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Effects of integrating physical and financial flows on a closed loop supply chain network under uncertain demand and return

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Abstract

The impact of financial challenges on the profit of a supply chain, have caused the researcher to model the supply chain network by considering the operational and financial dimensions. Also, the establishment of a closed loop supply chain (CLSC) network has a high effect on economic profit. So, the purpose of this study is to design a stochastic closed loop supply chain network by considering the operational and financial dimensions and tactical decision-making level. First, a deterministic mixed-integer linear programming model is developed. Then, the scenario-based of the proposed mixed integer linear programming model is presented. The main innovation of this research is to develop a mathematical model that simultaneously focuses on optimizing the financial and physical flows in an integrated manner and uses the financial ratios in the form of a closed loop supply chain. In order to illustrate the applicability of the proposed model, a test problem from the recent literature is used. The analysis of the results obtained from the developed stochastic mathematical model shows an averagely 4% increase in profit and a 27% reduction in semi-variance compared to deterministic developed models.

Keywords: Financial flow, closed-loop supply chain, supply chain management, stochastic programming, scenario-based approach.

1-Introduction

A supply chain is a network of suppliers, manufacturers, warehouses, and retailers that organized to produce and distribute goods in the right quantities, to the right locations, and at the right time. These activities have done in order to minimize total costs or maximize total profits. Above definition is a traditional meaning for the supply chain. But nowadays companies faced growing competition and increasing costs. Because of that, it is important for managers to design the network of the supply chain by considering the integrated models.

Considering integrated supply chain models, which include different aspects of the supply chain, has received attention during the last decade. Such integrated models show a realistic viewpoint of supply chain decisions. Because, all of the processes in supply chain management have related to each other, optimizing them in an integrated manner have a holistic viewpoint to decision makers. Many studies have conducted to integrate various supply chain activities (procurement, production, etc.). However, the integration of financial flows and operational decisions is one of the issues that have neglected.

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Considering the financial flow and capital working management are as important as product flow in supply chain management. But, according to chauffour and malouche (2011), the studies focusing on the planning of financial flow are very limited in proportion to the relevant literature. The traditional point of view has considered operational and financial decisions by optimizing them in separated models. But Deutz, a German motor manufacturer, improve their production process by optimizing their inventory levels along with payable and receivable accounts.

Neglecting to consider the financial flows not only weakens the financial performance of the supply chain but also affects all financial and operational decisions. For example, production planning and scheduling, have a direct dependence on financial resources. Inappropriate allocation of resources causes financial issues such as, increasing the costs, resource shortages, increasing in the price of the product and etc. In this situation, the profit of all supply chain component will be affected.

Because all decisions related to the supply chain planning are affected by allocating the financial resources, the financial flow should be considered at each of strategic, tactical, and operation levels. It should be noted that considering the financial flow in strategic planning is more important than other levels of decision-making. Because long-term decisions, such as determining the type of technology, configuration of the facilities, etc., require more investment. Also, if the resources are not properly allocated to these decisions, a lot of financial resources will be wasted. Therefore, it is important to address the impact of financial flows on strategic decisions.

Traditional or forward supply chain management (FSCM) is defined as the management of activities and flows related to managing products and materials from suppliers to customers (Hassanzadeh Amin et al., 2017). Many researchers have focused on planning or design forward supply chain. But, in recent years, due to resources shortages, increasing wastes, and environmental regulations, companies should organize their return product flows. This concept is known as reverse logistics (RL). The integration of forwarding and reverse logistics are known as the closed-loop supply chain (CLSC). Designating a CLSC have focused on both environmental and business factors. This characteristic has led to increased interest in studied about CLSC in recent decades. Figure 1 has shown a structure of a closed loop supply chain network. In a CLSC network, products or materials have returned to the repair centers, disposal centers, original producers, etc. Based on the characteristics of return products, the collection centers have sent them to the relevant centers.

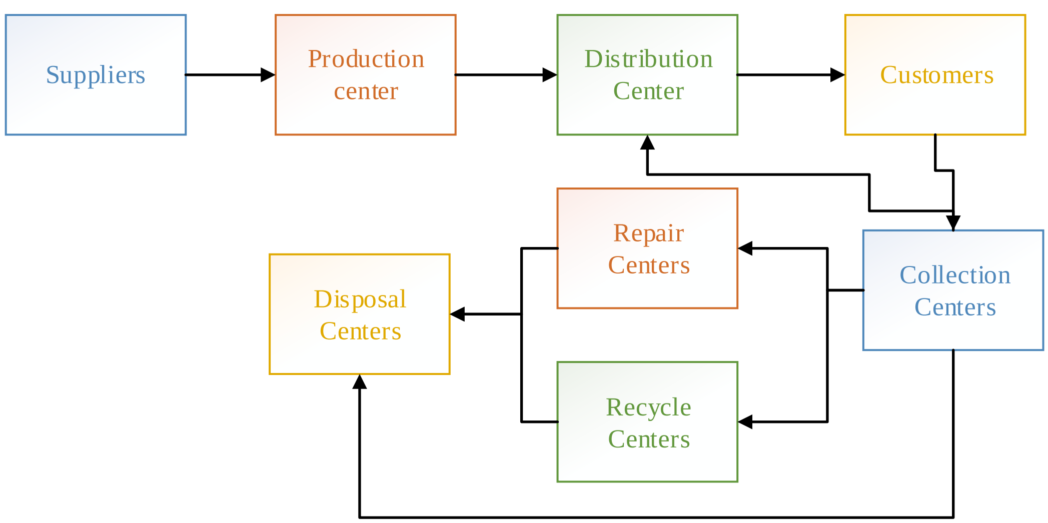

Fig 1. Structure of a closed-loop supply chain network

Uncertainty nature of input parameters is challenges that decision makers have encountered to them. Some parameters such as customer demand or quantity and quality of returned products have a high degree of uncertainty (Pishvaee et al., 2009). So, the decision makers should optimize the models in a way that they could handle the uncertainty of parameters. To handle the input parameters' uncertainty, various techniques such as stochastic programming and fuzzy mathematical programming have been developed. Stochastic programming models use in the issues that probability distributions are known or can be estimated (Shapiro and Philpott, 2007). Fuzzy mathematical programming provides a framework for the situation that insufficient historical data is available. Fuzzy mathematical programming is used to cope with the lack of knowledge of decision maker about the actual value of parameters (Pishvaee and Khalaf, 2016). In this study, we have used scenario-based stochastic programming to deal with the uncertainty of demand and rate of return products. We have chosen this method because the accurate and sufficient information about uncertain parameters of this study, is available.

With regard to the above-mentioned descriptions, the present research proposes a mathematical model to integrate the physical and financial flows in a multi-period, single-product closed-loop supply chain in order to maximize the operating profit. Also, in order to analyze and control the financial performance of the supply chain, some financial ratios are used. Moreover, the developed model employs the stochastic programming to handle the returned products and customer demand uncertainty. Finally, the application of the models is examined by using data from the recent literature.

The structure of the paper is as follows: In section 2, the relevant literature is reviewed. Section 3 describes the model assumptions and problem description. Section 4, represents the model formulation. In section 5, the stochastic programming approach is developed to cope with uncertainty in the model parameters. Section 6 represents numerical examples and discusses the computational results. Finally, the conclusions are presented in section 7.

2-Literature review

In order to illustrate the research gap and highlight the contributions of this paper, we investigate the related literature in this section. Papers related to the planning of financial flows through the SC is very limited in proportion to other planning issues of SC. Most of the researchers used financial factors such as tax, exchange rate and debt instead of asset-liabilities management equations in the previously published papers (Ramezani et al., 2014). The relevant articles can be classified into two categories. The first category includes the articles that used a part of balance sheet equations such as budget constraints to model the financial flow. For example, Wang et al. (2003) considered budget constraints in the relocation of facilities (taking the decision regarding opening or closing a facility). The objective of the developed model is to minimize the distance traveled to deliver goods to customers under budget constraints. Melo et al. (2005) consider the budget constraints in supply chain network design. In this model, taking into budget constraints, decisions such as relocating existing centers and transferring the capacity of these centers, the capital required for investment in order to relocate existing facilities, and other long-term decisions are considered. Using a MILP model, Hugo and Pistikopoulos (2005) investigated the combination of long-term and mid-term decisions (i.e., capacity planning, flows of materials, etc.) along with the concept of products life cycle and the relevant financial decisions. They used a bi-objective model to maximize net present value and minimize environmental impacts. Naraharisetti et al. (2008) introduced a MILP model to manage the assets and capital in a supply chain redesign problem. The results of the model show a 14% decrease in profit in the situation of ignoring disinvestment and/or relocation decisions. Dal Mas et al. (2010) developed a MILP model to design the biofuels supply chain. In this research, two criteria including Optional Value Opportunity (OV) and Value at Risk (VaR) are used to optimize the supply chain network. Gupta and Dutta (2011) investigated the cash flow optimization problem from the viewpoint of SC partners. Hahn and Kuhn (2012) proposed a MILP model to consider financial, operational, and investment decisions in a SC planning problem. In this research, the economic value added index is used as an objective function. Liu and Cruz (2012) examined the impact of financial risk and economic uncertainty on SC planning decisions. Elgazzar et al. (2012) developed a DS/AHP model to link the performance of SC processes to the company's financial strategy. Moussawi-Haidar and Jaber (2013) developed a model to combine the cash flow management and lot-sizing problems. Also, in this research, a delay in payment contract is used for retailers. Feng et al. (2015) analyzed the impact of budget constraints on buyback and revenue sharing contracts. Xu et al. (2015) examined the effectiveness of three well-known contracts (revenue sharing contract, output penalty contract, and cost-sharing contract) in coordinating the outsourcing SC. Vafa Arani and Torabi (2018) considered the cash flow management to integrate the financial and physical dimension of the SC. In this research, the net present value (NPV) is considered as the objective function.

