An Integrated Closed-loop Supply Chain Configuration Model and Supplier Selection based on Offered Discount Policies

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1. INTRODUCTION

In recent years, supply chain management is defined as the process of coordinating, improving and optimizing flows of information, goods, services and money. It is confronted with growing attention in both industry and academia. Supply chain network design (SCND) is one of the significant issues of companies' business strategy and have an influence on efficiency and performance of company for several years [1]. Closed loop supply chain (CLSC) which integrates forward and reverse activities is one of the important subjects of the SCND. Due to environmental regulations, social awareness, customers pressure and economic aspects, the reverse logistic and CLSC have gained notable attention in both industry and academia [2]. In a CLSC, the reverse logistic activities such as collecting used products, inspection and sorting, remanufacturing of recoverable products and disposal of non-recoverable products are considered along with the traditional forward logistic activities [3].

In most companies, a considerable part of product cost is related to the raw material cost [4]. The supplier selection policies are one of the important decisions that companies must integrate it with other strategic decisions. Considering the growing importance of purchasing policy, supplier selection and supplier relation management have become more strategic for companies. Most researches in this field, have investigated supplier selection problem in the forward supply chain and they have paid less attention to this issue in closed loop one [5]. Also, in most models, supplier selection is considered according to the effects of the raw materials unit cost offered by supplier on the supply chain total costs.

Nowadays, suppliers use different techniques in order to persuade buyers to buy more and create long term relationship with them. One of the importance and useful techniques is customer relation management (CRM). CRM is an enterprise approach which is used to understand and impress customer [6]. One of the
powerful and useful methods used for measuring of the customer relationship strength is RFM technique [7].
RFM is consisted of three elements of Recency (R), Frequency (F) and Monetary (M). Recency indicates the time interval between the time of the latest purchase and the present one. Frequency reflects the number of purchases in a period and monetary shows the total amount of spending in a period. The RFM has been implemented in various industries, such as retail industry, service industry, education industry, health care industry and marketing industry [8].

With regard to the matters enumerated, this paper introduces a new mathematical model for designing a multi-product, multi-stage, multi period and capacitated closed loop supply chain network (CLSCN). The proposed model integrates SCND and supplier selection problem in order to minimize the total cost. In this paper as main contribution, discount policy is formulated according to the quantity discount and loyalty of buyers and the model can hold historical data in order to configure and optimize the CLSCN.

The rest of this paper is organized as follows. Section 2 reviews the related research in the field of CLSC. The model definition is described in section 3 and the mathematical model is stated in section 4. Section 5 discusses computational results and sensitivity analysis of proposed model. In the last section, conclusions of the paper and offered topics for future studies are presented.

2. LITERATURE REVIEW

In this section, the related literature of this paper is briefly reviewed based on two main complementary categories: models which have been developed for the CLSCN design problem and the other ones which have considered supplier selection problem.

The first study in the field of integrated forward/reverse logistic was performed by Fleischmann et al. [9]. The extension of mentioned study carried out by Salema et al. [10]. Pishvae and Torabi [11] developed a multi-period, capacitated closed supply chain network model for minimization of the total cost and delivery tardiness under uncertain demands, returns, delivery times, costs and capacities. Subramanian et al. [12] formulated a MILP model for CLSCN design in order to minimize the total cost. Hatefi and Jolai [13] proposed a MILP model for an integrated forward–reverse logistics network design. A multi-objective, multi-stage and single period MILP model developed by Sahraeian et al. [14]. In addition to total cost minimization, they considered CO2 emission for environment influence as second objective. Fazli-Khalaf and Hamidieh [15] proposed a stochastic MILP model for CLSCN design to minimize supply chain total cost and maximizes social responsibility in an uncertain environment. An integrated forward and reverse supply chain network proposed by Chen et al. [16] in order to minimize the total cost and environmental pollution. Yazdi and Honarvar [17] developed a single-period, single-product, and multi-stage model for integrated CLSCN design and pricing problem. Zohal and Soleimani [18] designed a multi objectives MILP model for CLSC of gold industry. The proposed model developed the ant colony optimization algorithm to minimize the total cost and environment pollution. A multi-objective MILP model developed by Kadambala et al. [19] for maximizing the profits, optimizing customer surplus level and minimizing the energy consumption. Pedram et al. [20] formulated multi-product MILP model for an Iranian tire industry with considering uncertainty in demand, returned products and quality of returned product. Ghomi et al. [21] proposed a single objective mixed integer non-linear programming model. They considered extra inventory and lateral transshipment as resilience strategies in the model to deal with disruption risk.

