product recycling. It was shown that non-profit motive could provide higher profit than the profit maximizing objective.

Nukala and Gupta (2006) economically specified the quantity of the reprocessed used-products. Also, they determined the proper production facility and quantity of materials that were shipped along the related supply chain. Subulan and Tasan (2013) considered a closed loop supply chain with multi-echelon, multi-product, multi-period and minimizing transportation, remanufacturing, disposal, tardiness, and penalty charges. Tang and Xie (2007) proposed a reverse logistic network problem model consisting of customers, collection centers, repair centers and plants. A genetic-algorithm based heuristic was proposed which aims to minimize operational charges. Numerical studies depict that the proposed model could provide better results. Özceylan et al. (2014) presented a model that optimizes both strategic and tactical decisions. Strategic decisions deal with the amount of forward and backward flowing materials. Tactical decision correspond with issues of balancing disassembly.

Despite the vast number of studies performed on the closed loop supply chain design, only few of them desired to maximize the market share besides optimizing the expenses in the supply chain. This paper, therefore, aims to evaluate the effect of market share maximization on the reverse logistic network design. The main contribution of this paper is to design the proper closed-loop supply chain for remanufacturing firms as follows:

- Taking into account the market share as a novel objective function besides economic objective function.
- Concurrent consideration of collection, recycling and disposal centers in a closed loop supply chain to evaluate their role in a closed loop supply chain.
- Presenting an integrated reverse logistic model which concurrently takes into account establishment, transportation, supplier management and stock out charges.

3. Problem Description and Formulation

An ordinary supply chain produces a set of products using input materials provided by qualified suppliers. Products are distributed through distribution centers to serve arisen demand. The current problem incorporates several issues into echelons of supply chain. Initially, it evaluates the issue of supplier selection besides the lot-sizing issue. Then it takes into account production planning for the manufacturing phase and finally produced products are distributed to the market. It is desired to present an optimal decision in a midterm horizon which coordinates the 1-Supply plan 2-Production plan 3-Distribution plan. The model is designed in a closed-loop structure which allows a portion of the products to be delivered to the initial sectors of supply chain for reproduction process. Accordingly, a quantity of materials is shipped from market centers to the collection centers. Collection centers determine whether the materials are recyclable or not. Non-recyclable materials are sent to disposal centers while the recyclable materials are delivered to the recycling centers. Recycling centers will reprocess the materials and will send the repaired material to the distribution center while the unrepaired materials are sent to the production centers for reconstruction. Supply plan designates qualified suppliers and purchase quantity to each of them. Production plan determines the quantity of products produced at each production center and distribution plan determines the delivered quantity to each demand center. To construct the supply chain major decisions, two objectives are taken into consideration. The first objective desires to minimize the logistic charges including establishment, transportation, etc. while the second objective desires to maximize the attained share of the market. Market share, one of the most important objectives in supply chain decisions, have been noted as one the most significant factors in supply chains (e.g. (Romaniuk et al., 2018), (Marasco et al., 2016)). Such objectives are explicitly conflicting as attaining higher market share will impose higher level of expenses on the supply chain.

The main assumptions of the proposed model are as follows:

- Demand of final product is deterministic and is served through distribution centers.
- Unfulfilled demand by the proposed model will be served by competitors which could be considered as lost sale imposing extra charges on the system.
- Capacities of the components are restricted.
- Lead times are negligible with respect to the length of the planning horizon.

A schematic view of the proposed closed loop supply chain is depicted in Figure 1:

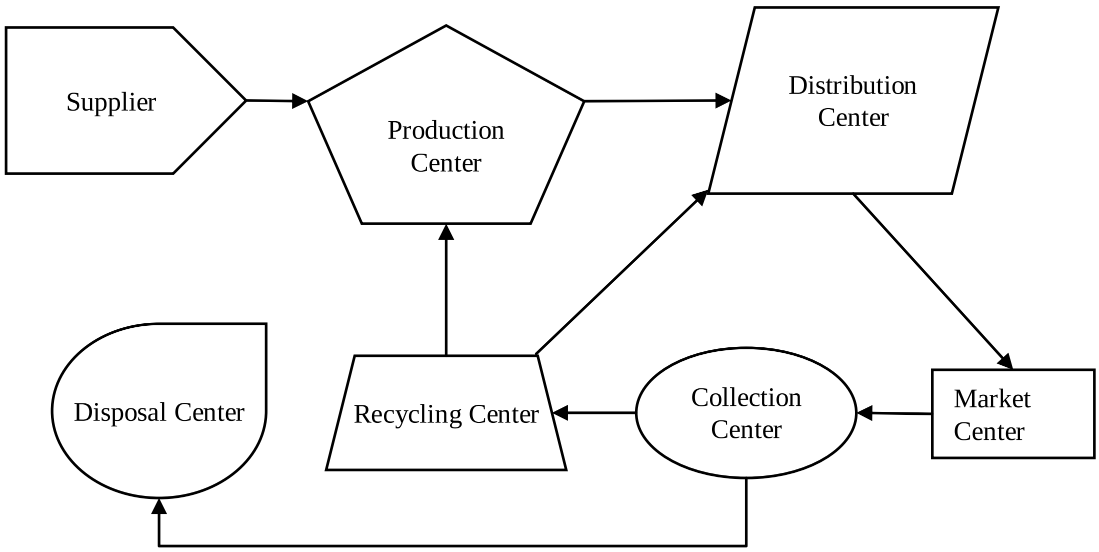

Figure 1. Schematic view of the proposed closed loop supply chain

3.1. Model formulation

The related model is formulated as follows:

Indices

k Market center (customer) index $k = \{1, \ldots, K\}$
i Collection center index $i = \{1, \ldots, I\}$
j Recycling center index $j = \{1, \ldots, J\}$
n Disposal center index $n = \{1, \ldots, N\}$

p	Production site index $p = \{1, \dots, P\}$
s	Supplier index $s = \{1,2, \dots S\}$
m	Distribution center index $m = \{1, \dots, M\}$

Parameters

d_k	Demand of market k
s	Average disposed percentage
q	Average percentage of material which could be directly sent from recycling center to distribution center without the need for reworking in production center
r_k	Returned quantity from market k
$Ccol_i$	Capacity of collection center i
$Crec_j$	Capacity of recycling center j
Cdt_m	Capacity of distribution center m
Cdp_n	Capacity of disposal center n
Cpr_p	Capacity of production site p
$Ecol_i$	Establishment cost of collection center i
$Erec_j$	Establishment cost of recycling center j
Edt_m	Establishment cost of distribution center m
Epr_p	Establishment cost of production center p
Edp_n	Establishment cost of disposal center n
Tm_{ki}	Unit transportation cost from customer k to collection center i
$Tcol_{ij}$	Unit transportation cost from collection center i to recycling center j
Tcd_{in}	Unit transportation cost from collection center i to disposal center n
$Trec_{jp}$	Unit transportation cost from recycling center j to production center p
Tsu_{sp}	Unit transportation cost from supplier su to production center p
Tpr_{pm}	Unit transportation cost from production center p to distribution center m
Trd_{jm}	Unit transportation cost from supplier su to production center p
Tdt_{mk}	Unit transportation cost from distribution center m to market k
ρ_k	Unit stock-out charge for customer at market k
Fs_s	Fixed management cost of supplier s

Variables

O_{ki}	Quantity of material shipped from market k to collection center i
R_{ij}	Quantity of material shipped from collection center i to recycling center j
T_{in}	Quantity of material shipped from collection center i to disposal center n
B_{jp}	Quantity of materials shipped from recycling center j to production center p
N_{sp}	Quantity of material from supplier s to production center p
U_{pm}	The quantity of materials shipped from manufacturer p to distribution center m
P_{jm}	Quantity of material shipped from recycling center j to distribution center m
Q_{mk}	Quantity of material shipped from distribution center m to customer k
φ_k	Quantity of demand at market k which is fulfilled by competitors

$$Y_i = \begin{cases} 1 & if\ collection\ center\ i\ is\ established \\ 0 & otherwise \end{cases}$$

$$Z_j = \begin{cases} 1 & if\ \text{recycling center}\ j\ is\ established \\ 0 & otherwise \end{cases}$$

$$S_m = \begin{cases} 1 & if\ \text{distribution center}\ m\ is\ established \\ 0 & otherwise \end{cases}$$

$$W_s = \begin{cases} 1 & if\ relationship\ with\ supplier\ s\ is\ established \\ 0 & otherwise \end{cases}$$

$$V_n = \begin{cases} 1 & if\ \text{disposal center}\ n\ is\ established \\ 0 & otherwise \end{cases}$$

$$M_p = \begin{cases} 1 & if\ \text{production center}\ p\ is\ established \\ 0 & otherwise \end{cases}$$