The second category of articles considers the financial flow through the asset-liability management system. In other words, these articles use equations of the balance sheet to model financial aspects of the SC. For example, Guillén et al. (2006) considered the effects of financial flow in a production planning and scheduling problem. Puigjaner and Guillén-Gosálbez (2008) used a dynamic simulation model to consider both environmental and financial aspects of a chemical supply chain. Sodhi et al. (2009) extended a mathematical model for supply chain planning under demand uncertainty and asset–liability management. Longinidis et al. (2011) presented a MILP model to address financial considerations in the design of supply chain network under demand uncertainty. In this paper, financial ratios and demand uncertainty are used to analyze the network decisions. Nickel et al. (2012), proposed a MILP model to design a supply chain network in order to simultaneously focus on the long-term and mid-term financial and physical decisions. Longinidis et al. (2013) use a non-linear and bi-objective model to integrate financial performance and credit solvency within the supply chain network design problem. Ramezani et al. (2014) developed a closed-loop supply chain network design model to combine long-term and mid-term decisions while integrating financial and physical flows. Cardoso et al. (2016) developed a MILP model to measure financial risk into the design and planning of closed-loop supply chains. Four different risk measures (i.e., VaR, CVaR, Variability Index, and Downside Risk) are used to evaluate the financial risk. Mohammadi et al. (2017), proposed a multi-objective MILP model to take into account the financial and physical flows within mid-term and long-term decisions. In this research, the economic value added, shareholders' equity and corporate value are used as the objective functions.

2-1-Research contribution

To provide a systemic view of the relevant literature, the relevant papers are classified in Table 3. Regarding the literature, considering the financial ratio in the issue of integrating financial and physical flows into a closed loop supply chain is the major contributions of this paper that distinguish this research from the other published papers. In other words, for the first time, we used some financial ratio in order to examine the supply chain performance in the integrated financial-physical problem.

Table 1. Review of the financial studies in supply chain

Authors	Period	Financial Ratios	Scope	Uncertainty parameters	Methods to deal with the uncertainty	Single objective	Multi objective	Solution method
Wang et al. (2003)	Single Period		Facility Location	-		Min the Total Weighted Travel Distance		NP-Hard [GI/TS/LR[1]]
Hugo and Pistikopoulos (2005)	Multi Period		Forward Supply Chain Network Design	-			Min the CPE Max the NPV Max the NRD	MILP
Melo et al. (2005)	Multi Period		Facility Location	-		Min the Total Cost		MIP
Guillén et al. (2006)	Multi Period		Planning/ Scheduling of Supply Chains	-		Max the Change in Equity		MILP
Badell et al. (2007)	Single Period		Planning/ Scheduling of Supply Chains	-			Max Gross Margins/ Min Discounts the Cleaning Cost	MILP
Puigjaner and Guillén-Gosálbez (2008)	Multi Period		Forward Supply Chain Network Design	Demand/ Transportation Time	Scenario Approach		Min the Environmental Impact/Max the Change in Equity	
Sodhi et al. (2009)	Multi Period		Planning of Supply Chain	Demand/ Interest Rates	Scenario Approach	Max the NPV	-	LP
Longinidis et al. (2011)	Multi Period		Forward Supply Chain Network Design	Demand	Scenario Approach	Max the Change in Equity		MILP
Nickel et al. (2012)	Multi Period		Forward Supply Chain Network Design	Demand/ Return on Investment	Scenario Approach	Max the Total Financial Benefit		MILP
Elgazzar et al. (2012)	Single Period		Supply Chain Processes' Performance	-	-	-	-	DS/AHP
Hahn and Kuhn (2012)	Multi Period		Planning of Supply Chain	Demand	Robust-Stochastic Programming	Max the EVA/Min the Downside Risk of EVA		MILP
Longinidis et al. (2013)	Multi Period		Forward Supply Chain Network Design	Economic Parameters [2]	Scenario Approach		Max the EVA/ Max the Altman's Z-score	MINLP [ε-Constraint]
Ramezani et al. (2014)	Multi Period		Closed-loop Supply Chain Network Design	-		Max the Change in Equity		MILP
Cardoso el al. (2015)	Multi Period		Closed-loop Supply Chain Network Design	Demand	Scenario Approach	-	Max the ENPV/ Min the Risk of ENPV	MILP [ε-Constraint]
Mohamma	Single		Forward	-	-	-	Max the	MILP [FGP[3]]

[1] Greedy-Interchange heuristic, Tabu Search technique, Lagrangian relaxation.

[2] Product demand, Short-term interest rate, Long-term interest rate, Risk-free rate of interest, expected return of the market, Underwriting cost, Market liquidity.

Authors	Period	Financial Ratios	Scope	Uncertainty parameters	Methods to deal with the uncertainty	Single objective	Multi objective	Solution method
di et al. (2017)	Period		Supply Chain Network Design				Corporate Value/Max the Change in Equity/Max the EVA	
Vafa Arani and Torabi (2018)	Single Period		Forward Supply Chain Network Design	Some Uncertainty Parameters	Interactive Fuzzy Stochastic Programming	-	Max the NPV of Manufacturing and Suppliers	MILP
This study	**Multi Period**	*	**Closed-loop Supply Chain Network**	**Demand /Return Rate**	**Scenario Approach**	**Max the Total Profit**	-	**MILP**

3-Problem definition and assumptions

The general structure of the studied supply chain network is illustrated in figure 2. The supply chain includes five stages: (1) production center, (2) production sites N, (3) production sites L (4), production sites M, (5) customer. In the forward direction, the production center is sending the semi-products to each production sites. The production sites N and L, have changed the semi-product and then sending them to production sites M. The production sites M are improving the products and are shipping them to the manufacturer. Finally, the manufacturer has produced the final goods and have shipped them to customers. In the reverse direction, the products have returned to production center after use. Some of the returned products have remanufactured in the production center. The paper considers the following assumptions and limitations:

- The model is multi-period.
- The model is single-product.
- The location of production center, production sites, and customers are known and fixed.
- The number of production sites to be set up via the model.
- The capacities of facilities are restricted.
- During the investigation period, the sales price of all products is fixed.
- During the investigation period, the amount of investment and interest rate, are fixed.
- The factory is able to receive long-term and short-term loans.
- All payable and receivable accounts will be liquidated at the end of each period.

The proposed mathematical model aims to determine the number of required production suites, the material flow that transfers between network nodes and the inventory level of each warehouse. These decisions are related to the physical flow of the supply chain. In addition to these decisions, the components of the balance sheet including current and fixed assets and liabilities are considered in the model. Also, some financial ratios have used to illustrate the financial condition of the proposed supply chain. From the above-discussed concepts, we develop a supply chain network design model which is an effort to analyze both financial and physical flows simultaneously. The purpose of this study is to maximize the total profit with respect to physical and financial constraints. We present the formulation of the proposed supply chain in the following section.

