

Adjusting the credit sales using CVaR-based robust possibilistic programming approach

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Abstract

The purpose of this study is to develop a dairy global supply chain planning model in which operational and financial dimensions are appropriately integrated in order to adjust the credit sale strategy. In order to evaluate the financial performance of the dairy supply chain, economic value-added index and some financial ratios are used. The proposed model is compared to traditional approaches, which usually use the profit maximization as an objective function. Also, the amount of credit sales is considered as a decision variable for the first time in this research. The developed model utilized a new risk measure, i.e., the fuzzy CVaR, to cope with the uncertainty of the exchange rate and the quality and quantity of returned products. The effectiveness and efficiency of the proposed model are analyzed and assessed using the data of a real dairy supply chain. The analysis of results obtained from the developed fuzzy mathematical model shows an increase in profit and a reduction in semi-variance compared to previously developed models. Also, some numerical experiments analyses index and the impact of credit sales strategy.

Keywords: Financial flow, milk supply chain, credit sales, economic value-added, fuzzy mathematical programming, robust possibilistic programming, global supply chain.

1 Introduction

The dairy supply chain starts on raw milk production farms. Milk moves from the cows to cooling storage tanks located on the farm. Tanker trucks pick up and transport the milk to dairy factories. In dairy factories, milk is homogenized, pasteurized, packaged, and shipped to retailers. Today, due to the increase in milk demand, dairy factories are faced with increasing competition and rising costs. Therefore, developing integrated supply chain planning models, which include both the financial and operational aspects of a supply chain (SC), becomes more critical. Because of the impact of financial factors on the efficiency of the supply chain, these factors notably affect the planning of the supply chain. Integrated financial-operational planning models have received significant interest during the last years. Such models give the managers a more realistic view of the SC problems. Since both physical and financial flow decisions are related to each other [10], the integration of them provides a comprehensive view of managers and the decision makers. Despite the importance of this issue, most of the published articles only focused on the integration of different SC activities, and the integration of financial and operational flows is thoroughly ignored. The financial dimension of supply chain planning can be considered from two viewpoints: (1) cost and profit optimization, (2) financial or cash flow optimization. Costs and investments move forward in the SC, and therefore, they contribute directly to overall profitability. Similarly, the optimization of SC investment affects the return on fund occupied in a company. The financial flow goes back from the consumer, through the other nodes in the chain. The financial aspect of the SC consists of some financial arrangements that flow in opposite directions, including receivables and payables. Therefore, in order to model the financial aspect of SC, the cash flow in both directions should be considered. SC financial planning has been considered in several studies previously. In most of these researches, several constraints are used to relate the financial and physical flows to each other. Nevertheless, along with the importance of linking the financial and operational decisions of a supply chain, it

is essential to evaluate the financial factors through an acceptable logic. The use of financial ratios can appropriately fulfill such need in SC planning problems. Determining the optimal amount of credit sales is another essential issue that has not been considered in the SC planning literature. In other words, previous works consider the credit sale as an exogenous parameter. Determining the optimal level of credit sale should be done according to two important reasons: 1) the amount of cash needed for regular and quotidian business activities; 2) the sensitivity of customer demand to the number of credit sales. Notably, the low percentage of credit sale lead to loss of customers. Most customers prefer to repay a percentage of their purchase as payable accounts. So, they desire to buy the products from the suppliers who sell a percentage of their products as a credit sale. In recent years, because of problems caused by increasing waste, the government has paid more attention to environmental protection. Manufacturers are taking responsibility for the whole product lifecycle. In addition to the importance of managing returned product because of its environmental impact, the associated costs and value of reverse logistics should be considered (Vlachos 2016). The value of returned products can be more than hundreds of millions of dollars for one retailer, and the costs of returned products are high. Due to the uncertain nature of the exchange rate and the quality and quantity of returned products, the uncertainty of these parameters must be examined. Generally, some methods are developed to control the ambiguity of parameters. Stochastic programming is one of the applied methods used in a situation that the sufficient and reliable information regarding the uncertain parameter is available. In a situation that there is not a sufficient amount of historical data, the knowledge and experience of experts would be used to estimate the possibility distribution of uncertain parameters. In this situation, the fuzzy mathematical programming is used. Finally, the robust programming approach obtained a robust solution according to changes in the value of parameters. The exchange rate is a parameter with repeated variation because of political and economic conditions. These fluctuations cause complex changes in this parameter. A somehow similar condition is true for the quality and quantity of returned products. According to limited historical data about these two parameters, it is not possible to determine their probability distribution function. So, fuzzy mathematical programming is an appropriate method for this situation [29]. With regard to the descriptions as mentioned above, the present research proposes a novel mathematical model to integrate the physical and financial flows in a global closed-loop supply chain in order to maximize the economic value-added index. Also, some financial ratios are used in order to analyze and control the financial performance of the supply chain. The proposed model can adjust the credit sale strategy to make a reasonable balance between the amount of cash and sales. Moreover, the developed model address fuzzy mathematical programming to deal with the uncertainty of the exchange rate and quality and quantity of returned products. Last but not least, the model is implemented in a milk supply chain to analyze the model's practicality and performance. The remainder of this paper is organized as follows. The next section reviews the related literature as well as some essential literature gaps. Section 3 describes the model assumptions and problem description. The proposed mathematical model is elaborated in Section 4. Section 5 explains the developed, robust fuzzy programming approach used to cope with uncertainty in the model parameters. Section 6 represents a case study and discusses the computational results. Finally, the conclusions and suggested future works are presented in Section 7.

2 Literature review

2.1 Financial aspect in supply chain management models

Moussawi-Haidar and Jaber [23] developed a model for combining cash flow management and lot-sizing problem. Also, in this research, a delay in a payment contract is used for retailers. Longinidis et al. [17] 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. [27] 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. [4] 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 financial risk. Feng et al. [8] analyzed the impact of budget constraints on buyback and revenue sharing contracts. Xu et al. [37] examined the effectiveness of three contracts (revenue sharing contract, output penalty contract, and cost-sharing contract) in coordinating the outsourcing supply chain. Mohammadi et al. [21], designed a multi-objective 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. Vafa Arani and Torabi [34] considered cash flow management to integrate the financial and physical dimensions of the supply chain. In this research, the net present value (NPV) is considered as the objective function.

2.2 Closed-loop supply chain planning with uncertainty

In order to demonstrate the method that considered to model the uncertainty of input parameters, we reviewed some papers examined uncertainty in closed-loop supply chain planning. Based on this review, most article modeled the uncertainty through the stochastic programming (Khatami et al., [16]; Jeihoonian et al., [12]; Özceylan, [24]; Zhang and Unnikrishnan, [39]; Hassanzadeh Amin et al., [11]; Ma and Li, [18]; Cui et al., [6]). Fuzzy mathematical programming (Mirakhorli, [19]; Dai and Zheng, [7]; Mohajeri and Fallah, [20]; Jindal et al., [13]) and robust optimization [3] also used to cope with the uncertainty of parameters in some articles. Using the hybrid methods such as robust-stochastic programming (Gao and Ryan, [9]; Vahdani and Mohamadi, [35]; Keyvanshokoo et al., [15]; Mohammed et al., [22] Safaei et al., [29]) is considered to handle the uncertainty is some papers. Considering the uncertainty of the returned product investigate in some articles. The uncertainty of the quality of the returned product only investigated in Chen et al. [5] and Jeihoonian et al. [12]. Therefore, simultaneously review the quantity and quality of the returned product is a topic that is neglected. Also, an examination of the exchange rate uncertainty has not been addressed in closed-loop supply chain literature.