The proposed Multi-Objective model is as follows:

$$\begin{aligned}\min OB_1 = {} & \sum_i Ecol_i \times Y_i + \sum_j Erec_j \times Z_j + \sum_p Edt_m \times M_p + \sum_s Epr_p \times W_s + \sum_m Edp_n \times S_m \\ & + \sum_k \sum_i Tm_{ki} \times O_{ki} + \sum_i \sum_j Tcol_{ij} \times R_{ij} + \sum_i \sum_n Tcd_{in} \times T_{in} \\ & + \sum_j \sum_p Trec_{jp} \times B_{jp} + \sum_s \sum_p Tsu_{sp} \times N_{sp} + \sum_p \sum_m Tpr_{pm} \times U_{pm} \\ & + \sum_j \sum_m Trd_{jm} \times P_{jm} + \sum_m \sum_k Tdt_{mk} \times Q_{mk} + \sum_k \rho_k \varphi_k + \sum_s Fs_s \times W_s\end{aligned} \tag{1}$$

$$\max OB_2 = \frac{\sum_m \sum_k Q_{mk}}{\sum_k d_k} \tag{2}$$

S.T.

$$\sum_m Q_{mk} + \varphi_k = d_k, \qquad \forall k \tag{3}$$

$$\sum_i O_{ki} \le r_k, \qquad \forall k \tag{4}$$

$$\sum_j R_{ij} - (1-s) \sum_k O_{ki} = 0, \qquad \forall i \tag{5}$$

$$\sum_n T_{in} - s \sum_k O_{ki} = 0, \qquad \forall i \tag{6}$$

$$\sum_m P_{jm} = q \sum_i R_{ij}, \qquad \forall j \tag{7}$$

$$\sum_p B_{jp} = (1-q) \sum_i R_{ij}, \qquad \forall j \tag{8}$$

$$\sum_j B_{jp} + \sum_{su} N_{sp} = \sum_m U_{pm}, \qquad \forall p \tag{9}$$

$$\sum_p U_{pm} + \sum_j P_{jm} = \sum_k Q_{mk}, \qquad \forall m \tag{10}$$

$$\sum_k O_{ki} \le Ccol_i \times Y_i, \qquad \forall i \tag{11}$$

$$\sum_i R_{ij} \le Crec_j \times Z_j, \qquad \forall j \tag{12}$$

$$\sum_p U_{pm} + \sum_j P_{jm} \le Cdt_m \times w_m, \qquad \forall m \tag{13}$$

$$\sum_i T_{in} \le Cdp_n \times V_n, \qquad \forall n \tag{14}$$

$$\sum_s N_{sp} + \sum_j B_{jp} \le Cpr_p \times M_p, \qquad \forall p \tag{15}$$

$$Y_i, Z_j, S_m, W_s, V_n, M_p \in \{0,1\} \tag{16}$$

$$O_{ki}, R_{ij}, T_{in}, B_{jp}, N_{sp}, U_{pm}, P_{jm}, Q_{mk}, \varphi_k \ge 0 \tag{17}$$

Equation (1) calculates the supply chain expenses including establishment, transportation and stock-out charges. Equation (2) shows the attained market-share which is desired to be maximized. Equation (3) determines that the demand could be fulfilled by the proposed supply chain or competitors. Equation (4) limits the quantity of returned materials from the market shipped to the collection center. Equation (5) determines the quantity of materials shipped from the collection center to the recycling centers. Equation (6) determines the quantity of materials shipped from the collection center to the disposal centers. Equation (7) determines the quantity of material shipped from recycling to the distribution centers. Equation (8) determines the quantity of material shipped from recycling centers to the production centers. Equation (9) ensures that the materials shipped to the production center from recycling centers and suppliers equal the quantity of material shipped from the production center to distribution centers. Equation (10) ensures that the incoming materials to distribution centers from production and recycling centers should equal the outgoing materials from distribution centers. Equations (11)-(15) are capacity constraints of collection centers, recycling centers, distribution, disposal and production centers, respectively. Equations (16) & (17) ensure that variables are binary and positive.