[3] Fuzzy Goal programming

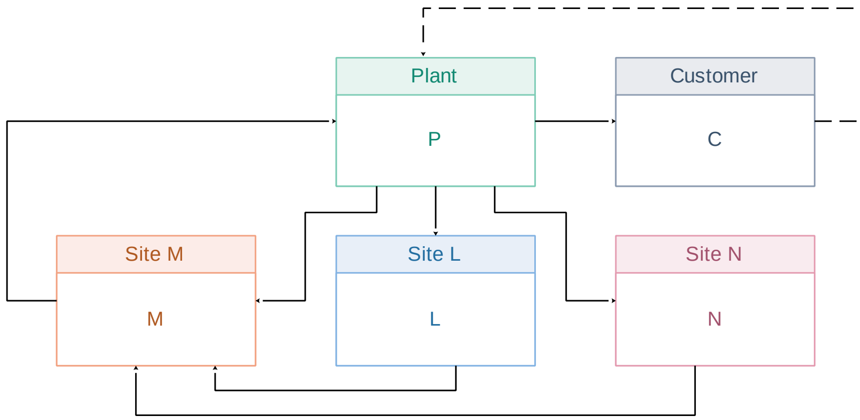

Fig 2. The structure of studied closed-loop supply chain network

4- Model formulation

Sets:

N	Set related to production site N (1…n…N)
L	Set related to production site L (1…l…L)
M	Set related to production site M (1…m…M)
T	Set related to time period (1…t…T)
C	Set related to customer zone (1…c…C)

Parameters:

d_{ct}	The demand for customer *c* in period *t*
rcp_{ct}	The rate of returned product from customer *c* in period *t*
$caps_t$	Storage capacity for semi-product at the production center in period *t*
$capf_t$	Storage capacity for final product at the production center in period *t*
$capn_{nt}$	Storage capacity for semi-product at production site *n* in period *t*
$capl_{lt}$	Storage capacity for semi-product at production site *l* in period *t*
$capm_{mt}$	Storage capacity for semi-product at production site *m* in period *t*
pri_t	Price per unit for the customer in period *t*
fcp_t	The fixed cost of production center in period *t*
fcn_{nt}	The fixed cost of production site *n* in period *t*
fcl_{lt}	The fixed cost of production site *l* in period *t*
fcm_{mt}	The fixed cost of production site *m* in period *t*
$tcpn_{nt}$	Transportation cost per unit semi-product from the production center to the production site *n* in period *t*
$tcpl_{lt}$	Transportation cost per unit semi-product from the production center to production site *l* in period *t*
$tcpm_{mt}$	Transportation cost per unit semi-product from the production center to production site *m* in period *t*
$tcnm_{nmt}$	Transportation cost per unit semi-product from production site *n* to production site *m* in period *t*
$tclm_{lmt}$	Transportation cost per unit semi-product from production site *l* to production site *m* in period *t*
$tcmp_{mt}$	Transportation cost per unit semi-product from production site *m* to production center in period *t*
$tcpc_{ct}$	Transportation cost per unit final product from the production center to customer *c* in period *t*
$tccp_{ct}$	Transportation cost per unit return product from customer *c* to production center in period *t*
hcs_t	Holding cost per unit of semi-product at the store of the production center in period *t*
hcf_t	Holding cost per unit of final product at the store of the production center in period *t*
hcn_{nt}	Holding cost per unit of semi-product at the store of production site *n* in period *t*

hcl_{lt} Holding cost per unit of semi-product at the store of production site *l* in period *t*
hcm_{mt} Holding cost per unit of semi-product at the store of production site *m* in period *t*
tr_t The tax rate in period *t*
dr_t Depreciation rate in period *t*
fai_t Fixed assets investment in period *t*
str_t The short-term interest rate in period *t*
ltr_t The long-term interest rate in period *t*
QR_t Lower bound for the quick ratio in period *t*
$FATR_t$ Lower bound for the fixed assets turnover ratio in period *t*
RTR_t Lower bound for receivables turnover ratio in period *t*
TDR_t Upper bound for total debt ratio in period *t*
DER_t Upper bound for the debt-equity ratio in period *t*

Variables:

XP_t The quantity of semi-product that produces in production center in period *t*
XPM_{mt} The quantity of semi-product shipped from the production center to the production site *m* in period *t*
XPL_{lt} The quantity of semi-product shipped from the production center to production site *l* in period *t*
XPN_{nt} The quantity of semi-product shipped from the production center to the production site *n* in period *t*
XNM_{nmt} The quantity of semi-product shipped from production site *n* to production site *m* in period *t*
XLM_{lmt} The quantity of semi-product shipped from production site *l* to production site *m* in period *t*
XMP_{mt} The quantity of semi-product shipped from production site *m* to the production center in period *t*
YP_t The quantity of final product that produces in production center in period *t*
XPC_{ct} The quantity of final product shipped from the production center to customer *c* in period *t*
XCP_{ct} The quantity of return product shipped from customer *c* to production center in period *t*
I_t The inventory level of semi-product in production center in period *t*
IP_t The inventory level of final product in production center in period *t*
IM_{mt} The inventory level of semi-product in production site *m* in period *t*
IL_{lt} The inventory level of semi-product in production site *l* in period *t*
IN_{nt} The inventory level of semi-product in production site *n* in period *t*
TC_t Total cost in period *t*
TFC_t Total fixed cost of centers in period *t*
TTC_t Total transportation costs in period *t*
THC_t Total holding costs in period *t*
FA_t Fixed assets in period *t*
CA_t Current assets in period *t*
$EBIT_t$ Earnings before interest and tax in period *t*
NIS_t New issued stocks in period *t*
P_t Interest paid in period *t*
INR_t Value of inventory in period *t*
NTS_t Net sales in period *t*
$NOPAT_t$ Net operating profit after taxes in period *t*
TI_t Total income in period *t*
DPR_t Depreciation in period *t*
STL_t Short-term liabilities in period *t*
LTL_t Long-term liabilities in period *t*
E_t Equity in period *t*
$Cash_t$ Cash in period *t*
RA_t Receivable accounts in period *t*

YM_{mt} $\begin{cases} 1 & \text{If the production site } m \text{ is activated in period } t, \\ 0 & \text{Otherwise;} \end{cases}$

YL_{lt} $= \begin{cases} 1 & \text{If the production site } l \text{ is activated in period } t, \\ 0 & \text{Otherwise;} \end{cases}$

YN_{nt} $= \begin{cases} 1 & \text{If the production site } n \text{ is activated in period } t, \\ 0 & \text{Otherwise;} \end{cases}$

According to the assumptions and notations, the MILP problem can be formulated as follows:

$$Max\ NOPAT_t = \sum_{t=1}^{T} [(1 - tr_t)\, TI_t^+ - TI_t^-] \tag{1}$$

$$TI_t^+ - TI_t^- = EBIT_t - IP_t \quad \forall t \tag{2}$$

$$P_t = ltr_t\, LTL_t + str_t\, STL_t \quad \forall t \tag{3}$$

$$EBIT_t = NTS_t - TC_t \quad \forall t \tag{4}$$

$$NTS_t = \sum_{c=1}^{C} XPC_{ct}\, pri_t \quad \forall t \tag{5}$$

$$TC_t = THC_t + TTC_t + TFC_t \quad \forall t \tag{6}$$

$$THC_t = hcs_t \left(\frac{I_t + I_{t-1}}{2}\right) + hcf_t \left(\frac{IP_t + IP_{t-1}}{2}\right) + \sum_{n=1}^{N} hcn_{nt} \left(\frac{IN_{nt} + IN_{nt-1}}{2}\right) + \sum_{m=1}^{M} hcm_{mt} \left(\frac{IM_{mt} + IM_{mt-1}}{2}\right) + \sum_{l=1}^{L} hcl_{lt} \left(\frac{IL_{lt} + IL_{lt-1}}{2}\right) \quad \forall t \tag{7}$$

$$TTC_t = \sum_{m=1}^{M} tcpm_{mt}\, XPM_{mt} + \sum_{n=1}^{N} tcpn_{nt}\, XPN_{nt} + \sum_{l=1}^{L} tcpl_{lt}\, XPL_{lt} + \sum_{n=1}^{N}\sum_{m=1}^{M} tcnm_{nmt}\, XNM_{nmt} + \sum_{l=1}^{L}\sum_{m=1}^{M} tclm_{lmt}\, XLM_{lmt} + \sum_{m=1}^{M} tcmp_{mt}\, XMP_{mt} + \sum_{c=1}^{C} tcpc_{ct}\, XPC_{ct} + \sum_{c=1}^{C} tccp_{ct}\, XCP_{ct} \quad \forall t \tag{8}$$

$$TFC_t = \sum_{m=1}^{M} fcm_{mt}\, YM_{mt} + \sum_{n=1}^{N} fcn_{nt}\, YN_{nt} + \sum_{l=1}^{L} fcl_{lt}\, YL_{lt} + fcp_t \quad \forall t \tag{9}$$

The objective function (1) maximizes the total operating profit. Given that the tax only belongs to the benefit, two independent variables (TI) are used. Constraint (2) calculate the taxable income of the chain. Constraint (3) formulate the interested pay calculation. Companies pay interests for both long-term and short-term financing that received from credit institutions. Constraint (4) shows the mathematical formula for calculating gross income. The gross income of a company (income before tax and interest) obtains from subtracting total costs of the chain (TC) from net sales (NTS). Constraint (5) shows the earning from the sale of products to customers. Constraint (6) formulate the total costs including fixed costs, transportation costs and, holding costs. Constraint (7), (8) and (9) represent the formulation of each cost. Above constraints show the mathematical equations that related to objective function calculation.