In the field of supplier selection and SCND, most articles have paid attention to unit price of the suppliers raw materials. Also, a lot of articles have been published in order to select and evaluate suppliers by applying multi criteria decision making method such as analytical hierarchy process (AHP) and TOPSIS which is not the purpose of this article. Thanh et al. [22] developed a multi-stage, multi-product MILP model for forward SCND with deterministic demands. Amin and Zhang [23] addressed supplier selection problem in CLSCN in order to maximize profit and minimize defective rate. In the proposed model unit price, delivery time, and quality of purchased item are considered as important criteria for assessment and selection of them. Govindan et al. [24] developed a multi objective integrated SCND and order allocation problem. To tackle the proposed model, a novel multi-objective hybrid approach has been used. Gholamian and Taghizadeh [25] formulated MILP model for designing of the wheat supply chain. The proposed model integrated forward supply chain decisions and supplier selection in which suppliers selected according to the proposed unit price of wheat. Mota et al. [26] formulated sustainable CLSCN based on Triple Bottom Line Optimization Modeling. In the proposed MILP model suppliers are selected based on the offered unit price of raw materials. Kamali et al. [27] developed a multi-objectives MINLP model to minimize the total cost through coordination of entire system including a single buyer and multiple vendors. The proposed model which integrates the quantity discount and coordination model for addressing supplier selection issue, has been solved by the particle swarm optimization algorithm and scatter search algorithm. The supplier selection problem
in the forward distribution network addressed by Pariazar et al.\cite{27}. In the proposed model, supplier failures and inspection as supplier selection were considered with other supply chain network decision in the uncertain environment. Urata et al.\cite{28} proposed a multi-objectives global supply chain network and supplier selection problem as MILP model. They considered the CO\textsubscript{2} emission and the unit price as important factors for selecting suppliers. Cortinhal et al.\cite{29} developed multi-period, multi-product MILP model for CLSCN to minimize the total cost. They executed a computational study on a large size of problem and consider the supplier selection according to unit price of raw materials.

To the best of our knowledge, there are no mathematical model integrated CLSCN design and RFM model as CRM technique. Thus, we proposed a multi-stage, multi-period, multi-product CLSCN and supplier selection problem based on the RFM model which is capable to hold historical data and is offered by suppliers. The objective function of the model consists of the costs of production, recovery of used product, transportation, inventory holding, purchasing and operational costs.

3. PROBLEM DEFINITION

The CLSCN considered in this paper is a multi-echelon, multi-product and multi-period logistics network including suppliers, production/recovery, distribution, collection, disposal centers and customers. The structure of the proposed CLSCN is illustrated in Figure 1.

It is assumed that in the forward flow, suppliers provide raw materials for production centers according to their orders. The products are transferred to the customers via distribution centers in order to satisfy their demands. In the backward flow, the return products are sent to collection centers. The returned products are then categorized into two recyclable and unrecyclable group after inspection. The recyclable products are transferred to production/recovery centers and used as recycled raw materials for production process in these centers. On the other hand, the other ones are sent to disposal centers.

The proposed model, which is a single objective problem, attempts to minimize the total cost of the supply chain through determining locations of network facilities, determining the quantity of purchased raw material, produced productions, inventory level at distribution centers and products shipment between the facilities.

To the best of the authors’ knowledge, this paper is the first research attempting to integrate the CLSCN design and RFM model.

It has been assumed that the suppliers use RFM model in order to motivate buyers to buy more and as frequent as possible. The production centers, which are considered as customer for suppliers, purchase their required raw materials in order to satisfy their customers demand. In this paper, suppliers propose different and independent discount policies based on purchased amount and customer loyalty.

Considering RFM model to have significant reciprocal benefit for both seller and buyer, it is very important for customer to take an appropriate decision. Thus supply chain decision makers can reduce the total cost according to determination of purchasing amount and purchasing time period or behaving as loyal customer in addition to other supply chain decisions.

It should be noted that the developed model based on RFM technique can be successfully applicable to various industries, such as retail industry, service industry, finance, telecommunication, electronic commerce, etc\cite{8}. In particular, this model can be applied in supply chains in which the suppliers selection based on offered different discount policy is important issue as the other supply chain network design decisions.

4. MODEL FORMULATION

The following sets, parameters and decision variables are used in the proposed model.

