INTEGRATED MODELING AND OPTIMIZATION OF MATERIAL FLOW AND FINANCIAL FLOW OF SUPPLY CHAIN NETWORK CONSIDERING FINANCIAL RATIOS

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Abstract. In today's competitive environment, businesses are searching for tools and instruments, using which they can reduce their costs as much as possible in order to increase profits. The supply chain as a process which requires comprehensive management can be a great help in this regard for companies. The majority of approaches evaluated in supply chain primarily deal with logistic and material flows and neglect a lot of financial dimensions. This is while the financial flow in the supply chain can play an effective role in improving and optimizing the chain and contribute heavily to the profitability of the business. This paper deals with the financial flow of the supply chain model along with the material flow. It indicates that while optimizing the financial flow will provide the maximum profit for the plant, through simultaneous modeling of both these flows, better results can be reached. On the other hand, optimizing the financial flow allows the financial factors to be also considered in the model, which helps the business reach higher profits and better management of financial processes, which in turn shifts the business towards a modern industrial unit.

1. **Introduction.** In the past, the diversity and the number of goods and services were more limited and the distance between the manufacturers and the consumers was much shorter. Hence, the distribution of goods was not considered to be a very important issue; the retailers were able to easily acquire the goods they needed. However, nowadays, with the increase in the diversity of goods, the increase in the number of consumers and their distance from the manufacturers, the importance of dealing with a proper manufacturing and distribution system has soared. On

the other hand, with the growing competition among the companies in the market, businesses strive to reach a more stable position, making the objective of the competition to include differentiating themselves from the competition and outperforming them.[K. Nurjanni and et al. 2017] This intense competition in the modern era has forced the managers and leaders of businesses and organizations to utilize modern science and technology to reach this objective. Hence, increasing the efficiency and reducing the costs are the two most important factors for acquiring a bigger share in the competition. Based on these, supply chain approaches and its management has emerged and forced organizations to implement this approach in the organization and take steps to utilize it. These approaches can be summarized as the flows present in the supply chain (material, information, and financial flows) and plants try to implement and optimize these flows in the workspace to be able to increase productivity.[L.Moussawi nad et al,2014]

Most previous study that Expressed in the literature review deals to material flow of supply chain and network of multiproduct and multilevel supply chain that are looking for specific purpose such as maximizing profit or minimizing cost. On the other hand the little research has been done in the area of financial flow and most of paper in this area deals to Financing and optimizing the economic value chain also many studies neglect financial factors such as interest rate and asset-liability, interest is so important factor in income of company and its so important for analysis to obtain considerable results. As well as more studies had been neglected the asset-liability as key role in change in equity but in this research we consider all aspects mentioned

This study tries to discuss the issue of material flow and financial flow in the supply chain. Research related financial supply chain are very low and not considered with material flow. So this issue is gap in these researches related to supply chain

2. **The Supply Chain.** Supply chain is considered to be a set of relations among suppliers, manufacturers, distributors, and retailers, which facilitates the conversion of raw material into the final product. The supply chain involves the mutual impacts among these members. Generally, the supply chain is divided into three primary levels of supplier, manufacturer, and distributor. These levels are expandable and other elements such as retailers, storage, and financial intermediaries can also be considered. Each one of these levels can include one or more completely independent units. For instance, at the supplier level, a number of apparently independent plants are responsible to supply different components and parts of a single product.[Cheng chan, Wu Yen.2013]

Scholars and researchers of supply chain, refer to the relations, interactions, and mutual impacts among various members of the chain as the flow, and divide it into three main areas: (1) material or physical flow, (2) information flow, and (3) financial flow.

2.1. **Material Flow.** Material flow refers to the physical and visible products, components, and shipments moved among the members and various levels of the chain. Physical flow is always the most obvious flow along the chain and indicates the process of changing and converting raw materials into the final product required by the customer. Generally, the physical flow is unidirectional from the supplier to the ultimate customer.[Cardon and Alvarez, 2011]

2.2. **Financial Flow.** Another key issue in the supply chain involves the financial flows among the business people involved in the chain. These people include the bulk suppliers of raw material, the manufacturers, wholesalers, distributors, carriers, retailers, banks, and credit associations. Generally, materials, components, and final products flow downstream (of course, returned products flow upstream) and the financial flow is directed upstream (while the information flow is in both directions). Therefore, for a supply chain system managing the upstream financial flow is as important as managing the downstream flow of products and goods. There are fundamental differences between downstream flow of goods and the upstream financial flow. In the downstream flow, storing goods and material will increase the inventory costs; while, in the upstream financial flow, storing money will lead to profits.[Kristofik and Kok.2012]

2.3. **Information Flow.** This issue involves the type of connections and information of organizations and various members of the supply chain. This flow starts at the moment a customer places an order or even before that when the order and market demand is predicted and moves in both directions along the chain in the form of bidirectional feedback.[Ivanovic and Fuxman.2010]

3. **Reviewing the Literature.** In this section, the previous literature is divided into two main categories. The first category involves the material flow of the supply chain, which includes the majority of previous studies. The second category is related to the studies on the financial flow of the supply chain, which is a very small category.

3.1. **Material Flow.** In global markets, businesses increasingly try to find strategies which give them competitive edge over their competitors. Cohen and Lee (2012) proposed a deterministic mixed integer nonlinear mathematical programming model based on the techniques of economic order values. In their study, they expanded the policy of appropriate resource allocation. After paying the taxes for the manufacturing facilities and the distribution centers, the profits were maximized through the target function of the model. Moreover, management restrictions, fixed logical restrictions, and raw material requirements as well as proper allocation were considered.