$$XP_t - I_t + I_{t-1} = \sum_{m=1}^{M} XPM_{mt} + \sum_{n=1}^{N} XPN_{nt} + \sum_{l=1}^{L} XPL_{lt} \quad \forall t \tag{10}$$

$$XPN_{nt} - IN_{nt} + IN_{nt-1} = \sum_{m=1}^{M} XNM_{nmt} \quad \forall t.n \tag{11}$$

$$XPL_{lt} - IL_{lt} + IL_{lt-1} = \sum_{m=1}^{M} XLM_{lmt} \quad \forall t.l \tag{12}$$

$$XPM_{mt} - IM_{mt} + IM_{mt-1} = XMP_{mt} \quad \forall t.m \tag{13}$$

$$YP_t - IP_t + IP_{t-1} = \sum_{c=1}^{C} XPC_{ct} \quad \forall t \tag{14}$$

$$XCP_{ct} = rcp_{ct}\, XPC_{ct} \quad \forall t.c \tag{15}$$

Constraints (10) - (14) assure the flow balance at production center/sites in forwarding flows. Constraints (15) related to the return product.

$$d_{ct} \le XPC_{ct} \quad \forall t.c \tag{16}$$

$$\sum_{m=1}^{M} YM_{mt} \ge 1 \quad \forall t \tag{17}$$

$$\sum_{n=1}^{N} YN_{nt} \ge 1 \quad \forall t \tag{18}$$

$$\sum_{l=1}^{L} YL_{lt} \ge 1 \quad \forall t \tag{19}$$

Constraint (16) ensures that the demands of all customers are satisfied in a way that total profit doesn't affect. Constraints (17) - (19) guarantee that at least one of each production site is active at any time period.

$$\frac{I_t + I_{t-1}}{2} \le caps_t \quad \forall t \tag{20}$$

$$\frac{IP_t + IP_{t-1}}{2} \le capf_t \quad \forall t \tag{21}$$

$$\frac{IN_{nt} + IN_{nt-1}}{2} \le capn_{nt} \quad \forall t.n \tag{22}$$

$$\frac{IM_{mt} + IM_{mt-1}}{2} \le capm_{mt} \quad \forall t.m \tag{23}$$

$$\frac{IL_{lt} + IL_{lt-1}}{2} \le capl_{lt} \quad \forall t.l \tag{24}$$

Constraint (20) – (24) show that in each time period, the inventory level of the warehouse cannot be more than the warehouse capacity.

In order to optimize the financial flow through the supply chain, the economic and accounting performance evaluation models should be used. In this study, we used the balance sheet equation to model the financial flow. In this equation, the left side (the assets) should be equal to the right side (sum of equity and liabilities). This equation only examines the financial performance of a supply chain. In order to use the economic performance evaluation models, financial ratios or financial criteria such as working capital, budgeting and economic value added, or a combination of them can be employed. In this study, we applied some financial ratio (see Section 4.1) in order to evaluate the economic performance of the supply chain.

Constraint (25) shows the basic equation of the balance sheet. This Equation shows the equality of the assets (*FA* + *CA*), to equity (E) and debts (*STL* + *LTL*).

$$FA_t + CA_t = E_t + STL_t + LTL_t \quad \forall t \tag{25}$$

$$DPR_t = dr_t \; FA_t \quad \forall t \tag{26}$$

Constraint (26) shows the mathematical formulation for calculating depreciation. In some previous articles, depreciation like other costs has been deducted from the net sale, which is wrong. Because depreciation is an intangible cost and should not be considered along with other costs. In other words, depreciation should be considered in fixed assets equation.

$$CA_t = CA_{t-1} + CASH_t + RA_t + INR_t \quad \forall t \tag{27}$$

Constraint (27) shows the current assets in each time period. Current assets include cash (*CASH*) and other receivable accounts with a fast liquidity. Receivable Accounts (*RA*), Inventory (*INR*), stocks and other marketable securities are considered as current assets.

$$CASH_t = NOPAT_t + STL_t + LTL_t + NIS_t - FAI_t \quad \forall t \tag{28}$$

Constraint (28) represents the net cash in each time. The cash available to each company obtains from the total amount of loans (*STL* + *LTL*), operating profit (*NOPAT*), and the amount of sold stock (*NIS*) during that period. The amount of investment for fixed assets (*FAI*) should be deducted from the cash.

$$INR_t = pri_t \; \frac{IP_t + IP_{t-1}}{2} \quad \forall t \tag{29}$$

Constraint (29) shows the inventory value at each time period, calculated via multiplying sales price (*pri*) in warehouse inventory (*Ip*).

$$FA_t = FA_{t-1} + FAI_t - DPR_t \quad \forall t \tag{30}$$

Constraint (30) shows the equation of fixed assets. The amount of investment in fixed assets is considered as an asset. Depreciation should be deducted from fixed assets.

$$E_t = NOPAT_t + RA_t - DPR_t + NIS_t + INR_t + E_{t-1} \quad \forall t \tag{31}$$

Constraint (31) shows the equity's mathematical formulation. The equity is calculated by considered the inventory value (*INR*), the profit obtained from issuing new stocks in the market (*NIS*), receivable accounts (*RA*) and operating profit (*NOPAT*).

4-1-Financial ratio constraints

The financial ratio or accounting ratio is a relative magnitude two selected amounts taken from the financial statements of a company. There are a number of standard proportions that try to assess the financial condition of a company or organization. Financial ratios can be used by a manager, current and potential shareholders, etc. Analyzing the financial ratios are used to compare the strengths and weaknesses of the different dimension of the company, such as the performance of a supply chain.

Constraints (32) – (36) show the financial ratios that we are chosen to demonstrate the financial condition of the supply chain.

$$\frac{CA_t - INR_t}{STL_t} \geq QR_t \quad \forall t \tag{32}$$

Constraint (33) shows the formulation of the quick ratio (acid test). This ratio investigates the company's ability to make payments on current obligations. The quick ratio is one of the liquidity ratios. Liquidity ratios demonstrate a company's ability to cover accounts payable, short-term debt, and other liabilities. In other words, these ratios represent the accessibility of cash and other assets that used to cover short-term liabilities.

$$\frac{NTS_t}{RA_t} \geq RTR_t \qquad \forall t \tag{33}$$

Constraint (34) shows the formulation of accounts receivable turnover. This ratio represents the rate of debt collection. In other words, this ratio shows the number of debt that received during one year. Accounts receivable turnover ratio is one of the asset management ratios. Asset management ratios or efficiency ratios can analysis the company's ability to collecting money of its credit sales.

$$\frac{NTS_t}{FA_t} \geq FATR_t \qquad \forall t \tag{34}$$

Constraint (35) shows the formulation of fixed asset turnover ratio. This ratio is one of the fixed asset management ratios. Fixed asset turnover ratio compares the company's revenue with its fixed assets. In other words, This ratio investigates the ability of the company to use fixed assets to generate revenue.

$$\frac{STL_t + LTL_t}{FA_t + CA_t} \leq TDR_t \qquad \forall t \tag{35}$$

$$\frac{STL_t + LTL_t}{E_t} \leq DER_t \qquad \forall t \tag{36}$$

Constraints (36) and (37) show the formulation of debt ratio and debt to equity ratio. Debt ratio measures the company's reliance on its assets to pay debts. Debt to equity ratio indicates the relative mix of the company's investor-supplied capital. These ratios chose from leverage ratios.

5-Stochastic optimization model

In this paper, we applied stochastic programming in order to deal with the uncertainty of demand and return rate uncertainty. To handle the input parameters' uncertainty, various techniques such as stochastic programming and fuzzy mathematical programming have been developed. The stochastic programming is used in a situation that the sufficient and reliable information regarding the uncertain parameter, is available. In other words, when the probability distributions governing the data are known or can be estimated, the stochastic programming is an appropriate approach to deal with the uncertainty of the parameter.