Sets:

\( I \) Set of suppliers

\( J \) Set of fixed locations for production/recovery centers

\( K \) Set of possible locations available for distribution, collection, disposal centers and customers

\( C \) Set of fixed locations of customers

\( N \) Set of fixed locations of disposal centers

\( V \) Set of transportation modes

\( R \) Set of raw materials

\( P \) Set of products

\( T \) Set of time periods in planning horizon

\( H \) Set of discount levels related to purchase amount

\( Q \) Set of discount levels related to loyalty

Figure 1. The network structure of the proposed model
Parameters:

- $\alpha, \beta$: A positive number
- $\epsilon$: A very small number close to zero
- $\theta$: Slightly more than $\epsilon$

Decision variables:

- $Q_{F_{jpt}}$: Quantity of finished products $p$ shipped from production/recovery center $j$ to distribution center or hybrid processing facility $k$ through vehicle $v$ in time period $t$
- $Q_{F_{kpt}}$: Quantity of products $p$ shipped from distribution center or hybrid processing facility $k$ to customer $c$ through vehicle $v$ in time period $t$
- $Q_{F_{npt}}$: Quantity of used products $p$ shipped from customer $c$ to collection center or hybrid processing facility $k$ through vehicle $v$ in time period $t$
- $Q_{S_{ik}}$: Quantity of non-recoverable products $p$ shipped from collection center or hybrid processing facility $k$ to disposal center $n$ through vehicle $v$ in time period $t$
- $O_{X_{i}}$: Quantity of raw material $r$ shipped from supplier $i$ to production/recovery center $j$ according to discount policy according to level $h$ in time period $t$
- $O_{Y_{i}}$: Quantity of recovered raw material $r$ used in product $p$ and utilized in hybrid processing facility $k$, otherwise 0
- $O_{W_{i}}$: Quantity of finished products $p$, otherwise 0
- $D_{P_{kpt}}$: Quantity of products $p$ shipped from production/recovery center $j$ through vehicle $v$ in time period $t$

4.1. Mathematical Model

\[
\text{Min Z} = \sum_{k} \sum_{j} \sum_{p} c_{jpt} \times Q_{F_{jpt}} + \sum_{k} \sum_{n} \sum_{p} c_{npt} \times Q_{F_{npt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}} + \sum_{k} \sum_{p} \sum_{q} c_{kpt} \times Q_{F_{kpt}}
\]
The objective function (1) aims to minimize the total cost which includes fixed costs for opening distribution, collection/inspection and hybrid centers, production and recovery cost in production/recovery centers, distribution costs of finished products, collection and quality control costs for used product in collection centers, disposal costs for non-recyclable products in disposal centers, inventory holding costs in distribution centers, transportation costs of products between facilities, raw materials purchasing cost from suppliers and cost saving related to discount offered by supplier based on purchasing amount and customer loyalty.

The constraints of the proposed model are expressed in details as follow:

\[
\sum_{j} \sum_{i} p_{j} \times QF_{ij} + \sum_{k} \sum_{p} p_{k} \times QF_{kp} - \sum_{j} \sum_{i} p_{j} \times QF_{ij} = 0 \quad \forall r, j, t \tag{2}
\]

\[
I_{kp} = I_{kp(r-1)} + \sum_{j} QF_{jkp} - \sum_{k} QF_{kpr} \quad \forall k, p, t \tag{3}
\]

\[
\sum_{k} QF_{kpr} = d_{kpr} \quad \forall c, p, t \tag{4}
\]

\[
QF_{kpr} = d_{kpr} \times x_{p} \quad \forall c, p, t \tag{5}
\]

\[
\sum_{k} \delta_{p} \times QF_{kpr} = \sum_{k} QF_{kpr} \quad \forall k, p, t \tag{6}
\]

\[
\sum_{c} \sum_{i} (1 - \delta_{p}) \times QF_{icp} = \sum_{a} QF_{iap} \quad \forall k, p, t \tag{7}
\]

\[
\sum_{j} QF_{ijh} \leq p_{ij} \times S \forall i, r, t \tag{8}
\]

\[
\sum_{k} QF_{kpr} \leq c_{j} \times f_{j} \quad \forall j, p, t \tag{9}
\]

\[
\sum_{k} QF_{kpt} \leq c_{j} \times f_{j} \quad \forall j, p, t \tag{10}
\]

\[
I_{kp} + \sum_{k} QF_{kpr} = c_{kpr} \times OX_{k} + c_{kpr} \times OW_{k} \quad \forall k, p, t \tag{11}
\]

\[
\sum_{c} QF_{icp} = c_{icp} \times OX_{k} + c_{icp} \times OW_{k} \quad \forall k, p, t \tag{12}
\]

\[
\sum_{k} QF_{kpt} = c_{kpt} \quad \forall n, p, t \tag{13}
\]

\[
OX_{k} + OW_{k} + OU_{k} \leq 1 \quad \forall k \tag{14}
\]