In a study, Valdes and Alvarez (2011) proposed a two-objective model for designing a two-level manufacturing-distribution network by considering manufacturing plants, distribution channels, and the customers. The most important contribution of this study to the literature is considering uncertainty of customer demand and the utilization of transportation vehicles among the layers of the chain by considering the minimization of costs and maximization of the quality of services provided for the customers as the criteria for the performance of the chain.[3]

In another study, Shi and Jicahng Sh (2012) proposed a model for designing the supply chain of manufacturing for orders. The model decides on the location of distribution centers in the sense that which center is allocated to which retailer. The demand is considered depending of the progress time and the balance between them and the logistic costs. Since obtaining a precise solution for this type of problem is difficult, Lagrange- based algorithms were proposed for this problem. [21]

Pham and Yenradee (2017)proposed alternative approach to formulate manufacturing network design problem. Features, such as multi-echelon, multi-commodity,

products structure, and manufacturing process, are taken into consideration as characteristics of the studied environment, they had said uncertainty factors are also integrated to the model by employing possibilistic theory. And they didnt use financial factor in their study[16]

Badri and Bashiri (2013) proposed a model for designing a multi-level and multi-product supply chain where time difference for tactical and strategic decisions were considered. In the proposed model, the chain expansion is carried out for the obtained accumulated profit and the externally supplied resources. A number of properties such as the minimum and maximum rates of using facilities, using public and rented storage were considered in this model. Moreover, in order to solve it, an approach based on Lagrange's relaxation method is developed. [2]

In a study, Chang and Yen (2013) studied a chain where the manufacturer simultaneously determined the price of the product and the design of the supply chain for maximizing the expected profit under the probable demand based on price. They proposed the L-shaped decomposition, which is a marketing method, to solve it and showed that the original problem remains a planning problem. Moreover, the pricing decision balanced expected income and the expected operational cost by increasing the expected profits. The model shows that integration of pricing and operational planning will lead to higher expected profits compared to individual decisions.[10]

Rostamzadeh, Sabaghi and Sofian (2015) studied and compared the existing models of supply, production and distribution in SC and propose a model which integrates criteria in supply chain management (SCM).they , propose a new method for calculation of fitness function in genetic algorithm (GA) process, This research also simulated the real company SC operations, and determines the most effective strategic and operational policies for an effective SC system. The result obtained from this model shows that it is robust. This model can also be applied to other industrial environments with slight modifications.

3.2. **Financial Flow.** The issue of the financial flow of the supply chain has not yet attracted a lot of attention from researchers. Hence, due to the lack of consensus among the scholars regarding this issue, classifying the literature of financial flow of the supply chain seems difficult. In the following, some of the previous studies regarding this issue are presented.

Kristofik, Kok, and Hoff (2012) deal with the general and relatively comprehensive explanations about the main concepts of managing the financial supply chain. In this study, the authors try to provide definitions and explanations about the financial supply chain, the management of the working capital, the financial supply of the supply chain, the purchase-payment cycle, and the order-payment cycle in order to provide a complete background in a simple language. Later in the study, the results of interviewing with managers and investigations of databases in small and medium construction companies in Netherlands and Slovakia are presented.[10]

Nurjanni and et al (2017) said that For decades, the main focus of SCM has been on efficient ways of managing the flows through complex networks of supplier, producers and customers.in their study. They proposed a new green supply chain (GSC) design approach has been proposed to deal with the trade-offs between environmental and financial issues in order to reduce negative impacts on the environment caused by the increasing levels of industrialization[15]

Raghavan and Mishra (2014) evaluated the financial supply of a supply chain involving a manufacturer and a seller with limited capital provided by a lending

financial institution. In their study, the model was evaluated under two scenarios: (1) the financial institution is aware of the relation between the manufacturer and the seller (which is called joined venture), (2) the financial institution is not aware of this relationship. Later in the study, using mathematical proofs and numerical studies it is proved that when the initial capital of the seller and manufacturer is low, joint venture will increase the profitability of the three organizations involved in the chain. [18]

The study carried out by Longinidis and Georgiadis (2011) is among the first studies carried out in the field of designing a supply chain network which considers the financial aspects under conditions of uncertainty. The main objective of this study was to maximizer the economic added value of the chain. The variables of the problem include the locations of the storage spaces and the distribution of a four-level supply chain. The programing model used is the mixed-integer linear programing (MILP) method and the uncertainty is represented using the scenario-based method. Authors use standard branch and bound method for solving the problem. Finally, a case study is presented for showing the applicability of the model.[13]

Gupta and Dutta (2011)use the literature on inventory to optimize the liquidity available in the organization. In other words, the cash input and output flows into and out of the organization are comparable to the product flow. Hence, the level of liquidity must be at an optimal level much like the cash available in the organization (not low so that the organization faces the costs of shortage and not high so that the organization faces storing costs). [6]

Moussawi, Dbouk, and Osman(2013) presented one of the most up to date studies which integrates the inventory and financial concepts. The authors model the minimization of total costs of a three-level supply chain including manufacturers, sellers, and the bank (as a financial intermediary). These costs include the inventory costs and financial costs such as purchase and order costs, inventory costs, storage costs, borrowings, financial transactions, opportunities, capital shortage, and so on for the supplier, and the seller as well as the bank's financial costs. [12]

The study carried out by Longinidis and Georgiadis (2011) proposes a model for designing a supply chain network. They expand the available models by involving the financial issues as financial ratios and considering uncertain demands. Furthermore, Mussawi and Jaber (2014) evaluate the problem of finding optimal operations (order amount and the payment time of the supplier) using cash management integration. They consider the problem as a non-linear problem and propose a procedure for finding the optimal solution. [13]

B.Marchi et. al (2016) states that joint economic lot size model allows investments financed cooperatively by the members of the supply chain. They consider a two-stage single-vendor single-buyer supply chain and assumes that the vendor has the option to invest in increasing its production rate. The outcome of these attempts to improve production capabilities, however, is uncertain and subject to an investment success probability. Due to different access to capital, the vendor and the buyer may also share the investment and the outcome uncertainty, which can be beneficial to both parties.

The current study utilizes the above-mentioned studies for determining financial factors and the target function of the financial flow. As mentioned in the above studies, many studies neglect financial factors such as interest rate and asset-liability, which the current study uses.

4. **Statement of the Problem.** In today's growing world, multinational and international corporations are faced with challenges for evaluating and shaping the manufacturing and distribution systems and strategies in order to minimize costs, maximize net profit, and minimize the delivery time. Under such conditions, accounting for all the factors influencing the chain seems necessary to reach a higher consistency between the proposed models and the real world scenarios.(Ramezani and Karimi,2014)

Logistics or the integrated system of manufacturing and distribution is one of the factors linking various parts of the organizations. The logistic components of the organization include the following:

(1) The supplier;
(2) Manufacturing plant;
(4) Distribution centers; and
(5) The customers.