To convert the above multi-objective model to a single objective model, a weighted goal programing approach is utilized. The original goal programing desires to purely minimize the deviations in the objective functions. In the weighted goal programing, a given weight is attributed to the deviation of each objective function. Weighted goal programming aims to concurrently minimize the weighted sum of deviations from the relative goals. This type of goal programming model is used when it is not possible to prioritize goals. The related formulation of weighted goal programming could be presented as follows:

$$\text{Min } Z = \sum_{i=1}^{K} (\varphi_i d_i^- + \omega_i d_i^+)$$

$$f_i(x) + d_i^- - d_i^+ = b_i, \qquad i = 1,..,K, \qquad x \in C$$

φ_i and ω_i represents the weights of $d_i^-$and d_i^+,respectively. φ_i equals $\frac{\theta_i}{h_i}$ where θ_i and h_i represent preferential and normalizing weight related to ith goal, respectively. In this study, h_i is considered as the value of ith objective function when it is optimized, $f_i(x)$ is the goal constraint, b_i is the desired value for goal i, and C is constraints set of the linear programming model.

4. Case Study

In order to evaluate the proposed model, it is applied in a manufacturer of electrical motor. Located near the city of Tehran, factory site occupies around 70,000 m^2. More than 60 different types of electrical motors are used in a variety of products including air-conditioner, washing machines, water-cooler pumps, axial fans, etc. Despite the variety in types of manufactured products, only few of them constitute substantial physical capacity of the factory as well as financial turnovers. The relative turnover of the air-conditioner electrical motors to the overall turnover percentage is presented in Table 1:

Table 1. Relative air-conditioner turnover

	2016	2017	2018
Air-conditioner turnover	62.73	59.82	64.93
Non air-conditioner turnover	37.27	40.18	35.07

The aim of the managerial team is to improve the market-share 2-3% annually by providing better service for customers besides fulfilment of demand optimally with least financial charges. Major customers of air-conditioner electrical motors are air-conditioner manufacturers and after-market. After-market include the need for new electrical motors replaced in defected house-hold air conditioners. The major focus of this paper is after-market in which defective electrical motors should be replaced. The major after-market customers for the existing manufacturer are at central, eastern and southern regions of Iran. It is desired to expand the after-market business to the western and northwestern of the country to improve the market share. The regions desired to design the closed-loop in are depicted in Figure 2.

4.1. Numerical Results

The proposed model is coded in GAMS software and is solved on a computer with a 4Gb RAM and 2.26GHz CPU. Solving the model for all problems took less than 100 seconds. Considering OB_1 as the only available objective, the proposed model only desires to minimize the expenses regardless of maximizing market share. The basic components of the objective function include establishment costs of collection, recycling, distribution, production and disposal centers. Transportation costs are considered as a whole and include the summation of all transportation expenses. Stock out and supplier management charges are the other expenses related to the model. Table 2 presents the share of each part in the objective function.

Figure 2. Desired regions to expand after-market business

Table 2. Share of each part in the objective function

Charges		Percentage
establishment costs	**collection**	1.95%
	recycling	3.12%
	distribution	7.42%
	production	15.62%
	disposal	3.51%
Transportation costs		20.70%
Stock out		45.31%
supplier management		2.34%

In this regard, the optimal value of OB_1 will be 4187254. On the other hand, by maximizing OB_2, the net market-share will be 52.32%. This limitation arises due to the capacity restrictions. In order to solve the model with the weighted goal programming approach, the best possible values of $OB_1$and OB_2 are considered for b_1 and b_2. The following values are considered for the weighted goal programing model.

$$\varphi_1 = 0, \varphi_2 = \frac{\theta_2}{h_2}, \omega_1 = \frac{\theta_1}{h_1}, \omega_2 = 0, h_1 = 4187254, \text{and } h_2 = 52.32\%$$

To depict the results of the weighted goal programming model, different values are considered for θ_1 and θ_2. θ_1 and θ_2 depict the relative importance of objective functions. Table 3 reports the values of objective functions for different values of θ_1 and θ_2.