In order to model the uncertainty based stochastic programming framework and consider a robust approach to tackle the demand and return uncertainty, we used the method stated in Leung et al. (2007). Robust optimization (RO), presented by Mulvey et al. (1995), is able to tackle the decision makers' favored risk aversion or service-level function. In order to express the robust stochastic model, we consider the following compact model:

$$\begin{aligned} & Max\ Z = fy + \tilde{c}x \\ & s.t. \\ & \tilde{b} \leq Ax \\ & Sx = \tilde{N}y \\ & x.y \geq 0 \end{aligned} \tag{37}$$

Z is considered as the objective function of the above model. The vectors *f*; *c*, and *b* represented the parameters of the model. The matrices *A*, *S* and, *N* are coefficient matrices of the constraints. Also, all binary decision variables are included into vector *y* and all the continuous decision variables are included into vector *x*. It is assumed that vectors *c* and b and the coefficient matrix *N* are the uncertainty parameters of this issue. Based on the above-mentioned descriptions and the method stated in Leung et al. (2007), the robust stochastic model defined as follows:

$$Max = \sum_{\theta} \pi_\theta Z_\theta - \lambda \sum_{\theta} \pi_\theta \left(Z_\theta + \sum_{\theta'} \pi_{\theta'} Z_{\theta'} + 2U_\theta \right) - \sum_{\theta} \pi_\theta \varepsilon_\theta w_\theta$$

$s.t.$

$Z_\theta = fy + C_\theta x_\theta \quad \forall\theta$

$b_\theta - \varepsilon_\theta \leq Ax_\theta \quad \forall\theta$

$S_\theta x_\theta - N_\theta y_\theta + \varepsilon_\theta = 0 \quad \forall\theta$

$Z_\theta - \sum_{\theta'} \pi_{\theta'} Z_{\theta'} + U_\theta \geq 0 \quad \forall\theta$

$$U_\theta . \varepsilon_\theta . x_\theta . y_\theta \geq 0 \tag{38}$$

θ shows the possible scenarios. Also, π_θ denotes the probability of scenario θ. The first term in the objective function is the expected value of Z that maximize the total profit of the system. The second term, attempt to minimize the deviation of the total profit. The third term, try to minimize the penalty violation of constraints. According to the above descriptions, the MILP model under uncertain demand and quantity of return products can be defined as follows:

Sets

In addition to the sets defined in Section 4, the following set is added.

Ω Set related to potential scenarios $(1 \ldots \theta \ldots \Omega)$

i Set related to some constraint $(1 \ldots i \ldots I)$

Some parameters defined in Section 4 are modified as the following parameters; others are the same as defined before.

Parameters

$d_{ct\theta}$ The demand for domestic customer c in period t under scenario θ

$rcp_{ct\theta}$ The rate of returned product from customer c in period t under scenario θ

$QR_{t\theta}$ Lower bound for the quick ratio in period t under scenario θ

$FATR_{t\theta}$ Lower bound for the fixed assets turnover ratio in period t under scenario θ

$RTR_{t\theta}$ Lower bound for receivables turnover ratio in period t under scenario θ

$TDR_{t\theta}$ Upper bound for total debt ratio in period t under scenario θ

$DER_{t\theta}$ Upper bound for the debt-equity ratio in period t under scenario θ

Variables

As with the parameters, some variables are modified and the others are the same as defined before.

$XP_{t\theta}$ The quantity of semi-product that produce in production center in period *t* under scenario θ

$XPM_{mt\theta}$ The quantity of semi-product shipped from production center to production site m in period *t* under scenario θ

$XPL_{lt\theta}$ The quantity of semi-product shipped from production center to production site *l* in period *t* under scenario θ

$XPN_{nt\theta}$ The quantity of semi-product shipped from production center to the production site *n* in period *t* under scenario θ

$XNM_{nmt\theta}$ The quantity of semi-product shipped from production site *n* to production site *m* in period *t* under scenario θ

$XLM_{lmt\theta}$ The quantity of semi-product shipped from production site *l* to production site *m* in period *t* under scenario θ

$XMP_{mt\theta}$ The quantity of semi-product shipped from production site *m* to production center in period *t* under scenario θ

$YP_{t\theta}$ The quantity of final product that produces in production center in period *t* under scenario θ

$XPC_{ct\theta}$	The quantity of final product shipped from the production center to customer *c* in period *t* under scenario θ
$XCP_{ct\theta}$	The quantity of return product shipped from customer *c* to production center in period *t* under scenario θ
$I_{t\theta}$	The inventory level of semi-product in production center in period *t* under scenario θ
$IP_{t\theta}$	The inventory level of final product in production center in period *t* under scenario θ
$IM_{mt\theta}$	The inventory level of semi-product in production site *m* in period *t* under scenario θ
$IL_{lt\theta}$	The inventory level of semi-product in production site *l* in period *t* under scenario θ
$IN_{nt\theta}$	The inventory level of semi-product in production site *n* in period *t* under scenario θ
$TC_{t\theta}$	Total cost in period *t* under scenario θ
$TTC_{t\theta}$	Total transportation costs in period *t* under scenario θ
$THC_{t\theta}$	Total holding costs in period *t* under scenario θ
$CA_{t\theta}$	Current assets in period *t* under scenario θ
$EBIT_{t\theta}$	Earnings before interest and tax in period *t* under scenario θ
$INR_{t\theta}$	Value of inventory in period *t* under scenario θ
$NTS_{t\theta}$	Net sales in period *t* under scenario θ
$NOPAT_{t\theta}$	Net operating profit after taxes in period *t* under scenario θ
$TI_{t\theta}$	Total income in period *t* under scenario θ
$E_{t\theta}$	Equity in period *t* under scenario θ
$Cash_{t\theta}$	Cash in period *t* under scenario θ

In the following, we have showed the constraints that have changed under uncertainty. Other phrases are the same as the Section 4:

$$Max\ NOPAT = \sum_{\theta} \pi_\theta Z_{\theta t} - \lambda \sum_{\theta} \pi_\theta \left(Z_{\theta t} + \sum_{\theta'} \pi_{\theta'} Z_{\theta' t} + 2U_{\theta t} \right) - w \sum_{\theta} \sum_{i} \pi_\theta \varepsilon_\theta^i \quad \forall t.\theta.i$$

$$Z_{\theta t} - \sum_{\theta'} \pi_{\theta'}\, Z_{\theta' t} + U_{\theta t} \geq 0 \qquad \forall \theta.t$$

$$Z_{\theta t} = (1 - tr_t)\, TI_{\theta t}^{+} - TI_{\theta t}^{-} \qquad \forall t.\theta$$

$$TI_{\theta t}^{+} - TI_{\theta t}^{-} + \varepsilon_\theta^1 = EBIT_{\theta t} - IP_t \qquad \forall t.\theta$$

$$EBIT_{\theta t} + \varepsilon_\theta^2 = NTS_{\theta t} - TC_{\theta t} \qquad \forall t.\theta$$

$$NTS_{\theta t} + \varepsilon_\theta^3 = \sum_{c=1}^{C} XPC_{\theta ct}\, pri_t \qquad \forall t.\theta$$

$$TC_{\theta t} = THC_{\theta t} + TTC_{\theta t} + TFC_t \qquad \forall t.\theta$$

$$THC_{\theta t} = hcs_t \left(\frac{I_{\theta t} + I_{t-1}}{2} \right) + hcf_t \left(\frac{IP_{\theta t} + IP_{t-1}}{2} \right) + \sum_{n=1}^{N} hcn_{nt} \left(\frac{IN_{\theta nt} + IN_{nt-1}}{2} \right)$$

$$+ \sum_{m=1}^{M} hcm_{mt} \left(\frac{IM_{\theta mt} + IM_{mt-1}}{2} \right) + \sum_{l=1}^{L} hcl_{lt} \left(\frac{IL_{\theta lt} + IL_{lt-1}}{2} \right) \qquad \forall t.\theta$$

$$TTC_{\theta t} = \sum_{m=1}^{M} tcpm_{mt}\, XPM_{\theta mt} + \sum_{n=1}^{N} tcpn_{nt}\, XPN_{\theta nt} + \sum_{l=1}^{L} tcpl_{lt}\, XPL_{\theta lt}$$

$$+ \sum_{n=1}^{N} \sum_{m=1}^{M} tcnm_{nmt}\, XNM_{\theta nmt} + \sum_{l=1}^{L} \sum_{m=1}^{M} tclm_{lmt}\, XLM_{\theta lmt}$$

$$+ \sum_{m=1}^{M} tcmp_{mt}\, XMP_{\theta mt} + \sum_{c=1}^{C} tcpc_{ct}\, XPC_{\theta ct} + \sum_{c=1}^{C} tccp_{ct}\, XCP_{\theta ct} \qquad \forall t.\theta$$

$$XP_{\theta t} - I_{\theta t} + I_{\theta t-1} = \sum_{m=1}^{M} XPM_{\theta mt} + \sum_{n=1}^{N} XPN_{\theta nt} + \sum_{l=1}^{L} XPL_{\theta lt} \qquad \forall t.\theta$$

$$XPN_{\theta nt} - IN_{\theta nt} + IN_{\theta nt-1} = \sum_{m=1}^{M} XNM_{\theta nmt} \qquad \forall t.n.\theta$$

$$XPL_{\theta lt} - IL_{\theta lt} + IL_{\theta lt-1} = \sum_{m=1}^{M} XLM_{\theta lmt} \qquad \forall t.l.\theta$$