The effective and efficient movement of products from the location of raw materials to the transportation facilities, manufacturing and assembling plants, distribution centers, retailers, and customers has become more and more sensitive in today's competitive environment. Decisions related to locating facilities is an integral element in strategic planning for a wide range of private and public companies. Moreover, tactical decisions such as planning the transportation of goods, planning the manufacturing process, and determining the size of the inventory in storage spaces are also very important.

The main objective of the current study is to propose a model for designing a multi-level supply chain utilizing an integrated model involving various decisions at different levels. On the other hand, as mentioned earlier, besides the flow of products and manufacturing, the supply chain also includes the financial flow. Generally, the proposed model not only accounts for decision integration, but it also accounts for manufacturing and financial flows. This model will enter financial flows into the model by considering a set of variables and will analyze the effects of these financial flows on other activities and decisions of the chain and evaluates the relationship between manufacturing and financial flows (Elgazzer and et al 2012)

It is worth mentioning that in the above-mentioned financial approach, the flows are not accounting flows; rather when the cash is received or the payment is done, they will be considered as financial flows. Moreover, profitability cannot necessarily be presented as the target function since it is possible that it can maximize the company's profitability management, but in this course it will exert too much risk on the company. Therefore, in the model, changes in equity will be considered as the target function which is represented by the financial approach in this study.

There have been many theories for changes in equity and this study utilizes the theory of property. This theory argues that assets belong to owners and liabilities are their responsibilities, the profit obtained will lead to a net increase in the assets (or the net equity). Therefore, it will be calculated using the following formula:

$$\text{Change in equity} = \text{total assets} - \text{total liabilitie}$$

5. **Hypotheses.** The model considers the number of layers that are located as well as the number of layers that are not located (such as customers). The hypotheses are formulated in a way that the material flow and the product flow is not allowed between facilities located in a single layer. Moreover, the input and output flows into and out of each facility will be equal.

The product flow entered into each one of the facilities in each layer of the chain cannot exceed the corresponding operational capacity. On the other hand, the effective presence of financial flows will be applied to the chain, which limits the manufacturing flows and other decisions in the network. The inclusion of financial flows is in a way that by considering a set of variables in the model, decisions about the input and output monetary flows will be made in each time period. In other words, in this model, there are financial and cash restrictions so that these flows are inseparable from manufacturing flows.

6. **The Proposed Model.** The model proposed in this study is a single-product multi-period model where are the parameters are absolute. Moreover, the distributors offer different prices for various customers of their products in different time periods. The supply chain network's framework is presented in Figure 1. As can be seen from this figure, there are relations and links between suppliers and the customer through various intermediary layers of plants, storage, and distributor.
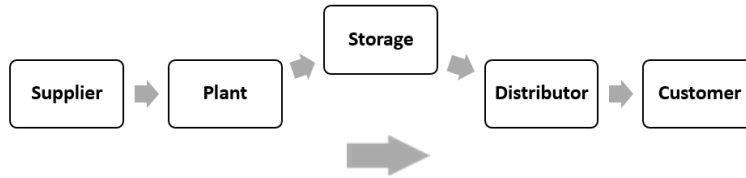

FIGURE 1. The Selected Supply Chain

In this network, the material flow can only occur between two consecutive levels of the network layers. Moreover, there is no interaction between the facilities in each layer. The proposed model is a model for designing a single-product multi-period supply chain which plans for integrating the facilities. Besides product flows, this model also considers the financial flows of the network.(Ramezani and Kimiagari.2014)

At this point, the modeling of the study will be carried out. At first, the logistic restrictions are discussed. Then the financial restrictions will be explored. Then, the financial and logistic restrictions are integrated and finally the target functions of material flow and financial flow in the supply chain will be discussed.

6.1. **Logistic Restrictions.**

$$\sum_s SPQ_{spt} = \sum_d PDQ_{pdt} + PPQ_{pt} \qquad \forall\, p, t \tag{1}$$

Equation 1 shows that for each machine and in each period, the total products flow from all the suppliers to the plant is equal to the total products flow from the plant to the distribution and storage centers.

$$PPQ_{pt} + PIR_{r(t-1)} = \sum_d IPQ_{pdt} + PIR_{pt} \qquad \forall\, p, t \tag{2}$$

Equation 2 shows that for each plant and in each period, the sum of products flow from the plant to the storage and the inventory remained from previous period is equal to the sum of product flows from the plant's storage to all the distribution centers and the remaining inventory.

$$\sum_p PDQ_{pdt} + \sum_p IPQ_{pdt} = \sum_c DCQ_{dct} \qquad \forall\, d, t \tag{3}$$

Equation 3 shows that for each distribution center and in each period, the sum of product flows from all the machinery and the plant's inventory to the distribution center is equal to the sum of product flows from the distribution center to all the customers.

$$\sum_d DCQ_{dct} = Demond_{ct} \qquad \forall\, c, t \tag{4}$$

Equation 4 shows that the demands of the customer in each period must be fulfilled.

$$\sum_p SPQ_{spt} \leq SC_{st} \qquad \forall\, s, t \tag{5}$$

Equation 5 shows that for each supplier and in each period, the sum of product flows from the supplier to all the machinery cannot exceed the capacity of the supplier.

$$\sum_d PDQ_{pdt} + PPQ_{pt} \leq PC_{pt} \times W_{pt} \qquad \forall\, p, t \tag{6}$$

Equation 6 shows that the sum of product flows from the plant to the distribution centers and storage cannot exceed the manufacturing capacity of that plant.

$$PIR_{pt} \leq IP_{pt} \times W_{pt} \qquad \forall\, p, t \tag{7}$$

Equation 7 shows the capacity of the plant's inventory in each period.

$$\sum_c DCQ_{dct} \leq DC_{dt} \times Y_{dt} \qquad \forall\, d, t \tag{8}$$

Equation 8 shows that the total input flow into each distribution center cannot exceed the capacity of the corresponding equipment.

$$W_{p(1-t)} \leq W_{pt} \qquad \forall\, p, t \tag{9}$$

$$Y_{d(t-1)} \leq Y_{dt} \qquad \forall\, d, t \tag{10}$$

Equations 9 and 10 show that after the installation of equipment, they cannot be closed down.