Constraint (2) states that the sum of the flows entering each production/recovery center from all suppliers and collection/inspection centers are equal to flow exiting each production/recovery center. Constraint (3) shows the inventory balance limitation in distribution centers for finished products. Constraint (4) guarantees customer demands satisfaction. Constraint (5) represents that the specific ratio of customers’ used products are collected by collection/inspection centers. Constraints (6) and (7) show that after inspection and quality checking if collected and used products are recyclable, they will be sent to production/recovery center, otherwise they will be transported to the disposal centers. Constraint (8) shows the maximum capacity of supplier for supplying the raw materials. Constraints (9) and (10) show the capacity of production and recovery in production/recovery center. Constraint (11) shows capacity of distribution center or hybrid processing facility. Constraint (12) the same as constraint (11), is associated with maximum collecting capacity of each collection/inspection center or hybrid processing facility. Constraint (13) shows the capacity of disposal center. Constraint (14) guarantees that, If needed only one of three distribution center, hybrid processing facility or collection center will be opened at a same potential location.

\[
\sum_{i} QF_{ijh} \leq \sum_{i} QF_{ijh} \leq \left( p_{ij(h+1)} - 1 \right) \times Z_{ih} \tag{15}
\]

\[
\sum_{i} Z_{ih} \leq 1 \quad \forall i, r, t \tag{16}
\]

Constraints (15) and (16) are related to monetary as one of the elements of RFM technique and refer to quantity discount offered by supplier according to purchasing amount.

Constraint (15) guarantees that purchasing amount stays within quantity discount intervals. Constraint (16) states that only one quantity discount level is considered for the purchasing amount.
A set of constraints (17) are pertinent to frequency and recency elements of RFM technique. It is assumed that purchase in the first two last periods results in benefiting from discount considered for customer loyalty. This assumption refers to frequency element of RFM technique. It should be noted that it is possible to consider more recent periods in the model. The purchasing in the previous period (t-1 period) has more discount in comparison to purchasing in t-2 period. This condition implies the recency element of RFM technique which means that the closer the purchase the more the discount.

For the purpose of modeling customer loyalty in the proposed model, a variable SLC is defined which is the linear combination of supplier selection in the two last periods (Equation (18)) wherein \(\alpha > \beta > \theta > \varepsilon > 0\). Therefore, there are four conditions in association with specific supplier in current time period (t) as follows: 1) the supplier has been only selected in time period t-1, 2) the supplier has been selected in time period t-2, 3) the supplier has been selected in both time periods t-1 and t-2, and 4) the supplier has not been selected in both time periods t-1 and t-2. For this reason, binary variable \(DP_{irqt}\) is considered for the each of the above mentioned four conditions which indicates that whether the supplier gives loyalty discount level \(q\) based on four conditions or not. Constraint (17) also guarantee that in each time period, at most only one binary variable \(DP_{irqt}\) will be 1 for the specific supplier and the raw material. Generally, the set of above mentioned constraints represent the condition listed in Table 1.

\[
QF_{k,p,r,t} \geq 0
\]

\[
\forall \ i,j,k,\varepsilon,\pi,\rho,\nu,\theta
\]

\[
O_{k} \cdot O_{k} \cdot O_{k} \cdot O_{k} \cdot Z_{irt} \cdot DP_{irqt} \cdot S_{irt} \in [0,1]
\]

\[
\forall \ i,j,k,r,\theta,q,t
\]

Constraints (19) and (20) enforce the non-negativity and binary conditions of decision variables, respectively.

### 4.2. Model Linearization

As can be seen, the last term of objective function is nonlinear, so that two binary and continuous variables are multiplied to each other. In order to convert nonlinear model to linear one, a novel method developed by Vidal and Goetschalckx [30] is used. According to this method, a new continuous variable is used instead of multiplying two binary and continuous variables. In the last term of objective function, continuous variable \(QS_{ijrht}\) is multiplied to binary variable \(DP_{irqt}\). The following Eq. (21) is replaced with nonlinear part of objective function and the set of constraint (22) should be added to the model.

\[
\sum_{i,j,r,l,u,t}^n w_{ijrht} \cdot DP_{irqt} \cdot U_{ijrht}
\]

\[
U_{ijrht} \leq M \cdot DP_{irqt}
\]

\[
U_{ijrht} \leq QS_{ijrht}
\]

\[
U_{ijrht} \geq QS_{ijrht} \cdot (1 - DP_{irqt}) \times M
\]

\[
\forall \ i,j,r,h,q,t
\]

Afterwards, by changing the nonlinear part of objective function with linear one and adding new related set of constraint, the proposed model is converted to linear programming model and can be solved.