Table 3. Objective functions for different values of θ_1 and θ_2.

θ_1	θ_2	OB_1	$OB_2(\%)$
1	9	15506656	45.65%
2	8	14117905	42.67%
3	7	12845776	40.46%
4	6	11782968	38.42%
5	5	10453550	30.62%
6	4	9809496	24.10%
7	3	9334057	19.82%
8	2	8691488	18.76%
9	1	7892210	14.17%

By evaluating the outputs, it is perceived that the relative increase of θ_1(decrease of θ_2) will intensify the importance of the first objective function. Thus, the higher the value of θ_1, the better (lower) the value of OB_1. In the opposite direction, as the value of θ_1 decreases, the value of OB_2 improves. It could be perceived that for decision makers who desire to improve market-share a low value of θ_1 should be picked.

4.2. Sensitivity Analysis

In the model, results basically depend on the input data including s and q. A low value for s is desired for decision makers who face substantial charges for disposal centers. By lowering the s values, the system can save a substantial portion of expenses for disposal center establishment and transportation charges. Effect of s on the components of the objective function could be depicted in Table 4.

On the other hand, q values present the direct flow from recycling to distribution centers without any need for the production center. Increases in q values make it possible to avoid reworks at production centers and provide free capacity which could improve both objective functions. The results for different values of q are presented in Table 5.

Table 4. Effect of s on the components of the objective function

		$s = 0.19$	$s = 0.15$	$s = 0.11$	$s = 0.07$	$s = 0.03$
establishment costs	**collection**	2.61%	3.11%	3.53%	4.47%	4.55%
	recycling	4.51%	4.92%	5.41%	6.41%	6.48%
	distribution	7.64%	7.66%	7.82%	8.13%	8.53%
	production	17.37%	16.81%	15.78%	14.84%	14.56%
	disposal	4.79%	3.51%	3.51%	2.63%	2.63%
Transportation costs		20.70%	24.35%	24.31%	24.14%	24.02%
Stock out		45.31%	36.04%	36.40%	35.99%	35.46%
supplier management		2.34%	2.69%	3.25%	3.78%	3.99%

Table 5. Effect of q on the objective functions

	$q = 0.4$		$q = 0.5$		$q = 0.6$		$q = 0.7$	
	OB_1	OB_2(%)	OB_1	OB_2(%)	OB_1	OB_2(%)	OB_1	OB_2(%)
$\theta_1 = 1, \theta_2 = 9$	16199653	48.03%	17161967	50.53%	17933456	53.36%	18895974	55.53%
$\theta_1 = 3, \theta_2 = 7$	13508851	42.47%	14239967	44.72%	14890854	46.69%	15610108	48.67%
$\theta_1 = 5, \theta_2 = 5$	11025621	32.35%	11558578	33.65%	12218630	35.52%	12908112	37.13%
$\theta_1 = 7, \theta_2 = 3$	9795351	20.66%	10312513	21.74%	10925013	22.77%	11462724	23.78%
$\theta_1 = 9, \theta_2 = 1$	8351628	14.93%	8707880	15.55%	9197715	16.42%	9704287	17.33%

It is clear that as the value of q increases, both objective functions improve. This implies that for decision makers who desire to improve both objective functions simultaneously, the highest possible value of q is recommended.

5. Conclusion

Designing an effective remanufacturing systems is of the most importance for organizations which deal with reverse logistics. This paper presents a closed-loop supply chain design. Main components of the model include collection, disposal, recycling, and production and distribution centers. A mixed integer programing model is presented to provide an optimal decision vector. Two objective functions are taken into consideration. The first objective function desires to minimize the economic charges involved in the proposed supply chain while the second objective function maximizes the attained market-share. Both objectives are combined into a single objective function using the weighted goal programing approach. The model is applied to a real-case supply chain. The results show that if the decision maker wants to attain a high market share, a lower value for θ_1 should be selected. On the other hand, if the main goal is to reduce the financial charges in the supply chain, a higher value for θ_1 should be selected.