6.2. Financial Restrictions.

$$Cash_t = Cash_{t-1} + ExnCash_t + Crdcash_t + Scucash_t - \sum_{t' \leq t} MPay_{tt'} \tag{11}$$

$$- \sum_{t' \leq t} PPay_{tt'} - \sum_{t' \leq t} HPay_{tt'} - \sum_{t' \leq t} TPay_{tt'} - Div_t + others_t \qquad \forall\, t$$

Equation 11 shows that the cash in each period equals the cash in the previous period ($Cash_{t-1}$), exogenous cash obtained from selling products, fixed assets and accounts received through collaterals ($Exncash_t$), net cash obtained from borrowed money or the cash deposited on credit cards ($Crdcash_t$), net cash obtained from or paid by stock transactions ($Scucash_t$), paying the costs of materials, transportation, movement, manufacturing paid in time exerted in previous periods on the

plant ($MPay_{tt'}$, $PPay_{tt'}$, $HPay_{tt'}$, $TPay_{tt'}$), dividends (Div_t), and other net cash obtained from other sources.

$$Exncash_t = \text{Re } c_{t-1_{del}} - \sum_{t-t_{del} \leq t' < t} p \lg_{t-t_{del}} + \sum_{t-t_{del} < t' \leq t} \eta \times P \lg_{t't} \qquad \forall\, t \quad (12)$$

Equation 12 shows that exogenous cash in each period equals the sum of receivable accounts corresponding to the $t - t_{del}$ period with its deadline in period t minus the total sum of receivable accounts which were secured in the period from $t - t_{del}$ to -1 , which belongs to the $t - t_{del}$ period plus the cash obtained from security of receivable accounts of the $t - t_{del} + 1$ periods with their deadline at period t.

Securities are a financial source which is based on transferring accounts receivable from the previous creditor to the new creditor. Securities are only used when we cannot obtain more credit from the bank. If our future receivable accounts are secured, then only a portion of the receivable amount, normally 80 percent, will have a deadline in that same period.

Therefore, Equation 13 indicates that the total receivable account of the period t, which has been secured from period t to the period $t + t_{del} - 1$, cannot exceed the amount of receivable accounts in period t.

Equation 14 indicates that the total credit in each period is a function of the credit in previous period, the value of the loan borrowed in period t for capital supply, the cash which is deposited into the credit account again, and the interest of the credit of the previous period.

$$\sum_{t \leq t' < t + t_{del}} p \lg_{tt'} \leq \text{Re } c_i \qquad \forall\, t \tag{13}$$

$$Crdline_t = Crdliine_{t-1} + Loan_i - \text{Re } pay_t + ir \times Crdline_{t-1} \qquad \forall\, t \tag{14}$$

Equation 15 indicates the net liquidity obtained from payments and expenditures for funding in period t.

$$CrdCash_t = loan_t - \text{Re } pay_t \qquad \forall\, t \tag{15}$$

Besides securities, a loan obtained from a bank can be another funding source which is obtained at the beginning of the period with an interest rate (IR) agreed upon by the company and the bank. In this case, the bank will force the company to limit the minimum cash ($Mincash$) and the money it receives from the bank to the $MaxCrd$. Restrictions 16 and 17 indicate this cash minimum as well as the maximum credit received in agreement with the bank.

$$Crdline_t \leq MaxCrd \qquad \forall\, t \tag{16}$$

$$Cash_t \geq MinCash_t \qquad \forall\, t \tag{17}$$

$$ScuCash_t = Scu_t - \sum_{t' > t} Iscu_{t't} + \sum_{t' > t} Cscu_{t't} + \sum_{t' < t} Iscu_{tt'}(1 + \mu_{tt'}) \tag{18}$$

$$- \sum_{t' < t} Cscu_{tt'}(1 + \lambda_{tt'}) \qquad \forall\, t$$

Equation 18 shows that in each period, the cash related to securities is equal to the sum of the money obtained from the initial portfolio of marketable shares minus the cash invested in the recent period as securities plus the cash obtained from selling marketable securities in the recent period plus all the cash obtained in the recent period through securities invested in previous periods with the investment

coefficient of $(\mu_{tt'})$ minus the securities sold in previous periods with the coefficient of $(\lambda_{tt'})$ whose deadline is the current period.

$$\sum_{t'<t} Cscu_{tt'}(1 + \lambda_{tt'}) \leq Scu_t + \sum_{t'<t} Iscu_{tt'}(1 + \mu_{tt'}) \qquad \forall\, t \qquad (19)$$

Equation 19 indicates that in each period, the total of shares sold in previous periods whose deadline is in the current period cannot exceed the cash obtained in the current period from the initial portfolio of marketable shares and the cash obtained in the current period from investing the marketable shares in previous periods.

$$\sum_{t'\geq t} \alpha_{t't} Mpay_{t't} \leq MExpns_t \qquad \forall\, t \qquad (20)$$

$$\sum_{t'\geq t} \beta_{t't} PPay_{t't} \leq PExpns_t \qquad \forall\, t \qquad (21)$$

$$\sum_{t'\geq t} \gamma_{t't} HPay_{t't} \leq HExpns_t \qquad \forall\, t \qquad (22)$$

$$\sum_{t'\geq t} \rho_{t't} TPay_{t't} \leq TExpns_t \qquad \forall\, t \qquad (23)$$

Equations 20 to 23 show the expenditures related to raw material, manufacturing, processing, and transportation with the related costs. Since our accounts payable may have delays or be on the deadline, the technical coefficients ($\alpha_{tt'}$, $\beta_{tt'}$, $\gamma_{tt'}$, $\rho_{tt'}$) are introduced into the restrictions in order to define the related levels showing whether it is delayed or it is paid on time.

Therefore, it is assumed that if the payments are on time, discounts will be obtained; otherwise, there will be no discounts.