### 5. COMPUTATIONAL EXPERIMENTS

To appraise validity and performance of the proposed model, the numerical example selected from literature, is solved and the related result are described in this section. The specifications of the test problem are as follows:

\[
|I| = 2, |J| = 2, |K| = 3, |\varepsilon| = 4, |N| = 1, |P| = 2, |R| = 2, |H| = 4, |Q| = 4, |V| = 3 and |T| = 4.
\]

The parameters of test problem are generated randomly according to the uniform distributions. The model was solved using the CPLEX solver provided via IBM ILOG CPLEX 12.6 on a computer of Intel core i3 3.30 GHz and 4.00 GB of RAM.

#### 5.1. Model Validation

To illustrate the validation of the proposed CLSCN design model, sensitivity analysis is carried out on the parameters of the holding cost and the raw material cost. As expected, with increasing raw material cost, the total cost is increased (Table 2). On the other hand, given that the customers demand must be fully satisfied, the total amount of purchased raw materials have not been changed.

### TABLE 1. Condition of supplier selection policy

<table>
<thead>
<tr>
<th>Supplier selection policy</th>
<th>Activation of related loyalty discount variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLC &lt; (\beta)\n(S_{v(t-1)} = 0, S_{v(t-2)} = 0)</td>
<td>(DP_{\alpha \beta} = 0, DP_{\alpha \nu} = 0, DP_{\alpha \theta} = 0).</td>
</tr>
<tr>
<td>(\beta \leq SLC &lt; \alpha)\n(S_{v(t-1)} = 0, S_{v(t-2)} = 1)</td>
<td>(DP_{\alpha \beta} = 1, DP_{\alpha \nu} = 0, DP_{\alpha \theta} = 0).</td>
</tr>
<tr>
<td>(\alpha \leq SLC &lt; \alpha + \beta)\n(S_{v(t-1)} = 1, S_{v(t-2)} = 0)</td>
<td>(DP_{\alpha \beta} = 0, DP_{\alpha \nu} = 1, DP_{\alpha \theta} = 0).</td>
</tr>
<tr>
<td>(\alpha + \beta \leq SLC)\n(S_{v(t-1)} = 1, S_{v(t-2)} = 1)</td>
<td>(DP_{\alpha \beta} = 0, DP_{\alpha \nu} = 0, DP_{\alpha \theta} = 1).</td>
</tr>
</tbody>
</table>
TABLE 2. Validation test on the raw materials cost

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Raw material cost</th>
<th>Supply chain total cost in each period</th>
<th>Supply chain total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>3,484,658</td>
<td>3,499,550</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>3,564,218</td>
<td>3,579,450</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>3,643,778</td>
<td>3,663,075</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>3,723,338</td>
<td>3,739,250</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
<td>3,802,898</td>
<td>3,819,150</td>
</tr>
</tbody>
</table>

Also, Figure 2 shows that by the holding cost increasing, the total inventory level of finished products in distribution centers are diminished in all time periods. These results reveal the validation of the model.

5. 2. Sensitivity Analysis

The inventory level of finished products in distribution centers is analyzed before and after considering only the M element of RFM technique. According to Figure 3, the inventory level is increased in the first time periods and then decrease in inventory level in the last time period is observed. As expected in order to gain the profit of discount, more raw materials are purchased and so the inventory level of finished products is increased in the first time periods.

In this part, sensitivity analysis of RFM technique are conducted. For this purpose, the effect of considering RFM technique on the total costs, the inventory holding costs and the raw materials purchasing cost is investigated. As it can be seen in Table 3, the raw material purchase cost is significantly decreased after considering discount based on RFM technique. On the other hand, the inventory holding costs in distribution centers are increased by including mentioned discount. The increase in inventory costs is less than the reduction in raw material purchasing cost and hence the total cost is finally dropped by 2.15%.

To analyze the considering of the discount based on the RFM technique, it is assumed that the first supplier proposes discount only for purchasing amount which is related to the M element. The second supplier considers lower discount for purchasing amount in comparison to the first supplier (on average 26% less discount), but on the other hand considers discount for the loyalty as R and F elements of RFM technique.