2.3 Dairy products supply chain planning

In this section, we review some articles related to the dairy products supply chain. The purpose of this review is to demonstrate the type of issues investigated in dairy supply chain literature. Investigating the proportion of milk supply chain planning to other dairy products supply chain planning and determining the number of articles that consider the uncertain nature of input parameters, are other aims of this review. The majority of existing studies about the dairy supply chain are assigned to production scheduling/planning. For example, production scheduling/planning of yogurt product (Sel et al., [30]; Sel et al., [31]), ice-cream product (Wari and Zhu, [36]) and milk product (Bilgen and Dogan, [3]; Touil et al., [33]), assigned the most articles related to the dairy products supply chain. Other domains in supply chain management such as distribution planning, procurement planning, routing (Sethanan and Pitakaso, [32]) are other issues which are very limited in proportion to planning problem. Supply chain planning for dairy products is a topic that is only investigated by Jouzdani et al. [14]. So, integrated financial-operational supply chain planning is a topic that is neglected in the dairy supply chain literature. Also, planning a supply chain for dairy products is limited in proportion to other issues in supply chain management. Regarding the literature, the main innovations of this study that differentiation this research from the other works mentioned in the literature can be summarized as follows:

- 1) Determine the optimal value of the credit sale and examine its impact of this on the overall profit of the chain and net cash.
- 2) Integrating physical and financial flows and considering financial ratio in a global closed-loop supply chain that has not been addressed in previous studies.
- 3) Using the CVaR based robust fuzzy programming approach to deal with the uncertainty of exchange rate, quality, and quantity of return product simultaneously, in the global closed-loop supply chain.
- 4) Using the data related to the Pegah dairy company in Tehran, as a real case study.

3 Problem definition and assumptions

The general structure of the considered SC network is explained in Figure 1. The considered SC includes four stages: (1) suppliers, (2) production center, (3) distribution centers, and (4) customers. In the forward direction, the suppliers are responsible for providing the raw milk to the production facility. The producer supplies raw milk from two raw milk-producing farms. A small amount of raw milk is purchased from the raw milk-production farms belonging to the production plant. The rest of the raw milk is supplied from the other raw milk-production farms at the province level. In other words, raw milk is supplied from two types of suppliers, raw milk production farms belonging to the Pegah factory and raw milk production farms not belonging to the Pegah factory (public raw milk production farms). After receiving the raw milk, two types of pasteurized and sterilized milk in the form of simple and flavored ones are produced at production centers. Without loss of generality, in this research, only the process of supply, production, and distribution of simple sterilized milk are taken into account. Simple sterilization milk has been selected because of two reasons: (1) the corruption period of this product is the same as the length of the accounting period; (2) the existence of accurate and reliable information regarding the simple sterilized milk. After the production and packaging stage, the products are shipped from plants to domestic and foreign customers via distribution centers. In order to transport the products to foreign customers, CIF (Cost, Insurance, and Price) agreement is used. The CIF is an international

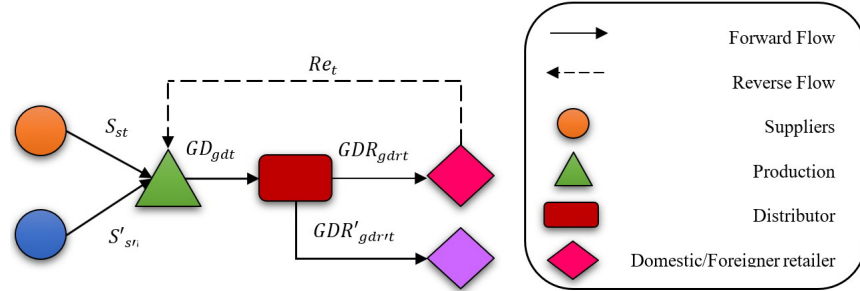


Figure 1: The structure of the studied global closed-loop supply chain network.

transferring contract applied in the shipping of the products between a seller and a buyer. This contract used only to inland waterway transport or sea. In the reverse direction, the amount of milk that is not sold at the appointed time (i.e., six months), will be returned to production centers from retailers. After treatment, the returned milk is used as part of the raw milk required by the plant. Other assumptions and simplifications used to model the above-mentioned problem are as follows:

- The problem is modeled as a multi-period and multi-product SC.
- The location of suppliers, production center, distributors, and customers are known and fixed.
- The capacities of facilities are restricted.
- The suppliers can supply the entire order of the producers.

4 Model formulation

The notations used in the developed model are defined in the following.

Indices:

g	Index of types of milk	$g = 1, \dots, G$
s'	Index of raw milk production farms	$s' = 1, \dots, S'$
s	Index of raw milk production farms belonging to the factory	$s = 1, \dots, S$
d	Index of distribution centers	$d = 1, \dots, D$
r	Index of domestic retailers	$r = 1, \dots, R$
r'	Index of foreigner retailers	$r' = 1, \dots, R'$
t	Index of time periods	$t = 1, \dots, T$

Parameters:

$pris_{st}$	Purchasing cost per unit of raw milk from supplier s in period t
$pris'_{s't}$	Purchasing cost per unit of raw milk from supplier s in period t
tcs_{st}	Transportation cost per milk unit from supplier s to production center in period t
$tcs'_{s't}$	Transportation cost per milk unit from supplier s to production center in period t
$pric_{gt}$	Price per unit of milk g for the domestic customer in period t
$pric'_{gt}$	Price per unit of milk g for foreigner customer in period t
$mindc_{gt}$	Minimum demand of domestic customer for milk g in period t
tcd_{dt}	Transportation cost per product unit from production center to distribution center d in period t
tcr_{dt}	Transportation cost per product unit from distribution center d to the domestic retailer in period t
tcr'_{dt}	Transportation cost per product unit from distribution center d to foreigner retailer in period t
$tcre_t$	Transportation cost per product unit from domestic retailer to production center in period t
cap_t	Store capacity for raw milk at the production center in period t
cap'_t	Store capacity for returned milk at the production center in period t
α_t	Quantity of returned product in period t
μ_t	Quality of returned product in period t
hcr_t	Holding cost per unit of raw milk at the store of production center in period t
hcr'_t	Holding cost per unit of return milk at the store of production center in period t

oc_t	Operating cost in production center in period t
ocm_t	Refinement cost per unit of raw milk in production center in period t
ocr_t	Refinement cost per unit of return milk in production center in period t
tr_t	Income tax rate in period t
tr'_t	Deposits tax rate in period t
er_t	Exchange rate in period t
et_t	Total export tariffs, customs duties and carriage insurance from distributor in period t
v_t	Depreciation rate in period t
ζ_t	Doubtful accounts rate in period t
C_t	Demand curve coefficient in period t
STI_t	Short-term investment in period t
STR_t	Short-term interest rate in period t
LTR_t	Long-term interest rate in period t
CI_t	Shareholders' cash in period t
QR_t	Quick ratio in period t
$NMPR_t$	Net profit margin ratio in period t
$ROER_t$	Return on equity ratio in period t
DR_t	Debt ratio in period t
DER_t	Debt-to-equity ratio in period t
$FATR_t$	Fixed asset turnover ratio in period t
ITR_t	Inventory turnover ratio in period t
$WACC_t$	Weighted average capital cost in period t
CIA_t	Prepayments in period t

Variables:

RM_{st}	Quantity of raw milk purchased from the supplier s in period t
$RM'_{s't}$	Quantity of raw milk purchased from the supplier s in period t
GG_{gt}	Quantity of milk g produce in production center in period t
GD_{gdt}	Quantity of milk g shipped from the production center to distribution center d in period t
$GDR_{gdr t}$	Quantity of product g shipped from distribution center d to retailer r in period t
$GDR'_{gdr' t}$	Quantity of product g shipped from distribution center d to retailer r' in period t
DC_{gt}	Demand of domestic customer for milk g in period t
DCF_{gt}	Demand of foreign customer for milk g in period t
Re_t	Quantity of return milk from domestic retailer to production center in period t
δ_t	Amount of credit sale in period t
I_t	Inventory level of raw milk in production center in period t
I'_t	Inventory level of return milk in production center in period t
TBC_t	Total purchasing cost of raw materials in period t
TPC_t	Total operating costs in period t
TTC_t	Total transportation costs in period t
THC_t	Total holding costs in period t
LR_t	Legal reserve 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
IP_t	Interest paid in period t
INR_t	Value of inventory in period t
NTS_t	Net sales in period t
$OPAT_t$	Net operating profit after taxes in period t
TI_t	Total income 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