6.3. **Integrated Restrictions.** In this section, the third set of restrictions are presented. These restrictions represent the flow of physical goods and financial flows and they also consider the profit performance and changes in equity.

$$MExpns_t = \sum_{s}\sum_{p} SPQ_{spt} \times Mat_{st} \qquad \forall\, t \qquad (24)$$

$$PExpns_t = \sum_{p}\sum_{d} PDQ \times \mathrm{Pr}\,o_{pt} + \sum_{p} PPQ_{pt} \times \mathrm{Pr}\,o_{pt} \qquad \forall\, t \qquad (25)$$

$$HExpns_t = \sum_{d}\sum_{c} DCQ_{dct} \times Ope_{dt} \qquad \forall\, t \qquad (26)$$

$$TExpns_t = \sum_{s}\sum_{p} SPQ_{spt} \times SPC_{spt} + \sum_{p}\sum_{d}(PDQ_{pdt} + IPQ_{pdt}) \times PDC_{pdt}$$
$$(27)$$
$$+ \sum_{d}\sum_{c} DCQ_{dct} \times DCC_{dct} \qquad \forall\, t$$

$$FExpns_t = \sum_{p}(w_{pt} - w_{p(t-1)}) \times EP_{pt} + \sum_{d}(Y_{dt} - Y_{d(t-1)}) \times ED_{dt} \qquad \forall\, t \quad (28)$$

$$IExpns_t = \sum_{p} RIP_{pt} \times Hop_{pt} \qquad \forall\, t \qquad (29)$$

In order to determine the cash output flows required for calculating the profits and changes in equity, it is necessary to calculate the costs of material, manufacturing, processing, transfer, installing facilities, and inventory costs, presented in Equations 24 to 29. These costs are related to accounts payable in Equations 20 to 23.

$$\text{Rec}_t = \sum_c Demand_{ct} \times \Pr ice_{ct} \qquad \forall\, t \tag{30}$$

Equation 30 shows that in each period, the accounts receivable are equal to the final sales of the products to the customers in that same period.

$$\Pr ofit = \sum_c \sum_t Demand_{ct} \times \Pr ice_{ct} - \sum_t MExpns_t - \sum_t PExpns_t \tag{31}$$
$$- \sum_t HExpns_t - \sum_t TExpns_t - \sum_t FExpns_t - \sum_t IExpns_t$$

Equation 31 shows that the profit obtained is equal to the total income from selling the products minus the costs which include the costs of material, manufacturing, transportation, processing, and implementing, installing and maintaining inventory.

$$\Delta E = \Delta SA + \Delta LA - \Delta SL - \Delta LL \tag{32}$$

$$\Delta SA = Cash_T + \sum_{T-t<t_{del}} \text{Rec}_t - \sum_{t,t'|T-t\le t_{del} \wedge t'>T-t_{del}} p\lg_{tt'} \tag{33}$$
$$+ \sum_p RIP_{pT} \times \Pr o_{pT} - Cash_{t_0} - \text{Rec}_{t_0} - \sum_p RIP_{pt_0} \times \Pr o_{pt_0}$$

$$\Delta LA = FExpns_T - FExpns_{t_0} \tag{34}$$

$$\Delta SL = Crdline_T + \sum_t MExpns_t + \sum_t PExpns_t + \sum_t HExpns_t + \sum_t TExpns_t \tag{35}$$
$$- \sum_t \alpha_{tt'} \times MPay_{tt'} - \sum_{tt'} \beta_{tt'} \times PPay_{tt'} - \sum_{tt'} \gamma_{tt'} \times HPay_{tt'}$$
$$- \sum_{tt'} \rho_{tt'} \times TPay_{tt'} - Crdline_{t_0}$$

Equation 32 indicates that changes in equity equal the changes in short-term and long-term assets minus the changes in short-term and long-term liabilities.

As can be seen from Equation 33, changes in short-term assets are equal to the difference between short-term assets (including cash, accounts receivable, and balance) are the end of the first and the last periods.

Equation 34 shows that changes in long-term assets involve the sum of implementation costs at the end of the last period minus the implementation costs at the end of the first period.

Equation 35 shows that changes in short-term liabilities equals the difference between short-term liabilities including liabilities and accounts payable related to material, manufacturing, implementation, processing, and transportation at the end of the first and the last periods.

TABLE 1. Results Obtained from Solving the Model

	ΔSA	ΔLA	ΔSL	ΔLL	ΔE	Profile
Financial flow	544349	105790	28500	0	678639	301233
Material flow	513840	69600	28500	0	549300	380341

6.4. The Target Function of the Financial Flow. $Maximize\ \Delta E$

In the financial flow, the target function is the changes in equity. This target function helps us to:

(1) Calculate all the short-term and long-term liabilities.
(2) Calculate all the short-term and long-term assets.
(3) Establish an optimal flow between the liabilities and the assets of the company in a way that changes in equity can be maximized.

6.5. The Target Function of the Material Flow. $Maximize\ \Pr ofit$

In the material flow, the target function is to maximize profits. As can be seen from Equation 31, profit equals the difference between the input cash flow obtained from selling the products minus the output cash flow related to the costs of raw material, manufacturing, inventory process, and transportation.

7. **Discussion and Results.** A supply chain network is considered which includes three potential locations for establishing manufacturing plants, two locations for establishing distribution centers, three customer centers, three suppliers, and four time periods.

In this network that data The data is taken from Textile Company in Iran, the initial cash is 300,000 monetary units. Moreover, the minimum cash for obtaining a loan from the bank is considered to be 120,000 units. Based on the agreement with the bank, the company has a credit with the bank with the annual rate of 10 percent with the maximum credit of 100,000 units. The initial credit is considered to be 65,000 units and the sales in each time period are executed with a delay of two time periods. Accounts receivable for sale are freed with the rate of 80 percent. Moreover, on time payments will be eligible for a two-percent discount. The technical coefficients related to the security transactions are assumed as 2.8% for purchase and 3.5% for sale. Furthermore, the dividends at the end of each time period equal 75,000, 100,000, 100,000, and 150,000, respectively.

Based on the defined parameters and the discussed variables and restrictions, the selected model is optimized. In order to solve the mixed-integer linear programing (MILP) model, we use the Gams optimization software.

In this study, we are trying to simultaneously increase the profits and maximize changes in equity. Along with implementing the model, the results will be presented from both a financial respect and a material flow respect without considering the financial flow, and then they will be compared. Moreover, the optimal flow among the selected decision variables will be proposed and we will discuss which approach can provide better and more acceptable results.

As can be seen from Tabel 1, the financial flow of the supply chain improves changes in equity by 19% (678639 for the financial flow and 6532995 for the material flow) while profits will be improved by 20% (301233 for the financial flow and 380341

for the material flow). This balance between the financial flow and the material flow provides us with acceptable results and helps decision makers to employ financial flow along with the material flow in the supply chain in order to obtain better and more acceptable results and heavily contribute to the improvement and efficiency of the plant. Moreover, it is worth mentioning that in this study, long-term liabilities are not considered.