It is assumed that supplier considers separate discount rate in current time period for purchasing in time period t-1, time period t-2 and both of the mentioned time periods simultaneously. As it can be seen in Figure 4, purchase from the supplier 1 is done only at time period 1, because of considering large discount for purchase amount. On the other hand considering that supplier 2 offers the loyalty discount, purchase from this supplier is done at all time periods and generally, about 87 percent of purchased raw materials are related to the supplier 2.

TABLE 3. Effect of considering discount on supply chain costs

<table>
<thead>
<tr>
<th>Test condition</th>
<th>Supply chain costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>purchasing cost</td>
</tr>
<tr>
<td>Regardless of discounts</td>
<td>3,189,200</td>
</tr>
<tr>
<td>Considering discount</td>
<td>2,877,564</td>
</tr>
</tbody>
</table>

Figure 2. The effect of changing the inventory holding cost on the total inventory level at the distribution centers

Figure 3. Comparison of inventory level at distribution centers before and after considering discount
Various solutions can be obtained according to the inventory holding costs at distribution centers, discount policies offered by suppliers, customers demand and capacity constraints. Considering discount policy based on the R and the F elements of the RFM technique causes beneficial and loyal relationship with suppliers. This relationship is profitable for both of the suppliers and buyers, so that the buyers gain advantages and attain discount of loyalty and on the other hand sellers preserve their market share and even expand it. Including discount policy based on the M element of the RFM technique results in determining optimal order quantity with regards to trade of supply chain costs such as inventory holding cost and purchasing cost. In general, taking into account the RFM technique in CLSCN leads to reduction of supply chain total costs in comparison to a model wherein the RFM discount policy is not considered. According to the proposed model, supply chain decision makers are capable of choosing best suppliers, intelligently determining how to communicate with them and determining order quantity and other supply chain decisions such as inventory level in distribution centers and transportation modes.

6. CONCLUSION

In this paper, a novel mathematical model is developed for multi-period, multi-stage, multi-product and capacitated a CLSCN to minimize the total cost of the supply chain. Nowadays, the supplier selection problem as strategic decision has significant effects on the performance of supply chains. The suppliers’ aim is to create long term and profitable relationships with customers and to this end, they offer different discount policies to persuade buyers to buy more and have long term relationship. Therefore, this paper integrates the CLSCN and supplier selection problem according to discount considered for purchase amount and the loyalty.

To appraise model validation and show its application, some sensitivity analyses were performed by CPLEX. Effects of considering discount policy on supply chain decision were illustrated. Results showed that supply chain decision makers prefer to order in large size and even increase the inventory level in distribution centers in order to benefit from quantity discount. Also, they have created long term relationship with a supplier which considers loyalty discount. Obtained results demonstrate that designing and modeling discount policy based on the RFM technique have significant effect on supply chain total costs reduction (2.15% reduction). The proposed model is able to optimize production plan, transportation mode, inventory levels, flows between facilities, purchase amount and how to behave as loyal customer in order to benefit from offered discount policy for achieving the lowest cost.

Developing exact methods or optimized meta-heuristic algorithm for solving the model in large scale due to high computational time can be a challenging issue for future study. In addition, considering uncertainty in the model parameters can be applied especially in the customers demand and the discount rate to make the model more sustainable and flexible. Also, developing integrated model of pricing problem and proposed model can be proposed as future study.

7. REFERENCES


Figure 4. The effects of considering different discount policies on purchase amount from each supplier.


An Integrated Closed-loop Supply Chain Configuration Model and Supplier Selection based on Offered Discount Policies

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Keywords: Supplier selection, Closed-loop Supply Chain Network, Loyalty, Discount

In this paper, a mathematical model for the problem of an integrated closed-loop supply chain network is developed. The model considers the selection of suppliers based on discount policies offered by them, which are based on the RFM (Recency, Frequency, Monetary) model. Unlike other models of supply chain network design that focus more on the cost of raw materials and a significant discount, the proposed model considers the discount policy based on customer loyalty, along with the cost of raw materials and a significant discount, in selecting the best supplier. The goal of this paper, which is a mathematical programming model, is to minimize the total costs of the supply chain network through the location of facilities, production planning, inventory levels, flow between facilities, type of transport, purchase, and the selection of the best supplier. Based on the RFM model, the effects of discount policies based on customer loyalty and purchase on costs and supply chain decisions are examined. The results of the computational and economic efficiency of the proposed model are presented.