BDP_t	Profit from bank deposits in period t
BDR_t	Bank deposit interest rate in period t
CGS_t	Cost of goods sold in period t

4.1 Objective function

In order to optimize the financial flow through the SC, the accounting and economic efficiency assessment techniques can be applied. In this study, we used the balance sheet equation to apply the accounting performance evaluation method. In order to apply the economic performance evaluation models, we applied a number of financial ratios in the model constraints and the economic value added (EVA) index in the objective function. The EVA formulation is given in Eq. (1).

$$Max EVA_t = \sum_{t=1}^T [NOPAT_t - (WACC_t)(FA_t + CA_t)] \quad (1)$$

In the above-mentioned equation, NOPAT is the net operating profit after tax reported in the balance sheet. WACC shows the weighted average cost of capital. The cost of capital belongs to the kind of financing. For example, if a company uses debt to start a business, the cost of capital also depends on the cost of debt. The cost of capital obtains by calculating a weighted average of capital sources. Notably, the cost of equity is calculated using the Capital Asset Pricing Model (CAPM).

$$WACC = (0.7 \times 10\%) + (0.3 \times 7\%) \quad (2)$$

$$NOPAT = er_t (1 - tr_t) TI_t^+ - TI_t^- \quad \forall t \quad (3)$$

$$TI_t^+ - TI_t^- = EBIT_t - IP_t \quad \forall t \quad (4)$$

$$IP_t = LTR_t LTL_t + STR_t STL_t \quad \forall t \quad (5)$$

Constraints (3) show the operating profit. In this formula, the exchange rate (er) is considered to integrate the domestic and foreign sales by a single currency. Constraints (4) calculate the taxable income and constraints (5) formulate the interest paid.

$$EBIT_t = NTS_t + BDP_t - TC_t \quad \forall t \quad (6)$$

$$NTS_t = \sum_{r \in R} \sum_{g \in G} \sum_{d \in D} [GDR_{gdr} pric_{gt} \delta_t + GDR_{gdr} pric_{gt} (1 - \delta_t)] + \sum_{r' \in R'} \sum_{g \in G} \sum_{d \in D} GDR'_{gdr't} pric'_{gt} er_t \quad \forall t \quad (7)$$

$$BDP_t = BDR_t STI_t (1 - tr') \quad \forall t \quad (8)$$

The gross income (i.e., income before tax and interest) is obtained from subtracting the total cost of (TC) from the total revenue. The revenue of the company may obtain from selling the products or other financial activities such as investment. In this case, we assume that the revenue of the company results from sold products (NTS) and profit from bank deposits (BDP). Constraints (6) show the mathematical formula for calculating gross income. Constraints (7) show the earning from domestic and foreign sales. Equation (8) represents the profit from bank deposits. Given that companies usually invest their capital in different banks, we define the bank deposits rate (BDR) as a variable. In other words, the model reports the optimal value for the bank deposits rate. However, in order to get a reasonable result as a bank deposit, a reasonable interval for bank deposit interest is set. In other words, we defined $BDR \in [0.2, 0.23]$. Constraints (9) represent the total cost.

$$TC_t = TBC_t + THC_t + TTC_t + TPC_t \quad \forall t \quad (9)$$

$$TBC_t = \sum_{s \in S} RM_{st} pris_{st} + \sum_{s' \in S'} RM'_{s't} pris'_{s't} \quad \forall t \quad (10)$$

$$THC_t = hcr_t \left(\frac{I_t + I_{t-1}}{2} \right) + hcr'_t \left(\frac{I'_t + I'_{t-1}}{2} \right) \quad \forall t \quad (11)$$

$$\begin{aligned}
TTC_t = & \sum_{s \in S} RM_{st} tcs_{st} + \sum_{s' \in S'} RM'_{s't} tcs'_{s't} + \sum_{g \in G} \sum_{d \in D} tcd_{dt} GD_{gdt} + tcre_t Re_t \\
& + \sum_{d \in D} \sum_{r \in R} \sum_{g \in G} tcr_{dt} GDR_{gdr} + \sum_{d \in D} \sum_{r' \in R'} \sum_{g \in G} tcr'_{dt} GDR'_{gdr't} et_t er_t \quad \forall t
\end{aligned} \tag{12}$$

$$TPC_t = \sum_{g \in G} oc_t GG_{gt} + ocr_t \mu_t Re_t + ocm_t \left(\sum_{s \in S} RM_{st} + \sum_{s' \in S'} RM'_{s't} \right) \quad \forall t \tag{13}$$

Constraints (10) show the cost of purchasing raw milk from different suppliers. Constraints (11) represent the holding cost for raw milk and returned milk at the production center. Constraints (12) illustrate the transportation cost between facilities. According to the CIF contract, tariff along with the exchange rate is multiplied in foreign transportation cost. Constraints (13) represent the operating cost, refinement cost of raw milk, and refinement cost of returned milk at the production center.

4.2 Constraints

4.2.1 Physical flow constraints

$$\sum_{s \in S} RM_{st} + \sum_{s' \in S'} RM'_{s't} + \mu_t Re_t + I_{t-1} + I'_{t-1} = GG_{gt} \quad \forall t, g \tag{14}$$

$$GG_{gt} = \sum_{d \in D} GD_{gdt} \quad \forall t, g \tag{15}$$

$$GD_{gdt} = \sum_{r \in R} GDR_{gdr} + \sum_{r' \in R'} GDR'_{gdr't} \quad \forall t, d, g \tag{16}$$

$$\sum_{d \in D} GDR_{gdt} \leq DC_{gt} \quad \forall t, g \tag{17}$$

$$\sum_{d \in D} GDR'_{gdr't} \leq DCF_{gt} \quad \forall t, g \tag{18}$$

Constraints (14) ensure the material flow balance at warehouses. Constraints (15) and (16) state that the sum of products shipped to domestic and foreign retailers should be equal to the products sent to distribution centers. Constraints (17) and (18) show the products shipped to domestic and foreign retailers. Constraints (19) calculate the percentages of the products returned from domestic retailers. α represents the percentage of returned goods. Constraint (20) and (21) ensure that in each period, the inventory level of the warehouse cannot be more than the warehouse capacity.

$$Re_t = \alpha_t \sum_{g \in G} \sum_{r \in R} \sum_{d \in D} GDR_{gdr} \quad \forall t \tag{19}$$

$$I_t \leq cap_t \quad \forall t \tag{20}$$

$$I'_t \leq cap'_t \quad \forall t \tag{21}$$

$$DC_{gt} = mindc_{gt} + C_t \delta_t \quad \forall t, g \tag{22}$$

Constraints (22) calculate the demand of customers. Generally, demand is a function of various factors, but in this study, minimum demand and credit sales are considered as the main factor affecting demand. The minimum of the demand is achieving based on forecasting the previous period. In order to determine the increase in demand due to the increase in credit sales, the coefficient C has been used. The vector C is a parameter calculated based on the historical information received from retailers. Based on data collected from retailers, we calculated the amount of increase in demand due to the increase in credit sales about 0.1 (Table -1). Then, based on the obtained value, we plot the demands curve (Figures 2 & 3).

Figures 2 and 3 represent the trend in the ton of demand in credit sales between 0.1 to 1. In order to depict them, we plot a demand curve by considering the minimum demand and the historical data about the coefficient C. Since

Table -1: Calculating the amount of demand according to the amount of credit sale.