Now, we turn to evaluating accounts receivable and the exogenous cash. Based on Figure 2, it can be seen that these two variables have a direct relationship to each other. In other words, the higher the accounts receivable of the company, including selling securities or the final products, the higher the exogenous liquidity of the company, which can be a proof for the accuracy of the proposed model.
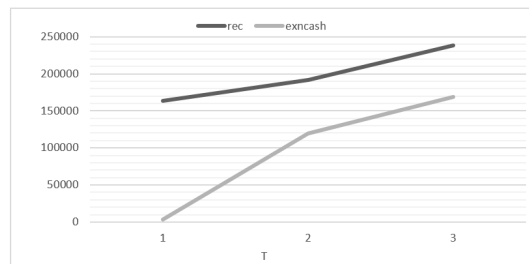

FIGURE 2. Trend of Changes in Exogenous Cash and Accounts Receivable during the Time Periods t

As can be seen from Figures 3 and 4, the liability in each period in the financial flow mode has a little difference from the material flow and it is higher. However, on the other hand, the cash amount in financial flow is higher than that of the material flow, which is because of the exogenous cash entered into the company through selling securities or obtaining a loan from a bank, which can increase the liquidity of the company so that it can fulfil its duties.
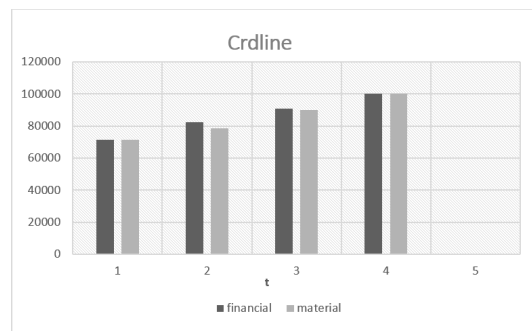

FIGURE 3. Liabilities in Time Periods for both Financial and Material Flows

7.1. **Evaluating Financial Ratios.** In order to analyze the financial status of a company, analysts use financial ratios. Financial rations can shed some light on some of the important facts about the results of the operations and the financial
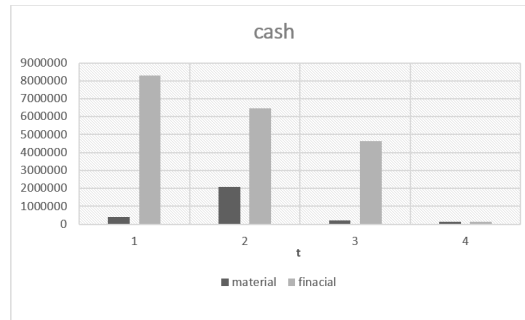
FIGURE 4. Cash in Time Periods for both Financial and Material Flows

status of a company very easily. Therefore, considering the objective and the applications, certain ratios can be analyzed. Investigation and calculation of financial ratio can show that research model is efficient or not. On the other hand can help to assessing the company's financial account. By calculating financial ratio described below, the efficiency of the model described and compare the changing the amount of cash with received account

Cash Ratios

These ratios are obtained by comparing the current assets or components with the current liabilities. The most important cash ratio is:

Current Ratio

The current ratio is obtained by dividing current assets by current liabilities.

$$current\ ratio = \frac{current\ asset}{current\ liability}$$

This ratio is the most common instrument for measuring the ability to pay the short-term liabilities since it can show how many times the assets which are turned into cash during the financial year are more than the liabilities whose deadlines are during the financial year. Generally, it can be said that the higher the current ratio, the more secure the creditors can be because if the current assets are damaged, the company can still satisfy the creditors. In this study, considering the results, the current ratio is 19 which can be an acceptable ratio so that the creditors can have more security from the current assets.

Leverage Ratios

These ratios determine and evaluate the relationship between the financial funds utilized by the business with regards to liabilities or equities. In fact, they evaluate the way these are combined. The most important leverage ratios include liability ratio, and the ratio of total liabilities to changes in equity.

(1) Liability ratio: this ratio is obtained by dividing the sum of liabilities by the sum of assets.

$$Liability\ ratio = \frac{total\ liability}{total\ assets}$$

Generally, the loan providers and creditors prefer relatively low liability ratios. High liability rations generally mean that the company has to utilize more facilities in order to supply the necessary resources.

In this study, the liability ratio is 0.05 which can be a good value for the

liability ratio, meaning that the company can pay the liabilities from the assets.

(2) The ratio of liabilities to equities: this ratio is obtained by dividing total liabilities by the equities.

$$ratio \; of \; liability \; to \; equity = \frac{change \; in \; equity}{total \; liabilities}$$

The above ratio shows the relationship between the total liabilities including current and long-term liabilities and the changes in equity, or, in other words, the relationship between creditors and stakeholders regarding property and ownership. Obviously, the higher this ratio, the lower the number of creditors. In this study, this ratio is 23, which shows that our liabilities are lower, but the changes in equity are higher, which indicates a lower number f creditors.

Profitability Ratios

Profitability ratios indicate how well the business is being managed. In fact, it measures the success of the company in obtaining net yield compared to the sales income or compared to the investments. The most important profitability ratios include return on equity, and return on sale.

(1) Return on equity: this ratio is obtained by dividing net profits by equity.

$$return \; on \; equity \; (in \; percent) = \frac{net \; profit}{changes \; in \; equity} \times 100$$

Stakeholders of a business consider this ratio to be more important than any other since the results obtained from their investments can be seen from this ratio. In this study, this ratio equals 44%, which can be useful for stakeholders and show the efficiency of the investment and their shares in the company.

(2) Return on sales: this ratio is obtained by dividing the net profits by the net sales.

$$return \; on \; sales \; (in \; percent) = \frac{net \; profits}{net \; sales} \times 100$$

This ratio shows how much profit is made from each sales (in percent).