The main contribution of this paper is to design a proper closed-loop supply chain for remanufacturing firms. It is shown that by designing the closed-loop supply chains higher profit and/or market-share could be attained by the increase in the used-product return rate. In summary, this paper contributes to the literature on supply chains by focusing on the definitions of closed-loop supply chains. It is strictly recommended that a conscious choice should be made as different closed-loop supply chains might be appropriate in different environments based on priority of objective functions over each other.

References

Abdulrahman, M. D., Gunasekaran, A. and Subramanian, N. (2014). Critical barriers in implementing reverse logistics in the Chinese manufacturing sectors. *International Journal of Production Economics,* Vol. 147**,** pp. 460-471.

Akcali, E., Çetinkaya, S. and Üster, H. (2009). Network design for reverse and closed- loop supply chains: An annotated bibliography of models and solution approaches. *Networks,* Vol. 53**,** pp. 231-248.

Amin, S. H. and Zhang, G. (2013). A three-stage model for closed-loop supply chain configuration under uncertainty. *International Journal of Production Research,* Vol. 51**,** pp. 1405-1425.

Amin, S. H. and Zhang, G. (2014). Closed-loop supply chain network configuration by a multi-objective mathematical model. *International Journal of Business Performance and Supply Chain Modelling,* Vol. 6**,** pp. 1-15.

Chen, J.-M. and Chang, C.-I. (2013). Dynamic pricing for new and remanufactured products in a closed-loop supply chain. *International Journal of Production Economics,* Vol. 146**,** pp. 153-160.

Coronado Mondaragon, A. E., Lalwani, C. and Coronado Mondragon, C. E. (2011). Measures for auditing performance and integration in closed-loop supply chains. *Supply Chain Management: An International Journal,* Vol. 16**,** pp. 43-56.

De la fuente, M. V., Ros, L. and Cardos, M. (2008). Integrating forward and reverse supply chains: application to a metal-mechanic company. *International Journal of Production Economics,* Vol. 111**,** pp. 782-792.

Francas, D. and Minner, S**.** (2009). Manufacturing network configuration in supply chains with product recovery. *Omega,* Vol. 37**,** pp. 757-769.

Guide jr, V. D. R., Jayaraman, V. and Linton, J. D. (2003). Building contingency planning for closed-loop supply chains with product recovery. *Journal of operations Management,* Vol. 21**,** pp. 259-279.

Huang, Y. and Wang, Z. (2017). Closed-loop supply chain models with product take-back and hybrid remanufacturing under technology licensing. *Journal of cleaner production,* Vol. 142**,** pp. 3917-3927.

Jayant, A., Gupta, P. and Garg, S. (2012). Perspectives in reverse supply chain management (R-SCM): A state of the art literature review. *JJMIE,* Vol. 6**,** pp. 87-102.

Jayaraman, V. (2006). Production planning for closed-loop supply chains with product recovery and reuse: an analytical approach. *International Journal of Production Research,* Vol. 44**,** pp. 981-998.

Liu, L., Wang, Z., Xu, L., Hong, X. and Govindan, K. (2017). Collection effort and reverse channel choices in a closed-loop supply chain. *Journal of cleaner production,* Vol. 144**,** pp. 492-500.

Marasco, A., Picucci, A. and Romano, A. (2016). Market share dynamics using Lotka–Volterra models. *Technological Forecasting and Social Change,* Vol. 105**,** pp. 49-62.

Nukala, S. and Gupta, S. M. (2006). Strategic and tactical planning of a closed-loop supply chain network: A linear physical programming approach. Proceedings of the 2006 POMS Meeting, pp. 004-210.

Östlin, J., Sundin, E. and Bjorkman, M. (2008). Importance of closed-loop supply chain relationships for product remanufacturing. *International Journal of Production Economics,* Vol. 115**,** pp. 336-348.

Özceylan, E., Paksoy, T. and Bektas, T. (2014). Modeling and optimizing the integrated problem of closed-loop supply chain network design and disassembly line balancing. *Transportation research part E: logistics and transportation review,* Vol. 61**,** pp. 142-164.