$$XPM_{\theta mt} - IM_{\theta mt} + IM_{\theta mt-1} = XMP_{\theta mt} \qquad \forall t.\theta$$

$$YP_{\theta t} - IP_{\theta t} + IP_{\theta t-1} = \sum_{c=1}^{C} XPC_{\theta ct} \qquad \forall t.\theta$$

$$XCP_{\theta ct} + \varepsilon_{\theta}^{4} = rcp_{\theta ct}\, XPC_{\theta ct} \qquad \forall t.c.\theta$$

$$d_{\theta ct} - \varepsilon_{\theta}^{5} \leq XPC_{\theta ct} \qquad \forall t.c.\theta$$

$$\frac{I_{\theta t} + I_{\theta t-1}}{2} \leq caps_t \qquad \forall t.\theta$$

$$\frac{IP_{\theta t} + IP_{\theta t-1}}{2} \leq capf_t \qquad \forall t.\theta$$

$$\frac{IN_{\theta nt} + IN_{\theta nt-1}}{2} \leq capn_{nt} \qquad \forall t.n.\theta$$

$$\frac{IM_{\theta mt} + IM_{\theta mt-1}}{2} \leq capm_{mt} \qquad \forall t.m.\theta$$

$$\frac{IL_{\theta lt} + IL_{\theta lt-1}}{2} \leq capl_{lt} \qquad \forall t.l.\theta$$

$$FA_t + CA_{\theta t} + \varepsilon_{\theta}^{6} = E_{\theta t} + STL_t + LTL_t \qquad \forall t.\theta$$

$$CA_{\theta t} + \varepsilon_{\theta}^{7} = CA_{t-1} + CASH_{\theta t} + RA_t + INR_{\theta t} \qquad \forall t.\theta$$

$$CASH_{\theta t} + \varepsilon_{\theta}^{8} = NOPAT_{\theta t} + STL_t + LTL_t + NIS_t - FAI_t \qquad \forall t.\theta$$

$$INR_{\theta t} = pri_t \; \frac{IP_{\theta t} + IP_{t-1}}{2} \qquad \forall t.\theta$$

$$E_{\theta t} + \varepsilon_{\theta}^{9} = NOPAT_{\theta t} + RA_t - DPR_t + NIS_t + INR_{\theta t} + E_{t-1} \qquad \forall t.\theta$$

$$\frac{CA_{\theta t} - INR_{\theta t}}{STL_t} + \varepsilon_{\theta}^{10} \geq QR_{\theta t} \qquad \forall t.\theta$$

$$\frac{NTS_{\theta t}}{RA_t} + \varepsilon_{\theta}^{11} \geq RTR_{\theta t} \qquad \forall t.\theta$$

$$\frac{NTS_{\theta t}}{FA_t} + \varepsilon_{\theta}^{12} \geq FATR_{\theta t} \qquad \forall t.\theta$$

$$\frac{STL_t + LTL_t}{FA_t + CA_{\theta t}} - \varepsilon_{\theta}^{13} \leq TDR_{\theta t} \qquad \forall t.\theta$$

$$\frac{STL_t + LTL_t}{E_{\theta t}} - \varepsilon_{\theta}^{14} \leq DER_{\theta t} \qquad \forall t.\theta$$

$$U_{\theta t}.\varepsilon_{\theta}^{i} \geq 0 \qquad \forall t.\theta.i \qquad (39)$$

It should be noted that the complexity of a stochastic programming problem increases, with the increase in the number of random scenarios. In problems with high complexity, solving model are encumbered by heavy computational process that can result in very long computational times and perhaps non-optimal solutions (Naderi and Pishvaee, 2017). There are some methods for reducing the number of random scenarios such as clustering technique or Benders decomposition method.

Clustering technique is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense) to each other than to those in other groups (clusters). Benders decomposition method is often used to solve problems that include continuous and discrete variables. The general idea of this algorithm is divided into two parts according to the division of the problem: a sub-problem, which consists of only continuous variables, and the main problem, which includes complex discrete variables and their constraints.

Since the number of scenarios associated with the uncertainty parameters of this paper is limited, there is no need to use the above methods to reduce the scenario. Using these methods can be considered in future works.

6-Computational experiments

6-1- Case study implementation and evaluation

In order to demonstrate the applicability of the proposed model, a case study is presented as reported in the recent literature (Yan Cui et al., 2017). The ILOG CPLEX 12.6 optimization software is employed to solve both models of the research. All the experiments are carried out by a Pentium dual-core 3.9 GHz computer with 8 GB of RAM.

The scale of the numerical experiment is as follows: the number production center is 1; the number of each production sites and the number of customer zones is 2. The number of time periods is 2. Considering the tactical decision horizon, each period in the model is six months. Table 2 provides the transportation cost in each period, while the demand and the rate of return are given in table 3. Table 4 presents the storage capacity of each center. Table 5 also illustrates the financial parameters such as the depreciation rate.

Table 2. Transportation cost (RMU[4]/Ton)

Transportation Cost	**Time Period**	
	t1	**t2**
Transportation cost per unit semi product from production center to production site *n1*	132	130
Transportation cost per unit semi product from production center to production site *n*2	137	138
Transportation cost per unit semi product from production center to production site *l1*	190	192
Transportation cost per unit semi product from production center to production site *l2*	187	189
Transportation cost per unit semi product from production center to production site *m1*	144	142
Transportation cost per unit semi product from production center to production site *m1*	137	139
Transportation cost per unit semi product from production site *n1* to production site *m1*	153	150
Transportation cost per unit semi product from production site *n1* to production site *m2*	145	143
Transportation cost per unit semi product from production site *n2* to production site *m1*	151	152
Transportation cost per unit semi product from production site *n2* to production site *m2*	144	143
Transportation cost per unit semi product from production site *l1* to production site *m1*	162	160
Transportation Cost	**Time Period**	
	t1	**t2**

[4] Relative Money Units

Table 2. Continued

Transportation cost per unit semi product from production site *l1* to production site *m2*	154	157
Transportation cost per unit semi product from production site *l2* to production site *m1*	163	161
Transportation cost per unit semi product from production site *l2* to production site *m2*	149	154
Transportation cost per unit semi product from production site *m1* to production center	123	125
Transportation cost per unit semi product from production site *m2* to production center	122	124
Transportation cost per unit final product from production center to customer *c1*	125	128
Transportation cost per unit final product from production center to customer *c2*	124	122
Transportation cost per unit return product from customer *c1* to production center	112	115
Transportation cost per unit return product from customer *c2* to production center	114	113

Table 3. Customer demand and rate of return (Ton)

Parameters	**Time Period**	
	t1	**t2**
Demand of customer *c1*	18	20
Demand of customer *c2*	16	15
Rate of returned product from customer *c1*	3%	2%
Rate of returned product from customer *c2*	4%	3%

Table 4. Capacity (Thousand Ton)

Storage Capacity	**Time Period**	
	t1	**t2**
Storage capacity for semi product at production center in	40	40
Storage capacity for final product at production center in	25	25
Storage capacity for semi product at production site *n1*	15	20
Storage capacity for semi product at production site *n2*	15	20
Storage capacity for semi product at production site *l1*	30	25
Storage capacity for semi product at production site *l1*	30	25
Storage capacity for semi product at production site *m1*	45	40
Storage capacity for semi product at production site *m2*	45	40

Table 5. Financial parameters

Parameters	**Time Period**	
	t2	**t2**
Tax rate	3%	4%
Depreciation rate	5%	6%
Short-term interest rate	14%	14%
Long-term interest rate	18%	18%
Lower bound for quick ratio	1.5	1.5
Lower bound for fixed assets turnover ratio	0.33	0.33
Lower bound for receivables turnover ratio	2.5	2.5
Upper bound for total debt ratio	0.7	0.7
Upper bound for debt–equity ratio	0.65	0.65

Tables 6 and 7 reports some results for each period of time. According to the results of table 6, for any production sites, 1 site has been selected from among the 2 potential ones. In other words, 1 site type M, 1 site type N and 1 site type L are enough to produce and assemble material at any period of time.

Table 7 reports the results associated with financial variables for two periods of time. According to the above table, the right side of the balance sheet is equal to its left side for two periods of time. This result indicates the accuracy of the financial model expressed in this research. The earnings before interest and tax, along with the amount of newly issued stocks, are presented in Table 7. The amount of newly issued stocks has been reported at a few levels for each period of time. This result represents the independence of the total profit from the sale of new stock. So, the company does not need to sell new stock in this situation.