As can be seen from Figure 5, the income obtained from selling the products is increases, therefore the net profit obtained from selling the products minus the costs of transportation, storage, implementation, and so on, depicted in Figure 6, is increased.
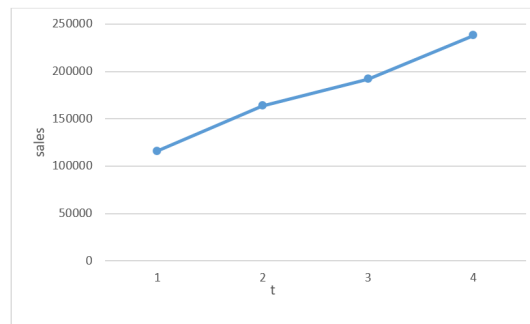

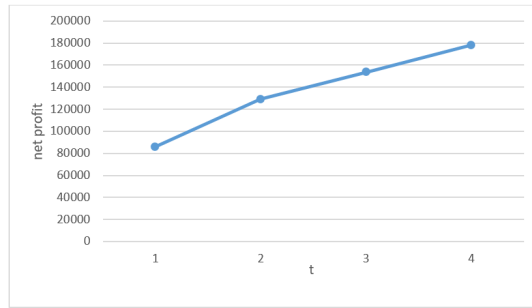FIGURE 5. Income from Sales in each Time Period

FIGURE 6. Net Profit in each Time Period

Based on the two charts above, we can obtain the return on sales, which is equal to the ratio of profits to sales. Figure 7 shows the return on sale in each time period, which can be an important and integral variable for any business. In fact, this chart shows how much profit is made in each time period from selling a unit of products. It can be concluded from this chart that the return on sales in all time periods are approximately in the same range, which can be useful for a business because it shows that the return on sales will not decrease significantly. Of course, the return on sales may depend on many factors such as economic fluctuations.
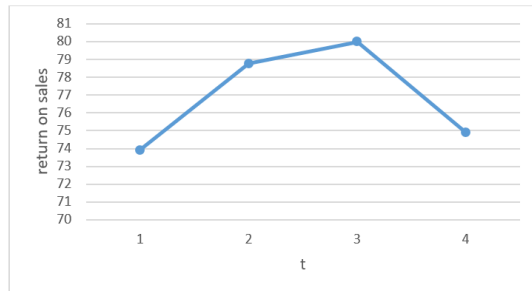

FIGURE 7. Return on Sales in each Time Period

8. **Conclusions.** This study evaluates two main flows in the supply chain which influence the profitability of any company and models these two flows in an integrated method. In fact, the innovativeness of the current study can be the consideration of financial factors such as interest rate, accounts receivable, borrowing loans, and short-term and long-term assets and liabilities as variables and the consideration of changes in the equity as the target function. On the other hand, the integration of these variables and logistic restrictions can be considered another one of the innovations of the current study.

In this study, regarding the material flow of the supply chain, we maximized the profitability of the company, which is the result of the difference between the sales and the costs of the chain, which led to the productivity of the chain. Moreover, the target function of the financial flow of the supply chain was to increase the equity which depends on the short-term and long-term assets and liabilities of the company.

Besides maximizing the equity, we optimized the short-term and long-term assets and liabilities of the company.

The financial flow of the supply chain increased the profitability of the company and maximized it. On the other hand, the material flow whose target function was to maximize profits contributed to maximizing the profit. The profits obtained in the material flow were slightly larger than that of the financial flow, but the difference was negligible. It is concluded that since the financial flow considers all the financial factors along with the material flow of the chain, optimizing the financial flow can help us reach an efficient and productive chain with maximum profits. At the end of the study, the financial ratios were described, which can be useful in the productivity of a company and provide acceptable results for the management of the business.

In considering financial ratios derived from this study, found that creditors can have more security than current assets, company will be can pay its debts. On the other hand, concluded, that proportion of the company's creditors is low but change of equity is high, also discovered that return on sales don't have large reduction and have stable process but net profit have increased in time period.

This study can be expanded by considering the model of financial flow in higher dimensions and solving it using metaheuristic algorithms, adding financial factors to the model, or considering multi-product manufacturing.

In the table we give the notations:

Sets	
S	Set of suppliers, indexed by s
P	Set of plants, indexed by p
D	Set of distribution centers, indexed by d
C	Set of customers, indexed by c
T	Set of time period, indexed by t
Parameters	
$Demand_{ct}$	Demand of customer c in period t
SC_{st}	Supply capacity of supplier s in period t
PC_{pt}	Production capacity of plant p in period t
IP_{pt}	Store capacity of plant p in period t
DC_{ct}	Processing capacity of distribution center d in period t
$\Pr o_{pt}$	Production cost per unit at plant p in period t
Ope_{dt}	Operating cost per unit at distribution center d in period t
SPC_{pdt}	Transportation cost per unit of material shipped from supplier s to plant p in period t
PDC_{pdt}	Transportation cost per unit of product shipped from plant p to distribution center d in period t

REFERENCES

[1] F. Altiparmak, M. Gen and L. Karaoglan, A steady state genetic algorithmfor multi product supply chain network design, *Computer and Industrial Engineering*, **56** (2009), 521–537.

DCC_{dct}	Transportation cost per unit of product shipped from distribution center d to customer c in period t
EP_{pt}	Fixed cost of establishing plant p in period t
ED_{dt}	Fixed cost of establishing distribution center d in period t
Hop_{pt}	Holding cost per unit at store of plant p in period t
$\Pr ice_{ct}$	Price per unit for customer c in period t
Scu_t	Marketable securities of initial portfolio maturing in period t
Hod_{dt}	Holding cost per unit at store of distribution center d in period t
ID_{dt}	Store capacity of distribution center d in period t
$MaxCrd$	Maximum debt allowed from bank
$MinCash$	Minimum cash imposed from bank
Div_t	Dividends in period t
$ir:$	Interest rate
$Other_t$	Other net cash obtained in period t
Mat_{st}	Material cost per unit purchased from supplier s in period t
Decision variables	
SPQ_{spt}	Quantity of material shipped from supplier s to plant p in period t
PDQ_{pdt}	Quantity of product shipped from plant p to distribution center d in period t
PPQ_{pt}	Quantity of product shipped from plant p to its store in period t
RIP_{pt}	Residual inventory at store of plant p in period t
IPQ_{pdt}	Quantity of product shipped from store of plant p to distribution center d in period t
DCQ_{dct}	Quantity of product shipped from distribution center d to customer c in period t
$Cash_t$	Cash in period t
$ExnCash_t$	Exogenous cash in period t
$CrdCash_t$	Net cash obtained by money borrowed or repaid to the credit line in period t
$ScuCash_t$	Net cash received or paid in securities transactions in period t
$PPay_{tt'}$	Payment for total costs of production/reproduction executed in period t on accounts payable incurred in period t'
$Mpay_{tt'}$	Payment for total costs of material executed in period t on accounts payable incurred in period t'
$HPay_{tt'}$	Payment for total costs of handling product in facilities executed in period t on accounts payable incurred in period tt'
$TPay_{tt'}$	Payment for total costs of transportation executed in period t on accounts payable incurred in period t'
Rec_t	Accounts receivable in period t
$p\lg_{tt'}$	Amount of accounts receivable pledged within period t' incurred in period t
$Crdline_t$	Debt in period t
$Loan_t$	Amount of cash borrowed to credit line in period t
$\text{Re}pay$	Amount of cash repaid to credit line in period t
$Iscu_{tt'}$	Total cash obtained in period t' by the marketable securities invested in period t
$Cscu_{tt'}$	Total marketable securities sold in period t maturing in period t'
$MExpns_t$	Expense of material in period t
$PExpns_t$	Expense of production/reproduction in period t