Percentages of credit sale	Amount of increase in demand	Normalization	Minimum demand	Total demand
0.1	58	4.83333	9006	9010.833
0.2	83	5.1875	9006	9011.188
0.3	106	5.57895	9006	9011.579
0.4	127	6.35	9006	9012.35
0.5	161	6.44	9006	9012.44
0.6	187	7.19231	9006	9013.192
0.7	210	7.24138	9006	9013.241
0.8	235	7.34375	9006	9013.344
0.9	270	7.10526	9006	9013.105
1	305	7.2619	9006	9013.262

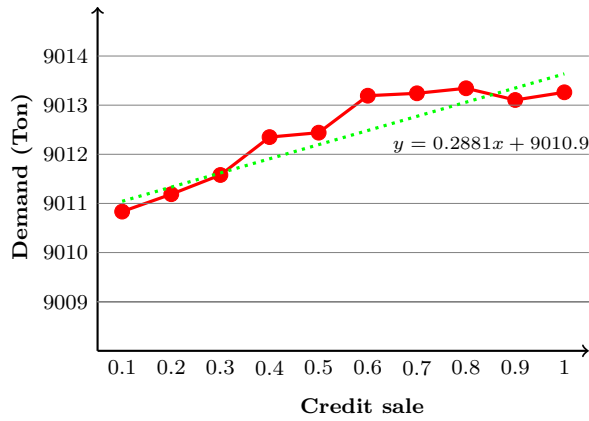


Figure 2: The demand curve for periods 1 & 2.

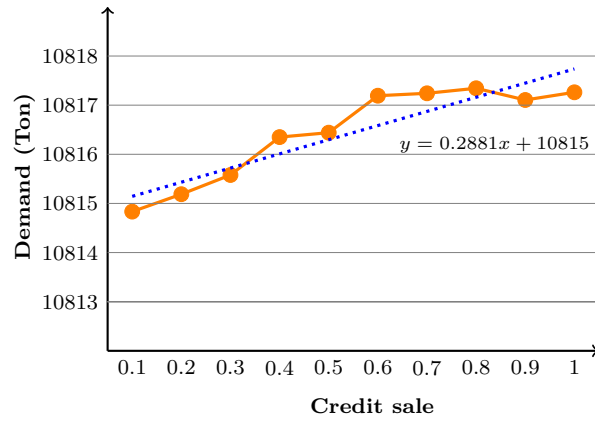


Figure 3: The demand curve for periods 3 & 4.

the minimum demand is different in the examined period, we drew two charts for demand, so that Figure 2 related to periods 1 and 2 and Figure 3 related to periods 3 and 4. Given the above curves, the demand functions are considered as follows:

$$DC_{gt} = 9010.9 + 0.2881\delta_t \quad \forall t, g \quad (23)$$

$$DC_{gt} = 10815 + 0.2881\delta_t \quad \forall t, g \quad (24)$$

4.2.2 Financial flow constraints

$$A_t + CA_t = E_t + STL_t + LTL_t \quad \forall t \quad (25)$$

$$A_t = CA_{t-1} + CASH_t + RA_t + INR_t + STL_t + CIA_t \quad \forall t \quad (26)$$

$$INR_t = \sum_{s \in S} pris_{st} \left(\frac{I_t + I_{t-1}}{2} \right) \quad \forall t \quad (27)$$

Constraints (25) show the fundamental equation of the balance sheet, which ensures that the assets should be equal to equity plus loans. Constraints (26) calculate the current assets in each period and constraints (27) show the inventory value formula.

$$RA_t = RA_{t-1} + (1 - \zeta_t) \left(\sum_{r \in R} \sum_{d \in D} \sum_{g \in G} GDR_{gdr} \text{pric}_{gt} \delta_t \right) \quad \forall t \quad (28)$$

$$RCASH_t = CASH_{t-1} + \sum_{r \in R} \sum_{d \in D} \sum_{g \in G} GDR_{gdr} \text{pric}_{gt} (1 - \delta_t) + \sum_{r \in R} \sum_{d \in D} \sum_{g \in G} GDR'_{gdr} \text{pric}'_{gt} er_t \quad \forall t \quad (29)$$

Constraints (28) represent the calculation of receivable accounts in each period. In this research, it is assumed that the receivable accounts only made from credit sales. It should be noted that a percentage of credit sales is considered as doubtful accounts (ζ_t). Constraint (29) represents the net cash formulation. Constraints (30) show the equation of fixed assets. The depreciation should be deducted from fixed assets. Because depreciation is an intangible cost and should not be considered along with other costs. Constraints (31) represent the equity's mathematical formulation. In this paper, the legal reserve (LR) is modeled for the first time. Constraints (32) and (33) show the formulation of this reserve. The legal reserve is the minimum amount of money that financial institutions such as banks, building societies, credit unions, and insurance companies are required by law to keep. According to note 140 of the Commercial Code in Iran, each company's board is required to save a 5% annual net profit as the legal reserve. When this reserve reaches 10% of the total capital, saving money as a legal reserve becomes optional.

$$FA_t = FA_{t-1} - v_t FA_t \quad \forall t \quad (30)$$

$$E_t = E_{t-1} + CI_t - LR_t + NOPAT_t - DP_t + INR_t \quad \forall t \quad (31)$$

$$LR_t = 0.025 NOPAT_t \quad \forall t \quad (32)$$

$$LR_t + LR_{t-1} \leq 0.1CI_t \quad \forall t \quad (33)$$

4.2.3 Financial ratio constraints

The financial ratio is a relative value taken from the financial statements of a firm. There are a number of standard ratios used to assess the financial aspect of a company or organization. The following financial ratios were selected based on the company structure.

$$\frac{CA_t - INR_t}{STL_t} \geq QR_t \quad \forall t \quad (34)$$

$$\frac{NOPAT_t}{NTS_t} \geq NMPR_t \quad \forall t \quad (35)$$

$$\frac{NOPAT_t}{E_t} \geq ROER_t \quad \forall t \quad (36)$$

$$\frac{STL_t + LTL_t}{FA_t + CA_t} \leq DR_t \quad \forall t \quad (37)$$

$$\frac{STL_t + LTL_t}{E_t} \leq DER_t \quad \forall t \quad (38)$$

$$\frac{NTS_t}{FA_t} \geq FATR_t \quad \forall t \quad (39)$$

$$\frac{CGS_t}{\frac{IS_t + IS_{t-1}}{2}} \leq ITR_t \quad \forall t \quad (40)$$

4.3 Model linearization

Constraints (7), (28) and (29) are nonlinear because in these equations, two variables are multiplied in each other. So these constraints convert to nonlinear ones. In order to linearize these equations, we use the following method. First of all, we considered δ as a variable that ranges between 0.1 to 1. By multiplying the δ to GDR, the model changes to a non-linear programming. In order to convert the non-linear term into the equivalent linear one, a new variable is defined as follows (Hammami and Frein, [10]):

$$GDR_{gdr t} \cdot \delta_t = V_{gdr t} \rightarrow \delta_t = \frac{V_{gdr t}}{GDR_{gdr t}} \xrightarrow{0 \leq \delta_t \leq 1} \frac{1}{10} GDR_{gdr t} \leq V_{gdr t} \leq GDR_{gdr t}$$

$$V_{gdr t} \leq GDR_{gdr t} \quad \forall t, g, d, r$$

$$V_{gdr t} \geq \frac{1}{10} GDR_{gdr t} \quad \forall t, g, d, r$$

$$V_{gdr t} \geq 0 \quad \forall t, g, d \quad (41)$$

Given the Assumption (41), the non-linear constraints of the model can be converted to an equivalent linear one as follows:

$$\begin{aligned}
NTS_t &= \sum_{r \in R} \sum_{g \in G} \sum_{d \in D} [V_{gdr} \text{pric}_{gt} + GDR_{gdr} \text{pric}_{gt} - V_{gdr} \text{pric}_{gt}] \\
&+ \sum_{r' \in R'} \sum_{g \in G} \sum_{d \in D} GDR'_{gdr't} \text{pric}'_{gt} \text{er}_t && \forall t \\
RA_t &= RA_{t-1} + (1 - \beta_t) \left(\sum_{g \in G} \sum_{d \in D} \sum_{r \in R} V_{gdr} \text{pric}_{gt} \right) && \forall t \\
CASH_t &= \left(\sum_{r \in R} \sum_{d \in D} \sum_{g \in G} GDR_{gdr} \text{pric}_{gt} - V_{gdr} \text{pric}_{gt} + \sum_{r \in R} \sum_{d \in D} \sum_{g \in G} GDR'_{gdr't} \text{pric}'_{gt} \right) \\
&+ CASH_{t-1} && \forall t \\
V_{gdr} &\leq GDR_{gdr} && \forall t, g, d, r \\
V_{gdr} &\geq \frac{1}{10} GDR_{gdr} && \forall t, g, d, r \\
V_{gdr} &\geq 0 && \forall t, g, d, r
\end{aligned} \tag{42}$$

