



## Developing an Optimal Financing Model for the Production Chain

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### ABSTRACT

Financial interactions play a critical role in inter-organizational transactions, particularly in complex supply chains where cash flow, risk sharing, and access to credit are vital for operational continuity. However, the integration of financial mechanisms into supply chain decision-making remains underexplored, especially for small and medium-sized enterprises (SMEs) that often face significant resource constraints. This study addresses this gap by developing a dual-objective optimization model for production chain financing that balances logistical efficiency with financial viability. The proposed model employs a fuzzy ideal programming approach, allowing for decision-making under uncertainty by incorporating both operational and financial constraints into a unified mathematical framework.

The research adopts a quantitative and applied methodology, with empirical data drawn from Koroosh Food Industries, a representative SME operating in a dynamic and resource-limited environment. The model is validated through a numerical case study using LINGO optimization software, which demonstrates how different supply chain structures can influence optimal financing strategies. Results show a strong relationship between supply chain configuration and financial performance, emphasizing the importance of integrated planning in capital-constrained settings.

This study contributes to both theory and practice by providing a robust decision-support tool that aligns production planning with financial considerations. Its findings are particularly relevant for SME managers, policymakers, and supply chain analysts seeking to enhance financial resilience and operational agility. The model's flexibility also makes it adaptable to various industries where uncertainty and financing challenges intersect.

**Keywords:** Supply Chain Finance, Metaheuristic Models, Optimization, Fuzzy Programming, SMEs



## 1. Introduction

Supply Chain Management (SCM) plays a fundamental role in integrating material, informational, and financial flows across enterprises to improve responsiveness and competitiveness (Mirzaei et al., 2015). While logistics and information systems have been extensively modeled, financial flows—particularly working capital financing—remain underexplored in supply chain research. This gap is especially significant for small and medium-sized enterprises (SMEs), which often face liquidity constraints and limited access to external financing sources (Talaghani et al., 2013).

Financial bottlenecks can severely affect procurement, production, and delivery schedules. Traditional perspectives on supply chains—such as the cyclical and push-pull models—primarily focus on operational flows without incorporating financial realities (Sabet Motlagh & Moghar, 2016). However, with the increasing complexity of global markets and heightened uncertainty due to economic disruptions, the need for integrated financial and operational planning has become more pronounced (Chen et al., 2023).

Prior studies have used various approaches such as fuzzy AHP (Ghahraman et al., 2019), robust optimization (Pishvae & Razmi, 2012), and hierarchical decision-making models to enhance supply chain decision-making under uncertainty. However, these models typically treat financing decisions independently of production planning. Moreover, although metaheuristic algorithms like Tabu Search, Simulated Annealing, and Genetic Algorithms have shown promise in portfolio and investment optimization (Mehrani et al., 2019a; Talbi, 2009), their application to integrated supply chain finance models remains limited.

This study addresses this gap by proposing a bi-objective fuzzy ideal programming model that simultaneously minimizes total operational costs and maximizes product quality, while considering financial constraints such as liquidity shortages and available credit mechanisms. The model is validated through a real-world case involving a food manufacturing company in Iran, demonstrating its practical relevance to capital-constrained production environments.

By incorporating financial mechanisms directly into tactical supply chain planning, the research contributes a novel, integrated decision-support tool

for SMEs. It provides insights for managers and policymakers aiming to improve resource allocation and risk management in uncertain economic contexts.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature on supply chain finance and metaheuristic optimization. Section 3 introduces the proposed mathematical model and its components. Section 4 presents the numerical validation using LINGO software. Section 5 discusses the findings and concludes with practical implications and directions for future research.

## Method

This study adopts an applied and quantitative research design aimed at addressing real-world challenges in production chain financing. The methodology is descriptive and retrospective (post-event), relying on both primary modeling and secondary data. Data collection was conducted using library and document-based sources, and the statistical population includes Koroosh Food Industries, a representative case of small and medium-sized enterprises (SMEs) operating under financial constraints.