$HExpns_t$	Expense of handling product in facilities in period t
$TExpns_t$	Expense of transportation in period t
$\mathrm{Pr}\, ofit$	Profit of enterprise
ΔE	Change in equity of enterprise
ΔLA	Change in long-term assets of enterprise
ΔLL	Change in long-term liabilities of enterprise
ΔSA	Change in short-term assets of enterprise
ΔSL	Change in short-term liabilities of enterprise
Binary variables	
W_{pt}	$\begin{cases} 1 & If\ plant\ established\ in\ time\ period\ t \\ 0 & otherwise \end{cases}$
Y_{dt}	$\begin{cases} 1 & If\ distribution\ center\ d\ established\ in\ time\ period\ t \\ 0 & otherwise \end{cases}$
Greek letters	
$\alpha_{tt'}$	Technical discount coefficient relevant to the payment of material costs executed in period t incurred in period t'
$\beta_{tt'}$	Technical discount coefficient relevant to the payment of production/reproduction costs executed in period t incurred in period t'
$\gamma_{tt'}$	Technical discount coefficient relevant to the payment of handling costs executed in period t incurred in period t'
$\rho_{tt'}$	Technical discount coefficient relevant to the payment of transportation costs executed in period t incurred in period t'
η	Percentage that accounts receivable pledged corresponding to this value
$\lambda_{tt'}$	Technical coefficient related to sale of marketable securities
$\mu_{tt'}$	Technical coefficient related to investment of marketable securities

[2] H. Badri and M. Bashiri, Integrated strategic and tactical planning in supply chain network design wth a heuristic solution method, *Computer and Operation Research*, **40** (2013), 1143–1154.

[3] Y. Cardona-Valdés, A. Álvarez and D. Ozdemir, A bi-objective supply chain design problem with uncertainty, *Transportation Research Part C*, **19** (2011), 821–832.

[4] S. H. Elgazzar, N. S. Tipi, N. J. Hubbard and D. Z. Leach, Linking supply chain 22 performance to a company's financial, *European Journal of Operational Research*, **223** (2012), 276–289.

[5] R. B. Franca, E. C. Jones and J. P. Richards, Multi-objective stochastic supply chain modeling to evaluate tradeoffs between profit and quality, *Int. J. of Production Economics*, **127** (2010), 292–299.

[6] S. Gupta and K. Dutta, Modeling of financial supply chain, *European Journal of Operational Research*, **21** (2011), 47–56.

[7] A. Ivanovic and L. Fuxman, Fundamental of financial supply chain management, *Megabrand*, (2010), 63–73.

[8] P. Kristofik, J. Kok, S. D. Vries and J. V. Sten-vsnì Hoff, Financial supply chain management-challenges and obstacles, *ACRN Journal of Entrepreneueurship Perspectives*, **1** (2012), 132–143.

[9] J. M. Lainez, L. Puigjaner and G. V. Reklaitis, Financial and financial engineering considerations in supply chain and product development pipeline management, *Computers and Chemical Engineering*, **33** (2009), 1999–2011.

[10] C. C. Lin and Y. C. Wu, Optimal pricing for build to order supply chain design under price dependent stochastic demand, *Transportation Research Part B*, **56** (2013), 31–49.

[11] P. Longinidis and M. C. Georgiadis, Integration of financial statement analysis in the optimal design of supply chain networks under demand uncertainty, *Int. J. Production Economics*, **129** (2011), 262–276.

[12] L. Moussawi-Haidar, W. Dbouk, M. Y. Jaber and I. H. Osman, Coordinating a three-level supply chain with delay in payments and a discounted interest rate, *Computers & Industrial Engineering*, **69** (2013), 29–42.

[13] L. Moussawi-Haidar and M. Y. Jaber, A joint model for cash and inventory management for a retailer under delay in payments, *Computers & Industrial Engineering*, **66** (2014), 758–767.

[14] P. NgaThanh, B. Bostel and O. Peton, Dynamic model for facility location in the design of complex supply chain, *Int. J. Production Economics*, **113** (2008), 678–693.

[15] K. Nurjanni, M. S. Carvalho and L. Costa, Green supply chain design: A mathematical modeling approach based on a multi-objective optimization model, *Int. J. Production Economics*, **183** (2017), 421–432.

[16] T. Pham and P. Yenradee, Optimal supply chain network design with process network and BOM under uncertainties: A case study in toothbrush industry, *Computers & Industrial Engineering*, **108** (2017), 177–191.

[17] M. Protopappa-Sieke and R. W. Seifert, Interrelating operational and financial performance measurements in inventory control, *European Journal of Operational Research*, **204** (2010), 439–448.

[18] N. S. Raghavan and V. K. Mishra, Short-term financing in a cash-constrained supply chain, *Int. J. Production Economics*, **134** (2014), 407–412.

[19] M. Ramezani, A. Kimiagari and B. Karimi, Closed-loop supply chain network design: A financial approach, *Applied Mathematical Modelling*, **38** (2014), 4099–4119.

[20] A. Ross and V. Jayaraman, An evaluation of new heuristics for the location of cross-docks distribution centers in supply chain network design, *Computer Industrial Engineering*, **55** (2008), 64–79.

[21] J. M. Shi, G. Q. Zhang and J. C. Sha, A Lagrangian based solution algorithm for a build to order supply chain network design problem, *Advanced in Engineering Softwar*, **49** (2012), 21–28.