Panda, S., Modak, N. M. and Cardenas-barron, L. E. (2017). Coordinating a socially responsible closed-loop supply chain with product recycling. *International Journal of Production Economics,* Vol. 188**,** pp. 11-21.

Qu, X. and Williams, J. A. S. (2008). An analytical model for reverse automotive production planning and pricing. *European Journal of Operational Research,* Vol. 190**,** pp. 756-767.

Ramezani, M., Kimiagari, A. M., Karimi, B. and Hejazi, T. H. (2014). Closed-loop supply chain network design under a fuzzy environment. *Knowledge-Based Systems,* Vol. 59**,** pp. 108-120.

Romaniuk, J., Dawes, J. and Nenycz-thiel, M. (2018). Modeling brand market share change in emerging markets. *International Marketing Review,* Vol. 35**,** pp. 785-805.

Salema, M. I. G., Barbosa-povoa, A. P. and Novais, A. Q. (2007). An optimization model for the design of a capacitated multi-product reverse logistics network with uncertainty. *European journal of operational research,* Vol. 179**,** pp. 1063-1077.

Salema, M. I. G., Barbosa-povoa, A. P. and Novais, A. Q. (2010). Simultaneous design and planning of supply chains with reverse flows: A generic modelling framework. *European journal of operational research,* Vol. 203**,** pp. 336-349.

Sasikumar, P. and Hao, A. N. (2010). Analysing interactions among battery recycling barriers in the reverse supply chain. *Enterprise Networks and Logistics for Agile Manufacturing.* Springer.

Schultmann, F., Zumkeller, M. and Rentz, O. (2006). Modeling reverse logistic tasks within closed-loop supply chains: An example from the automotive industry. *European journal of operational research,* Vol. 171**,** pp. 1033-1050.

Shaharudin, M. R., Govindan, K., Zailani, S., Tan, K. C. and Iranmanesh, M. (2017). Product return management: Linking product returns, closed-loop supply chain activities and the effectiveness of the reverse supply chains. *Journal of cleaner production,* Vol. 149**,** pp. 1144-1156.

Subulan, K. and Tasan, A. S. (2013). Taguchi method for analyzing the tactical planning model in a closed-loop supply chain considering remanufacturing option. *The International Journal of Advanced Manufacturing Technology,* Vol. 66**,** pp. 251-269.

Tang, Q. and Xie, F. (2007). A genetic algorithm for reverse logistics network design. Third International Conference on Natural Computation (ICNC 2007), IEEE, pp. 277-281.

Torabi, S. A. and Hassini, E. (2008). An interactive possibilistic programming approach for multiple objective supply chain master planning. *Fuzzy sets and systems,* Vol. 159**,** pp.193-214.

Vahdani, B., Tavakkoli-moghaddam, R., Modarres, M. and Baboli, A. (2012). Reliable design of a forward/reverse logistics network under uncertainty: a robust-M/M/c queuing model. *Transportation Research Part E: Logistics and Transportation Review,* Vol. 48**,** pp.1152-1168.

Wang, X. and Wang, Y.-H. (2013). Coordination and pricing for closed-loop supply chain based on demand and collection disruptions. *Computer Integrated Manufacturing Systems,* Vol. 19**,** pp. 624-630.

Wu, C.-H. (2015). Strategic and operational decisions under sales competition and collection competition for end-of-use products in remanufacturing. *International Journal of Production Economics,* Vol. 169**,** pp. 11-20.

Xu, J. and Liu, N. (2017). Research on closed loop supply chain with reference price effect. *Journal of Intelligent Manufacturing,* Vol. 28**,** pp. 51-64.

Zeballos, L. J., Mendez, C. A., Barbosa-povoa, A. P. and Novais, A. Q (2014). Multi-period design and planning of closed-loop supply chains with uncertain supply and demand. *Computers & Chemical Engineering,* Vol. 66**,** pp. 151-164.

Zhou, Y., Xiong, Y., Li, G., Xiong, Z. and Beck, M. (2013). The bright side of manufacturing–remanufacturing conflict in a decentralised closed-loop supply chain. *International Journal of Production Research,* Vol. 51**,** pp.2639-2651.