Table 6. Number of active production sites

Site type	**M**		**N**		**L**	
Time Period	**t=1**	**t=2**	**t=1**	**t=2**	**t=1**	**t=2**
Number of active sites	1	1	1	1	1	1

Table 7. Model results (RMU/Ton)

Variables under random data	**Time Period**	
	t=1	**t=2**
E+LTL+STL	229143	269900
FA+CA	229143	269900
EBIT	6692400	6988245
NIS	3	0

The cost related to the supply chain is one of the factors that have a significant impact on reducing the operating profit. Managers have always been looking for a way to reduce costs. In order to evaluate the effect of each cost on the reduction of operating profit, the effect of transportation cost and holding cost has been investigated separately. In order to regardless of the effect of the tax on reducing the overall profit, we have examined the impact of costs on earnings before interest and tax (EBIT).

Figure 3 shows the effect of a growth of 5 unit of costs on profit. In order to demonstrate the impact of transportation cost and holding cost, four experiments have been designed. In each experiment, storage and transportation costs have increased by 5 units individually and the results have reported in figure 3. As illustrated in this figure, the decrease in transportation costs and holding costs increase the EBIT. However, the transportation cost decreases the EBIT with a greater amount compared with the holding cost.

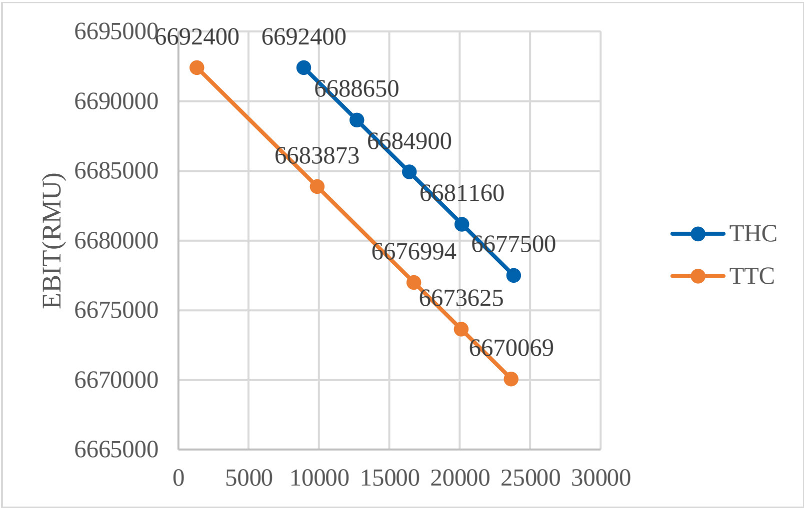

Fig 3. Impact of transportation cost and holding cost on earnings before interest and tax

In addition to the usual costs of the supply chain, such as fixed or holding cost, there is another cost that affected the supply chain's profit. WACC showed the weighted average cost of capital. The cost of capital depends on the type of financing. For example, if the cost of starting a new business is only provided through the investors, the cost of capital only depends on the cost of equity. On the other hand, if a company uses debt, the cost of capital also depends on the cost of the debt. The cost of capital obtains by calculating a weighted average of capital sources. For example, if capital structure of the company is consisting of 70% of shares and 30% of debt and the cost of stock and debt be 10% and 7%, the weighted average cost of investment will be calculated as follows:

$$WACC = (0.7 * 10\%) + (0.3 * 7\%) \tag{40}$$

It should be noted that the cost of equity is calculated using the Capital Asset Pricing Model (CAPM). Based on this model, the cost of equity calculated as follows:

Cost of Equity = Risk-Free Rate of Return + Beta * (Market Rate of Return – Risk-Free Rate of Return). Here, Beta is the measure of risk calculated as a regression of the company's stock price. In order to calculate the cost of debt, we can use the following formula:

Cost of Debt = (Risk Free Rate + Credit Spread) * (1 – Tax Rate). Here, credit spread depends on the credit rating. For example, given the following information, the cost of equity and the cost of debt calculated as follows:

Risk free rate = 2%.

Credit Spread = 3%.

Tax Rate = 38%.

Market rate of return = 4%

The beta of the stock = 1.8

Cost of Equity = Risk Free Rate of Return + Beta * (Market Rate of Return – Risk-Free Rate of Return) = 2% + 1.8 * (4% - 2%) = 0.056 = 5.6%.

Cost of Debt = (Risk Free Rate + Credit Spread) * (1 – Tax Rate) = (0.02 + 0.03) * (1 – 0.38) = 0.031 = 3.1%.

In order to show the impact of this cost, we use the Economic value added (EVA) as the objective function. The EVA formulation is given in Eq. (41).

$$EVA_t = NOPAT_t - (WACC_t) * (FA_t + CA_t) \tag{41}$$

EVA formulation simultaneously increases the NOPAT and reduces the WACC. Using EVA not only reduces the cost of capital but also have a significant impact on operating profit. Figure 4 represents the impact of considering EVA as the objective function. Based on this figure, using economic value added significantly increase the net profit. In the second period, the NOPAT growth is more significant in model 1 (EVA as an objective) in comparison to model 2 (NOPAT as an objective). Also, the impact of WACC on reducing the net profit has shown in figure 5.

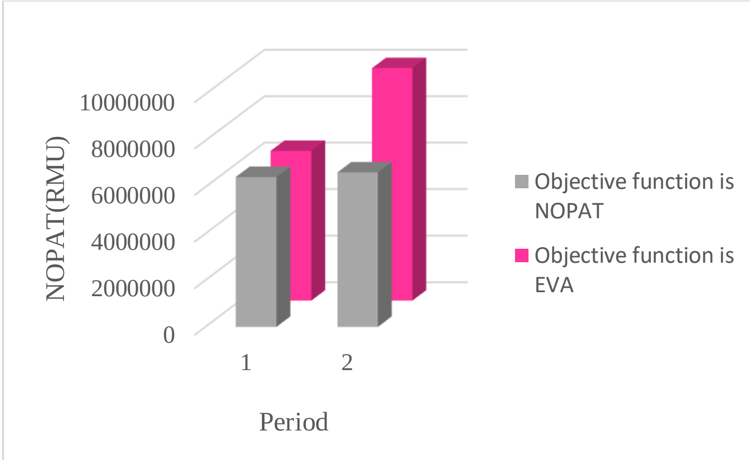

Fig 4. Impact of EVA on NOPAT

In order to demonstrate the impact of this cost, four experiments have been designed. In each experiment, WACC has increased 5 units. WACC decreases the NOPAT with a steeper gradient compared with the other costs. Therefore, the cost of capital has a greater impact on the reduction of profit compared to other costs. (Compare figures 3 and 5).

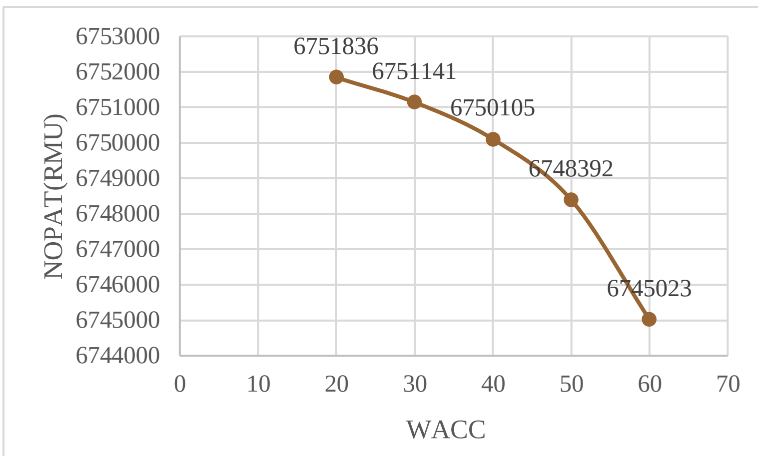

Fig 5. Impact of WACC on NOPAT

6-2- Impact of adding financial ratios on model result

In order to illustrate the impact of considering financial ratio, a comparison is made between operating profit and debt structure in the form of proposed approach (integrated financial and physical flow along with the financial ratio (model 1)) and integrated approach (integrated financial and physical flow). Figure 6 is demonstrated the difference in operating profit in 2 models. Based on this chart, model 1 reported the highest level of operating profit in comparison to model 2. Since the operating profit is directly affected by financial flows, it seems that the integrated financial and physical flow along with the financial ratio has improved this variable.