The core of the research lies in the development of an integrated production-financing model under uncertainty. The model incorporates logistical and financial variables into a unified mathematical framework and is formulated as a mixed-integer linear programming (MILP) problem. To address the dual-objective nature of the problem—minimizing total cost and maximizing product quality—fuzzy ideal programming is used as the optimization approach. This method introduces membership functions for each objective, allowing simultaneous improvement toward ideal values.

### The constraints in the model are categorized into three groups:

**Logistical Constraints:** These ensure the balance of material flow between suppliers, manufacturers, and customers, subject to production capacities and inventory limits.

**Financial Constraints:** These represent liquidity shortages and the impact of various supply chain finance (SCF) tools, including dynamic discounting, working capital loans, and debt purchase facilities.

Integrated Constraints: These link the physical and financial dimensions of the supply chain, enabling coordinated decision-making.

The model is implemented using LINGO optimization software. A small-scale case study is conducted to validate the model's performance, in

which the results demonstrate how financing constraints affect production decisions and supply chain efficiency. The complete definition of variables and symbols used in the model is provided in the Nomenclature section.

**Nomenclature**

Symbol	Description
SS	Set of suppliers
JJ	Set of producers (manufacturing plants)
CC	Set of customers or retailers
TT	Set of time periods
LL	Quality levels of raw materials
qq	Quality levels of final product
KK	Skill levels of human resources
DetD <sub>{ct}</sub>	Demand of customer cc in period tt
PslP <sub>{sl}</sub>	Cost of purchasing one unit of raw material from supplier ss with quality ll
PCjqPC <sub>{jq}</sub>	Production cost of one unit of product with quality qq in plant jj
TCsjTC <sub>{sj}</sub>	Transport cost per unit from supplier ss to producer jj
TCjcTC <sub>{jc}</sub>	Transport cost per unit from producer jj to customer cc
LCjktLC <sub>{jk}</sub> <sup>t</sup>	Labor cost for skill level kk in factory jj, period tt
FCjktFC <sub>{jk}</sub> <sup>t</sup>	Firing cost for employee with skill kk in factory jj, period tt
HCjktHC <sub>{jk}</sub> <sup>t</sup>	Hiring cost for employee with skill kk in factory jj, period tt
TRjj <sup>t</sup> TR <sub>{jj}</sub> <sup>t</sup>	Training cost to upgrade from skill kk to k'k' in factory jj, period tt
AjktA <sub>{jk}</sub> <sup>t</sup>	Available time for worker with skill level kk in factory jj, period tt
RljktR <sub>{ljk}</sub> <sup>t</sup>	Number of workers of skill kk needed to work on material ll in factory jj, period tt
SCjSC <sub>j</sub>	Storage cost per unit in factory jj
CapstCap <sub>{slt}</sub>	Maximum supply capacity from supplier ss, quality ll, period tt
MM	A sufficiently large positive constant (used for linearization)
PTjklPT <sub>{jkl}</sub>	Production time for one unit by operator kk using raw material of level ll in factory jj
XjqtX <sub>{jtq}</sub>	Quantity of product of quality qq produced in factory jj, period tt
YsjltY <sub>{sjlt}</sub>	Amount of raw material with quality ll transported from supplier ss to producer jj, period tt
ZjklqtZ <sub>{jklq}</sub> <sup>t</sup>	Product produced using operator level kk and raw material ll in factory jj, period tt
WjqtqW <sub>{jqtq}</sub>	Quantity of product with quality qq transported from producer jj to customer cc, period tt
IjqtI <sub>{jqtq}</sub>	Inventory level of product with quality qq in factory jj, period tt
HjktH <sub>{jk}</sub> <sup>t</sup>	Number of human resources with skill kk in factory jj, period tt
FjktF <sub>{jk}</sub> <sup>t</sup>	Number of employees fired from factory jj, skill kk, period tt
UjktU <sub>{jk}</sub> <sup>t</sup>	Number of employees hired into factory jj, skill kk, period tt
TRjkk <sup>t</sup> TR <sub>{jkk}</sub> <sup>t</sup>	Number of employees trained from skill kk to k'k' in factory jj, period tt