5 The proposed robust fuzzy mathematical programming approach

As the literature emphasizes (Pishvae and Khalaf, [25]), fuzzy mathematical programming can be classified into two main categories: (1) flexible programming (FP) and (2) possibilistic programming (PP). FP is used to cope with flexibility on the objective function targets and soft constraints. PP is used to deal with the lack of knowledge about the actual value of input parameters. Given that the purpose of this study is to investigate the effect of uncertainty of some parameters, The PP approach is applied to deal with the epistemic uncertainty of such parameters. Pishvae et al. [26] classified robust fuzzy programming methods into three main categories: (1) hard-worst case robust programming, (2) soft-worst case robust programming, and (3) realistic robust programming. For example, the realistic fuzzy programming attempts to establish a reasonable trade-off between the robustness and the average performance of the concerned model. The exchange rate is a parameter with repeated variation because of political and economic conditions. These fluctuations cause complex changes in this parameter. The complex and unpredictable tendency of the exchange rate makes it difficult or impossible to find the probability distribution of this parameter. In this situation, using fuzzy mathematical programming could be desirable. A somehow similar condition is true for the quality and quantity of returned products. According to limited historical data about these two parameters, it is not possible to determine their probability distribution function. Also, the amount of returned milk and its quality directly depend on the retailer's commitment to return the milk timely.

5.1 The fuzzy membership function

Given that fuzzy mathematical programming uses numbers and fuzzy sets to model the uncertain parameters, it is necessary to specify the membership function of imprecise parameters. Mainly, there are six methods used in experiments with the aim of constructing membership functions such as Polling, Direct rating (point estimation), and etc.

In this paper, we use the direct rating method to determine the membership function of each uncertain parameter. In the direct rating method, at first, the numbers are assigned to each uncertainty parameters, and then some domain experts are asked to assign the appropriate value to each number. For example, to determine the height membership function, five numbers A, B, C, D, F are assigned and then, the experts are asked to specify 1 to 5 numerals for each value. The steps used to determine the membership function of the quality of returned milk are shown in Figure 4. First of all, we wanted experts to determine the quality of the returned milk by a score between 0 and 1. Then, we asked them to specify a number between 0 and 10 to concession the values obtained from the previous step. Based on the results obtained from previous steps, we determined the abundance chart for the values distinguished for the quality of returned milk. Finally, we normalized the collected results and defined the membership function. Notably, a similar procedure is used to determine the membership function of the exchange rate and quantity of returned products.

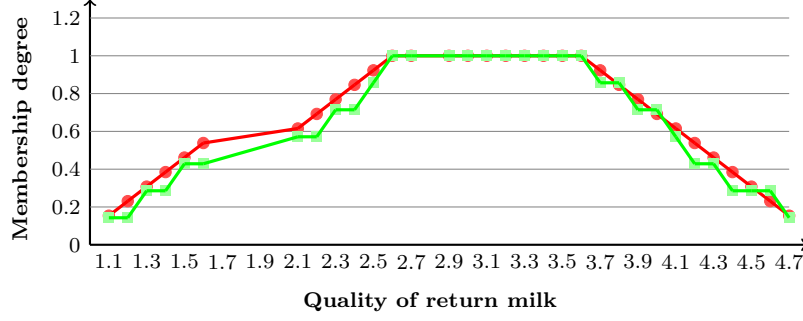


Figure 4: The structure of the studied global closed-loop supply chain network.

5.2 The robust possibilistic programming

To use the advantages of both possibilistic and robust programming, the robust possibilistic programming (RPP) approach is applied in this research to deal with uncertain parameters. Pishvae et al. [26] proposed six different RPP models, that only RPP-I, RPP-II, RPP-III, MRPP use a realistic approach to deal with uncertainty. In order to express the RPP model, we consider the following compact model:

$$\begin{aligned}
 &Max Z = fy + \tilde{c}x \\
 &s.t : \\
 &Ax \geq \tilde{d} \\
 &Bx = \tilde{e} \\
 &Sx \leq \tilde{N}y \\
 &x \geq 0, y \in \{0, 1\}
 \end{aligned} \tag{43}$$

Where the vectors f, c, e and d show the parameters of the proposed problem and A, B, S and N show the coefficient matrices of the constraints. Additionally, vectors x and y define the continuous and binary variables, respectively. It is assumed that vectors c, d, e and the coefficient matrix N are the uncertain parameters of the studied problem. Some articles use credibility. In order to define the credibility measure, let $(\tilde{\xi})$ be a fuzzy variable with membership function $\mu(x)$ and r be a real number. Considering a confidence level of δ , the credibility measure for fuzzy event $\{\tilde{\xi} \leq r\}$ and $\{\tilde{\xi} = r\}$ defined as follows (Ahmadvand and Pishvae [1]):

$$Cr\{\tilde{\xi} \leq r\} \geq \delta \rightarrow r \geq (2 - 2\delta)\xi_3 + (2\delta - 1)\xi_4 \tag{44}$$

$$Cr\{\tilde{\xi} \geq r\} \geq \delta \rightarrow r \leq (2\delta - 1)\xi_1 + (2 - 2\delta)\xi_2 \tag{45}$$

$$Cr\{\tilde{\xi} = r\} \geq \delta \rightarrow \begin{cases} \delta \leftrightarrow r \geq \left(\frac{\delta}{4}\right)(\xi_3 + \xi_4) + \frac{1}{2}(\xi_1 + \xi_2)\left(1 - \left(\frac{\delta}{2}\right)\right) \\ \delta \leftrightarrow r \leq \left(\frac{\delta}{4}\right)(\xi_1 + \xi_2) + \frac{1}{2}(\xi_3 + \xi_4)\left(1 - \left(\frac{\delta}{2}\right)\right) \end{cases} \tag{46}$$

In order to deal with the uncertainty of parameter c in the objective function, the fuzzy expected value method is used. The expected value model is a simple method that can be applied more conveniently without increasing the computational complexity of the original model. Also, to choose the appropriate realistic RPP method, the preferences of the decision-makers on the value of the objective function should be analyzed. In cases in which the decision-maker cares about the deviations of the objective function over or under the expected optimal value, RPP-II would be the appropriate choice. Since the objective function of this problem aims to maximize the profit, only deviations under the average performance (i.e., expected value) are undesirable. Based on the above-mentioned descriptions, the credibility-based RPP-II model can be formulated as follows (Pishvae et al., [26]; Yousefi and Pishvae [38]):

$$\begin{aligned}
& \text{Max } E[Z] - \mu(E[Z] - Z_{\min}) - \theta[d_4 - (1 - \alpha)d_3 - \alpha d_4] - \delta[\gamma N_1 + (1 - \gamma)N_2 - N_1] \\
& - \rho \left[e_3 - \left(1 - \frac{\beta}{2}\right) e_2 - \frac{\beta}{2} e_3 \right] - \rho \left[\left(1 - \frac{\beta}{2}\right) e_3 + \frac{\beta}{2} e_2 - e_2 \right] \\
& \text{s.t. :} \\
& Ax \geq (2 - 2\alpha)d_3 + (2\alpha - 1)d_4 \\
& Bx \geq \left(1 - \frac{\beta}{2}\right) e_2 + \frac{\beta}{2} e_3 \\
& Bx \leq \left(1 - \frac{\beta}{2}\right) e_3 + \frac{\beta}{2} e_2 \\
& Sx \leq [(2 - 2\gamma)N_2 + (2\gamma - 1)N_1]y \\
& x \geq 0; y \in \{0,1\} \\
& 0 \leq \alpha, \beta, \gamma \leq 0.5
\end{aligned} \tag{47}$$