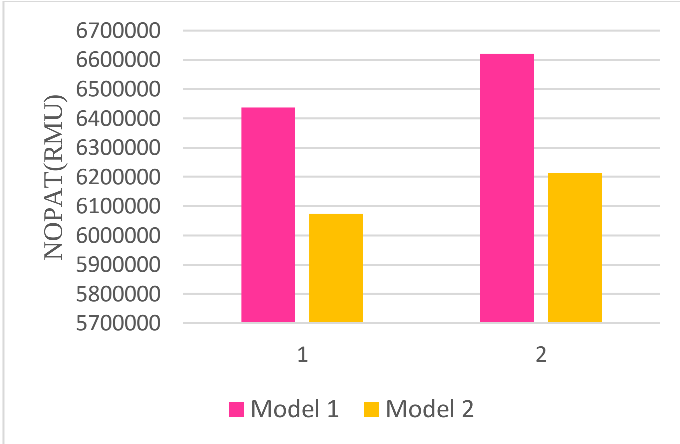

Fig 6. Operation profit

Investigating the impact of the financial ratio on debt structure is the other analysis of this section. Figure 7 shows the difference in debt structure in 2 models. Based on the result of this chart, model 1 reported the lowest amount for debt structure in each period. So, the model developed in this study, which has both financial flows and financial ratios, is reported the best result for debt structure.

According to the above results, using the financial ratios along with the financial flows can improve the performance of the supply chain condition.

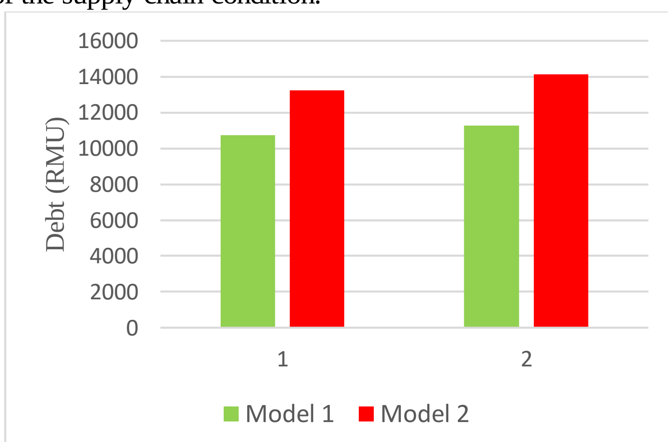

Fig 7. Debt structure

6-3- Stochastic model performance evaluation

As mentioned previously, we used a scenario-based model to deal with the uncertainty of rate of return and customer demand. In order to evaluate the performance of both definite and stochastic model, several numerical experiments are implemented and the related results are reported in this section. First, all the models are solved with nominal data (i.e., data represented in Tables 2, 3, 4 and 5). The corresponding results of the definite model are shown in the previous section. Then, to show the desirability and robustness of the derived solutions, 10 random realizations are generated uniformly. Afterward, obtained solutions under nominal data, are replaced in the realization model. A linear programming model, defined as follows:

$$Max\left[(1-tr)\,TI^{+*}-TI^{-*}\right]-\sum_{i=1}^{2}\pi\,(\Psi_i^{+}+\Psi_i^{-})$$
$$s\cdot t\cdot$$
$$XCP_c^{*}-rcp_{real}\,XPC_c^{*}=\Psi_1^{+}-\Psi_1^{-}\qquad\forall c$$
$$d_{real}-XPC_c^{*}\leq\Psi_2^{+}-\Psi_2^{-}\qquad\forall c\qquad(42)$$

In this model, Ψ_i^{+} and Ψ_i^{-} are the only decision variables that determine the violation of chance constraints under realization. The π represents the violation fine of constraints that apply when Ψ^{+} takes a value. In the above model, d_{real} and rcp_{real} represent the realization value of the demand and return. Values such as XCP^{*} that marked with * represent the solution obtained by the models under nominal data. Other factors such as tr show the parameters of the problem. Table 8 shows the performance of the proposed models under nominal data.

Table 8. The performance of proposed models under nominal data

No. of realization	Demand	Return	Deterministic	Stochastic
1	17.0736	0.0362	6436900	6661900
2	13.6349	0.0440	6436600	6662200
3	16.1618	0.0371	6436800	6662000
4	14.3925	0.0397	6436700	6662100
5	17.7875	0.0362	6436900	6662000
6	17.5290	0.0114	6436300	6661800
7	17.5669	0.0474	6436400	6662300
8	13.4877	0.0403	6436600	6662200
9	15.7344	0.0257	6436300	6661800
10	17.8244	0.0168	6436600	6661600
Average			6436610	6662020
Semi variance			59100	46557

In order to show the evaluation of the proposed scenario-based model, the average and semi-deviation of objective function values are used. The proposed stochastic model has a more average and less semi-deviation in comparison to definite model. The results demonstrate the efficiency of the proposed model. Also, for all experiments, the values of the objective function (operating profit) is improved in the stochastic model in comparison to the definite model. The results indicate the better performance of the scenario-based model in all numerical tests compared to the deterministic one. Figures 8 and 9 show the performance of two definite and stochastic models. In these figures, we demonstrate the average and the amount of 10 realizations that state in table 8. As shown in figures 8 and 9, the average of the total profit of the supply chain in the stochastic model has about 4% increase compared to deterministic one. Also, semi-variance has decreased about 27%.

Fig 8. The performance of deterministic model

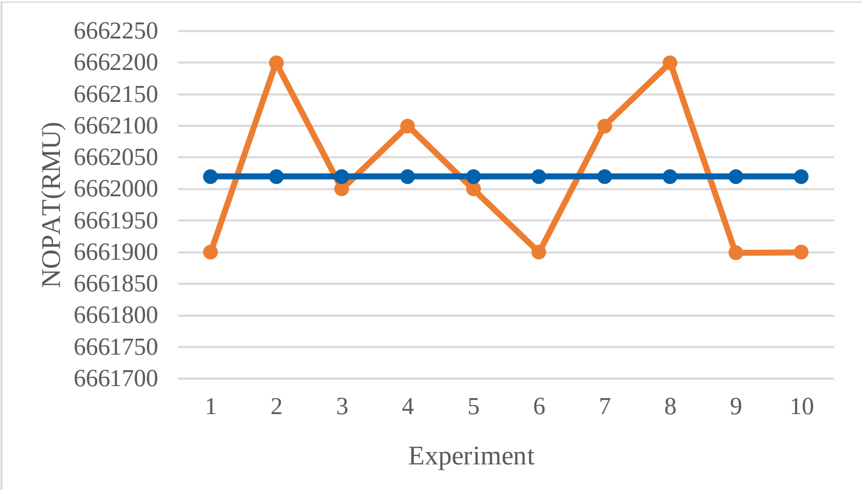

Fig 9. The performance of stochastic model

Also, the results show that the increase in return ratio decreases the total profit for both of the models. However, as illustrated in figure 10, the total profit is more sensitive to decreasing the return ratio in definite model compare to the stochastic model. In other words, the total profit for the definite model decrease with a steeper gradient compared with the stochastic model. This gradient is absolutely clear from 0.6 to 1.

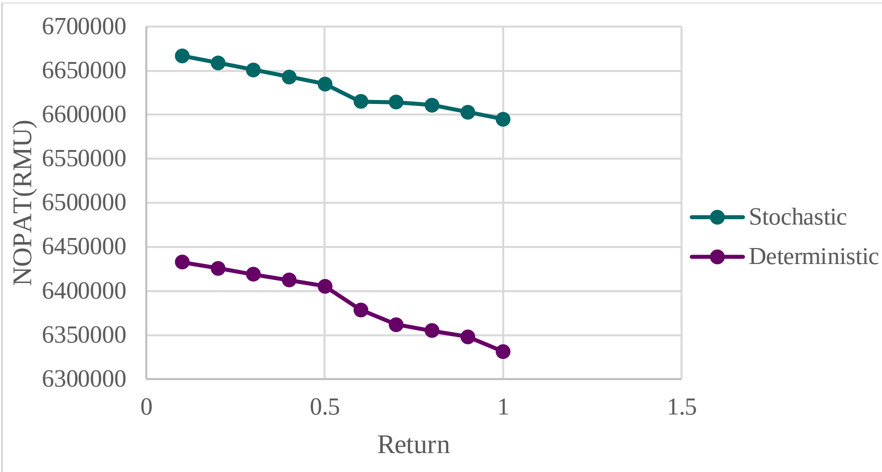

Fig 10. Stochastic model vs. deterministic model

7-Conclusions

Given the importance of evaluating financial flow in the closed loop supply chain, this paper has addressed a MILP model that simultaneously focuses on both financial and physical flows. In order to assess the financial performance, some financial ratio such as quick ratio is used. Along with integrating the financial and physical flows in a closed loop supply chain, because of the imprecise nature of the demand and return rate, the stochastic programming is applied to handle the inherent uncertainty of such parameters. Using the random data inspired by the recent literature, both the stochastic and deterministic models are solved and compared to each other. The results showed that some of the decision such as total profit is improved in uncertainty model in comparison to deterministic one. Finally, the performance of the stochastic model is illustrated and analyzed. The relevant results show the power of this model in reducing the deviation in objective function value.

Considering other financial measures such as working capital and budgeting can be regarded as future research. Another area for future researchers is taking into account the uncertainty of the financial factors such as Inflation rate and tax rate.

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