The first term of the objective function is the expected value of Z that maximizes the expected total profit of the system. The second term, i.e., $\mu(E[Z] - Z_{\min})$ attempts to minimize the deviation under the expected value. Notably, μ represents the importance of the second term against the two other terms in the objective function. Other terms of the objective function are used to control the feasibility robustness of the chance constraints. For example, the third term, i.e., $\theta[d_4 - (1 - \alpha)d_3 - \alpha d_4]$ is used to control the feasibility robustness of the first constraint. θ indicates the per unit penalty of violation and α shows the confidence level of the constraint. The traditional RPP models use terms such as $E[Z] - Z_{\min}$ to control the performance deviation of the concerned system. For cases such as the financial issue where a minor deviation is undesirable, it is better to use financial risk measures to control the deviations in RPP models. Babazadeh et al. [2] developed a RPP approach that uses absolute deviation to consider the risk (SD-based RPP). One of the well-known indicators extensively applied to measure the financial risk is the conditional value-at-risk (CVaR) defined by Rockafellar and Uryasev [28] as follows:

$$\begin{aligned}
CVaR_\theta &= \left(VaR_\theta + \frac{1}{1 - \theta} \Omega \right) \\
\Omega &\geq VaR_\theta - Z
\end{aligned} \tag{48}$$

Where Z represents the objective function of the maximization problem. θ indicates the confidence level between 0 and 1, which determines by the decision-maker. The positive variable Ω measures the positive difference between the value-at-risk and the objective function (Z) obtained in each scenario. Compared to VaR, CVaR has some advantages that make it more useful. For example, VaR function is continuous only for the normal probability distribution but, CVaR is continuous for all probability distributions. Also, CVaR can control the scenarios larger than VaR or in other words, the loss exceeding the VaR. In this paper, we consider CVaR as a part of the objective function that is optimized beside the mean value. The use of CVaR as a part of the RPP model was firstly applied by Yousefi and Pishvae [38]. Given the proof obtained from this paper, the CVaR value for the trapezoidal fuzzy variable $\tilde{\xi}$ and the confidence level ∂ can be calculated as follows:

$$\xi_{Var} = \begin{cases} 2(\xi_1 - \xi_2)\partial - \xi_1 & \partial \leq 0/5 \\ 2(\xi_2 - \xi_3)\partial + \xi_3 - 2\xi_2 & \partial > 0/5 \end{cases} \tag{49}$$

$$\xi_{CVar} = \begin{cases} \partial\xi_1 - (1 + \partial)\xi_2 & \partial \leq 0/5 \\ (\partial - 1)\xi_2 - \partial\xi_3 & \partial > 0/5 \end{cases} \tag{50}$$

5.3 The proposed CVaR-based robust possibilistic programming model

In this research, we adopt trapezoidal possibility distributions to model the imprecise parameters and the credibility measure (for both non-equal constraints), and necessity measure (for equal constraint) is employed to solve the proposed model. We used necessity measure for equal constraint because of the decision maker's sensitivity to this constraint. But, due to the self-duality of credibility measure and less sensitivity of decision-maker on these constraints, we used

credibility measure for non-equal constraints. As mentioned previously, in this research, the RPP model is used to deal with the uncertainty of input parameters. In this model, in addition to expected value maximization, the performance deviation is controlled via the CVaR measure. The uncertain parameters include the exchange rate, quality, and quantity of returned products. In order to express the CVaR-based RPP model in a more convenient way, we consider the following compact model.

$$\begin{aligned}
& \text{Max } Z = ay + \tilde{b}x \\
& \text{s.t. :} \\
& Cx \geq \tilde{D}y \\
& Ex = \tilde{F}y \\
& Gx \leq \tilde{H}y \\
& x, y \geq 0
\end{aligned} \tag{51}$$

The vectors a and b represent the parameters of the problem and C, D, E, F, G and H show the coefficient matrices of constraints. Additionally, vectors x and y denote the continuous variables, respectively. It is assumed that vectors b and the coefficient matrix D, F and H are the uncertain parameters. Accordingly, the proposed CVaR-based robust possibilistic programming model is defined as follows:

$$\begin{aligned}
& \text{Max } E[Z] - \psi [(\lambda - 1)b_2 - \lambda b_3] - \varphi [D_4 - (1 - \alpha)D_3 - \alpha D_4] - \phi [\delta H_1 + (1 - \delta)H_2 - H_1] \\
& - \varpi \left[F_3 - \left(1 - \frac{\beta}{2}\right) F_2 - \frac{\beta}{2} F_3 \right] - \varpi \left[\left(1 - \frac{\beta}{2}\right) F_3 + \frac{\beta}{2} F_2 - F_2 \right] \\
& \text{s.t. :} \\
& Cx \geq ((2 - 2\alpha)D_3 + (2\alpha - 1)D_4)y \\
& Ex \geq \left(\left(1 - \frac{\beta}{2}\right) F_2 + \frac{\beta}{2} F_3 \right) y \\
& Ex \leq \left(\left(1 - \frac{\beta}{2}\right) F_3 + \frac{\beta}{2} F_2 \right) y \\
& Gx \leq ((2 - 2\delta)H_2 + (2\delta - 1)H_1)y \\
& x, y, \psi, \varphi, \phi, \varpi \geq 0 \\
& 0 \leq \alpha, \beta, \delta \leq 0.5
\end{aligned} \tag{52}$$

5.4 Linearization

As it can be seen from the model (52), the coefficients α , δ and β are decision variables range between 0 and 0.5. By multiplying these coefficients in continuous variable y , the model becomes a non-linear programming. In order to convert the non-linear terms into the linear ones, new variables are defined as follows.

$$\alpha \times y = A \quad \beta \times y = B \quad \delta \times y = C \tag{53}$$

Given the Assumption (53), the non-linear constraints of the model (52) are converted to equivalent linear ones as follows:

$$\begin{aligned}
& \text{Max } E[Z] - \psi [(\lambda - 1)b_2 - \lambda b_3] - \varphi [D_4 - (1 - \alpha)D_3 - \alpha D_4] - \phi [\delta H_1 + (1 - \delta)H_2 - H_1] \\
& - \varpi \left[F_3 - \left(1 - \frac{\beta}{2}\right) F_2 - \frac{\beta}{2} F_3 \right] - \varpi \left[\left(1 - \frac{\beta}{2}\right) F_3 + \frac{\beta}{2} F_2 - F_2 \right] \\
& \text{s.t. :} \\
& Cx \geq ((2y - 2A)D_3 + (2A - y)D_4) \\
& A \leq y
\end{aligned} \tag{54}$$

$$\begin{aligned}
A &\geq \frac{1}{2}y \\
Ex &\geq \left(\left(y - \frac{B}{2} \right) F_2 + \frac{B}{2} F_3 \right) \\
Ex &\leq \left(\left(y - \frac{B}{2} \right) F_3 + \frac{B}{2} F_2 \right) \\
B &\leq y \\
B &\geq \frac{1}{2}y \\
Gx &\leq ((2y - 2C) H_2 + (2C - y) H_1) \\
C &\leq y \\
C &\geq \frac{1}{2}y \\
x, y, \psi, \varphi, \phi, \varpi, A, B, C &\geq 0
\end{aligned} \tag{55}$$

6 Computational results

In this section, the developed model is applied to a real case study from Iran. The ILOG CPLEX 12.6 optimization software is employed to solve the optimization models. All the experiments are carried out by a Pentium dual-core 3.9 GHz computer with 8 GB of RAM. Several numerical tests were made to evaluate the performance of the models and the corresponding results are reported in this section.

6.1 Deterministic model performance evaluation

A real-world dairy supply chain in Tehran is used to illustrate the applicability of the proposed model. Tehran, the capital of Iran, is one of the most populated areas in the world. Due to the fact that milk is an essential ingredient in the people's food basket, an increase in population results in the increment of dairy products' demand. The Iran dairy industry (Pegah) is the largest dairy producer in Iran that satisfies a significant amount of demand for dairy products in Iran. This company is started in 1957 and right now, has 17 factories as the subsidiaries of the main corporate company, which produces dairies for 13 main cities. Pegah factory in Tehran is one of the main branches of the Iran dairy industries. Now, Pegah factory in Tehran produces more than 74 types of dairy products and transfers them to the domestic and foreign markets.

As mentioned previously, in this research, we study the procurement, production, and distribution of the sterilized milk product of the Pegah factory in Tehran. Among the dairy products produced by this plant, milk has been selected because of its special characteristics. Milk has the largest amount of demand in comparison to other dairy products. However, a percentage of the produced milk in each time period may not be sold before the corresponding expiration date. In this situation, the manufacturer should return the expired dairy products from retailers. The studied supply chain includes six out-house, and four in-house raw milk production farms, one production center, ten distribution centers; ten domestic retailers and four foreign retailers. Also, four time periods are taken into account. Tables 0 and 1 provide real data obtained from Pegah company

Table 2 shows the upper and lower bounds of financial ratios. Notably, the appropriate range for the financial ratio

Table 0: Demand (ton) and returned products data (percentage).

Parameters	time period			
	t1	t2	t3	t4
Minimum retailer demand for milk type 1	1810	1810	1510	1510
Minimum retailer demand for milk type 2	1810	1810	1510	1510
Minimum retailer demand for milk type 3	1810	1810	1510	1510
Minimum retailer demand for milk type 4	1799	1799	1498	1498
Minimum retailer demand for milk type 5	1799	1799	1498	1498
Minimum retailer demand for milk type 6	1782	1782	1480	1480
Quantity of return products	4	3.5	3.4	4
Quality of return products	5	5.5	5.3	6

Table 1: The numerical value of financial ratios (percentage).

Parameters	time period			
	t1	t2	t3	t4
lower bound for quick ratio	0.41	0.41	0.41	0.41
lower bound for net profit margin ratio	0.13	0.13	0.14	0.14
lower bound for return on equity ratio	1.2	1.2	1	1
Upper bound for debt ratio	0.97	0.97	0.88	0.88
Upper bound for debt-to-equity ratio	2.7	2.7	2.2	2.2
lower bound for the fixed asset turnover ratio	10.2	10.2	9.1	9.1
lower bound for inventory turnover ratio	7.8	7.8	7.9	7.9

Table 2: The calculation of the quick ratio (percentage).

Pegah Branches	$\frac{CA_t - INR_t}{STL_t}$		(CA_t)		(INR_t)		(STL_t)	
	t2	t1	t2	t1	t2	t1	t2	t1
Fars	0.518861659	0.518862	669952	591912	298872	302045	715181	689697
Golpayegan	0.772861744	0.772862	287043	263645	128206	161296	205518	265063
Esfahan	0.488958605	0.488959	607829	399230	279595	243753	671292	592739
Hamedan	0.082008106	0.082008	169536	281185	150172	137244	236123	338907
Lorestan	0.263917663	0.263918	179427	184628	104012	130670	285752	280231
Zanjan	0.343810336	0.34381	171358	124563	83926	76735	254303	259368
Average	0.411736352	0.411736						

is different in each industry. To estimate the appropriate value for upper and lower bounds, we used the information of other branches of Pegah dairy company for the previous two years. Table 2 illustrates the method used to estimate the quick ratio.

In this research, the economic value added is used to assess the financial performance of the supply chain. Figure 5 shows the structure of current assets in Models (1) and (2), which the first one maximizes the economic value-added as the objective function, and the latter maximizes profit as the objective function. Based on figure 5, The amount of current assets increases more in Model (1) compared to Model (2). Another issue that illustrates the significant impact of EVA, is the increase in equity. The financial resources usually obtain through taking loans and shareholders' capital. An increase in capital value through business activities is an important issue for investors. The cost of the investment is one of the most important factors that can reduce the shareholders' capital value. Figure 6, shows the amount of increase in equity by considering a reduction in the cost of investment. According to these results, it can be concluded that the economic value added provide better control over both the cost of capital and total profit.

Determining the optimal level of credit sale is one of the main contributions of this paper. As mentioned previously, this issue is important because it affects the level of profit and cash in each period. Figure 7 shows the optimal amount of credit sale for four periods. As Figure 7 shows, the number of credit sales increases incrementally during the periods. Accordingly, the upward trend in customer demand shown in Figure 8. The analysis of the results indicates an average of 100 tones increases in customer demand by a 4% increase in a credit sale. For example, between T=1 and T=2, customer demand increased by about 156,000 tons. Therefore, selling a percentage of products in the form of credit sale, not only does not reduce the profit of the supply chain but also increase the demand and the total profit.

In order to illustrate the impact of financial ratio, a comparison is made between three models including (1) the integrated financial-physical flow model which also considers the financial ratio (i.e., Model 1), (2) the integrated financial-physical flow model (i.e., Model 2) and (3) the traditional model which only considers the physical flow (i.e.,

Table 3: The model results.

Variables	Variables under real case data			
	t1	t2	t3	t4
FA+CA	65019	224582	518075	976657
LTL+STL+E	65019	224582	518075	976657
Bank deposits rate	0.02	0.02	0.023	0.02
Raw milk purchased	49810.55	74230.4	105200.2	122380.8
Return milk	4.421079	10.62095	12.35623	18.16358

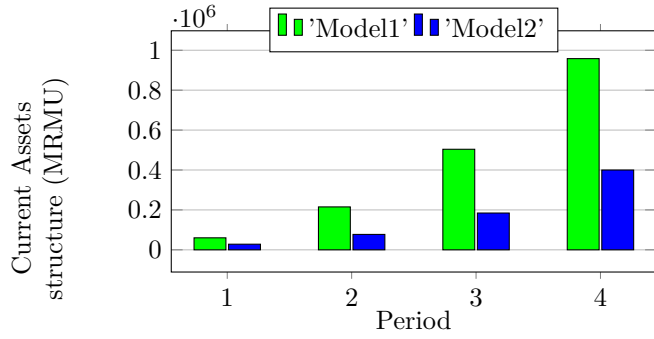


Figure 5: Current asset structure.

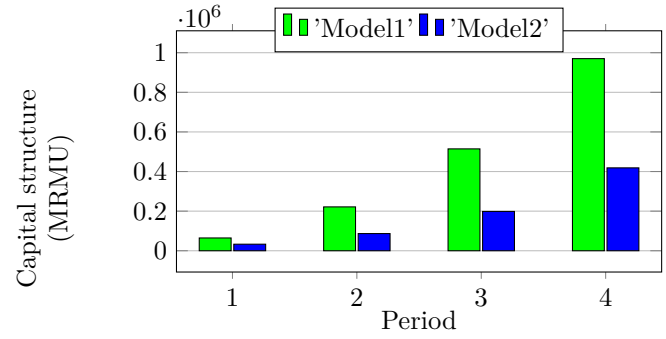


Figure 6: Structure of equity.

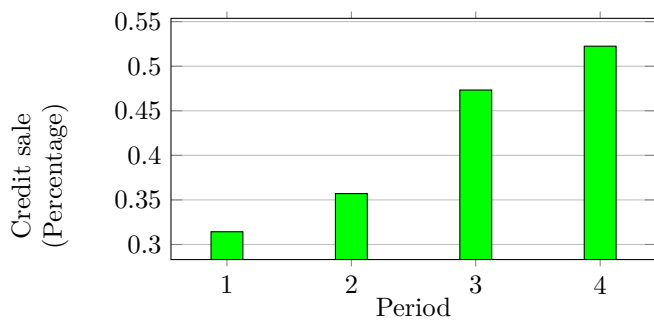


Figure 7: Credit sale value.

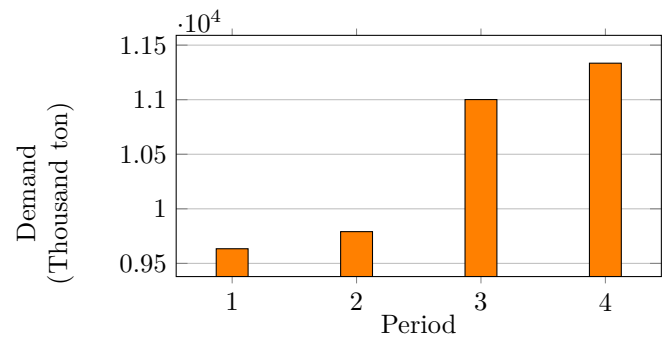


Figure 8: Demand value.

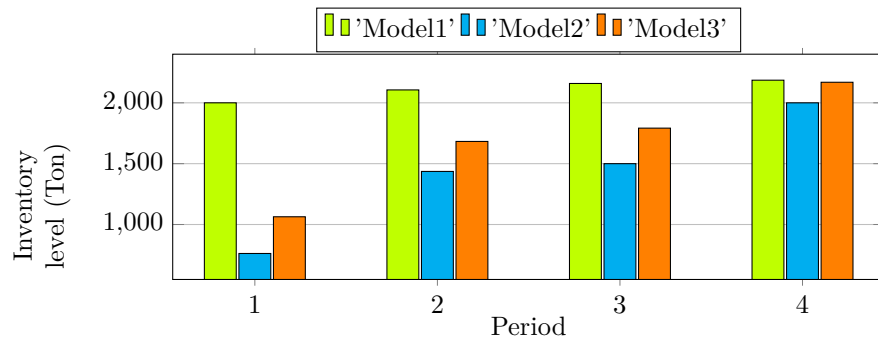


Figure 9: Inventory level.

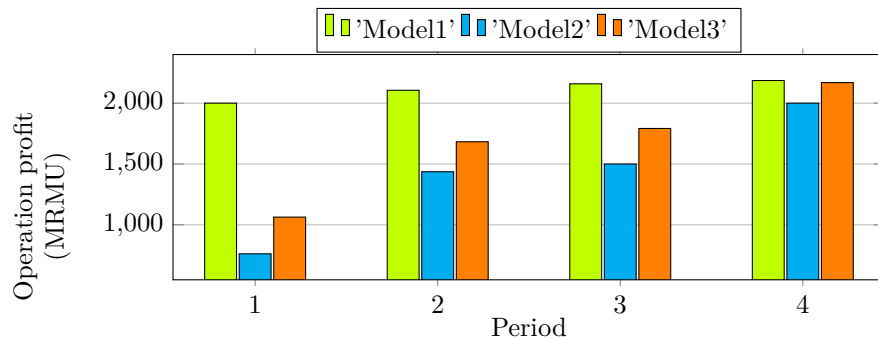


Figure 10: Operation profit level.

Table 4: Fuzzy parameters.

Parameters	Trapezoidal fuzzy number	
	t=1, t=2	t=3, t=4
Exchange Rate	(3000, 3050, 3100, 3150)	(3042, 3095, 3122, 3160)
Quantity of returned milk	(1.1, 2.6, 3.6, 4.6)	(1.1, 2.6, 3.6, 4.6)
Quality of returned milk	(4.1, 5.5, 6.5, 7.6)	(4.1, 5.5, 6.5, 7.6)

Model 3). Figure 9 shows the difference in inventory level in the considered three models. As shown in this figure, the inventory level in Model (1) has the lowest amount compared to other models. It is obvious that the lower inventory level is more desirable according to the perishability of raw milk and inventory holding costs. Figure 10 demonstrates the difference in operating profit in the three considered models. As shown in Figure 10, Model (1) provides the highest level of operating profit in comparison to other models.

6.2 Fuzzy model performance evaluation

In order to evaluate the performance of the deterministic and RPP models, several numerical experiments are implemented and the related results are reported in this section. The four prominent values of trapezoidal fuzzy numbers used to indicate the imprecise parameters are randomly generated between the two extreme points of the corresponding possibility distribution function (i.e., $er_{real} \sim [er_1.er_4]$). Table 4 shows the fuzzy numbers generated for uncertain parameters. The weight of each term that represented in the objective function is set based on the opinion of the experts and decision-makers (DMs). In this paper, we assume that the DM is non-conservative. Also, in order to determine the value of each term, we used the expert's opinions. The values of the coefficients are set as follows:

$$\psi = 0.5 \quad \gamma = \delta = 0.3 \quad (56)$$

Several numerical tests are performed to evaluate the performance of developed models and the corresponding results are reported in this section. To this aim, firstly, all the models are solved under nominal data. Then, to show the desirability and robustness of the derived solutions, ten random realizations are generated uniformly. Afterward, the obtained solutions under nominal data, are replaced in the realization model similar to model (56).

$$Max Z = ay^* + b_{real} x^* - \sum_i \pi_i (\Psi_i^+ + \Psi_i^-)$$

s.t :

$$C x^* \geq D_{real} y^* + \Psi_1^+ - \Psi_1^-$$

$$E x^* = F_{real} y^* + \Psi_2^+ - \Psi_2^-$$

$$G x^* \leq H_{real} y^* + \Psi_3^+ - \Psi_3^-$$

$$x, y \geq 0$$

(57)

In this model, Ψ_i^+ and Ψ_i^- are the only decision variables which determine the violation of chance constraints under realization (see Pishvae et al., [26]). π represents the violation penalty of constraints. Amounts such as b_{real} represent the realized value of the corresponding imprecise parameters. Values such as x^* that marked with * represent the optimal solutions obtained by the models under nominal data. Table 5 shows the performance of the proposed models under nominal data. In order to assess the performance of the proposed CVaR-based model, the average and semi-deviation of objective function values under random realizations are comparison to traditional RPP-II and SD-based RPP model. Based on this table, the total profit obtained by the CVaR-based model shows about 11% increase compared to traditional RPP-II. Also, the semi-variance has decreased about 13%. Therefore, it can be concluded that using the CVaR to control the deviation of the RPP model can improve the results significantly.

7 Conclusions

This paper has addressed a MILP model that simultaneously focuses on both financial and physical flows. In order to assess the financial performance, the economic value added and some financial ratios are used. Along with integrating

Table 5: The performance of the proposed models under realized data.

No. of realization	RPP-II model With CVaR	RPP-II model With SD	Traditional RPP-II model	Deterministic model
1	567758885.8	556531282.5	545410582	527212986.3
2	569717973.4	555886670.2	529158527	510532698.9
3	558433731.9	537588313.5	529846153	517199907.7
4	557759793.4	539927700.3	5231987338	510571718.3
5	545908723.4	539073677.3	524341792	520710515.4
6	567387559.8	550088197.5	538896422	532595302.7
7	557726091.3	546499140.8	541379086	529182430.1
8	566551170.7	549703420.6	531958952	521309347.9
9	565043596.5	553671930.8	542408541	536003114.8
10	576831858	565424827.5	553126410	542669965.1
Average	563311934.8	549439516.1	535972520	524798798.7
Semi variance	4025952.882	4483989.952	4907776.63	5465069.178

the financial and physical flows in a global closed-loop supply chain, because of the imprecise nature of the exchange rate, quality and quantity of return products, the fuzzy mathematical programming is applied to handle the inherent uncertainty of such parameters. In the proposed fuzzy mathematical model, the CVaR measure is used to control the deviation of model performance. Using the real data inspired by the real case study (Pegah dairy company), both the fuzzy and deterministic models are solved and compared to each other. The results showed the impact of considering both financial flow and financial ratio on improving the operational decision of the supply chain. Also, increasing the demand and operating profit in the results of modeling the credit sale, is another result of the proposed model. Finally, the performance of the CVaR measure is illustrated and analyzed. The relevant results show the power of this measure in reducing the deviation in objective function value. Considering other financial measures such as Net Present Value (NPV) can be regarded as the future research. Also, using other financial ratios such as the Dividend Payout Ratio (DPR) or Capitalization Ratio (CAR) should be considered in future work. Finally, the financing method and pricing could be adopted in supply chain network design. In terms of the uncertainty, taking into account the uncertainty of the other global financial factors such as customs duties and tax rate could be considered in the global supply chain problem. In this study, we used CVaR as a risk measure. Using EVaR or VaR as a risk measure can be considered in future works.

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