In this modeling, the constraints are divided into three categories: constraints related to material flow and production, financial constraints, and finally, their integration to model the second scenario. Ultimately, production and financial variables and objective functions of the problem are examined in different scenarios. This model is created with an advanced planning approach to determine tactical decisions. The

mathematical model of the problem is also the MILP model. The parameters, variables, symbols, and mathematical relationships of the constraints and objective functions of the problem are explained below.

### **Defining Constraints and Functions**

The model's constraints can be classified into three parts: logistical constraints related to the flow of goods and materials, financial constraints related to financial flows, and constraints that connect the two previous constraints. The first category establishes a balance between the flow of materials and goods and the capacity of production facilities. The second category shows financial flows and their limitations in each period, and the third category creates integration and coordination between the two flows of materials and finances. Based on the defined parameters, variables, and symbols, the design of the supply chain network of the problem under study is mathematically expressed below.

### **Constraints and Functions of Logistics Flow (Traditional Scenario)**

The first category of constraints, which is related to the flow of materials and products, is explained in this section. Equations 1 to 22 relate to the constraints and balance of the flow of parts and products in the chain related to suppliers and the factory, and this ensures that the total input and output flows of parts and products to each of the chain members are according to the assumptions of the problem.

Equation 1 relates to the production limit of suppliers. The production volume of each period must be less than or equal to the production capacity of the suppliers. Also, the production volume in the factory must be less than the production capacity of the factory in each period.

### **Constraints of Not Providing Optimal Financing**

The amount of available liquidity causes limitations in production. Because the cost of production requires liquidity, the lack of it causes limitations in production. In this research, only the financial supply ability of suppliers, which are small and medium-sized food companies and generally have weaknesses in financing, has been investigated. The amount of cash shortage is actually a percentage of production costs in which the supplier cannot fully meet the factory's demand in the optimal state. In this research, suppliers usually do not have the ability to fully finance due to the prevailing recession and other common financial challenges, and in each period, they do not have access

to a percentage of the total liquidity needed, which is obtained from the uniform probability distribution function. Equation 3-21 shows this.

### **Financial Flow Constraints and Functions (Scenario with Financial Perspective)**

As shown, the amount of financial shortage for suppliers causes a decrease in their production and consequently a decrease in their profit. Therefore, in this section, an attempt has been made to reduce the amount of lost profit due to the financial shortage of suppliers by using some SCF tools that can be used in domestic supply chains. For this purpose, three methods of dynamic discounting, working capital facilities, and debt purchase facilities have been used in this section.

#### **Dynamic Discounting**

Dynamic Discounting (DD) is a process that allows buyers and suppliers in the chain to change payment terms to speed up payment based on a discount scale. This payment method, based on the agreement between the seller and the buyer in the supply chain, can be implemented in various ways. Different situations of pre-purchase periods and the amount of pre-purchase of products by the buyer affect the discount rate, and the cost of the credit period will be different for the buyer. Dynamic discounting affects the accounts receivable and payable of the members of the supply chain. Figure 3-5 shows the executive process of dynamic discounting in the supply chain using SCF concepts.

#### **Bank Facilities**

Given the current banking services in Iran, in this research, two types of common facility granting methods that can be used in SCF methods have been used in the form of working capital and debt purchase. The amount of required facilities is obtained from the difference between the cost required for production in the optimal state and the amount of available liquidity of the suppliers (Equation 3-21).

#### **Working Capital Loans**

Working capital loans are paid by the bank to the members of the supply chain in order to compensate for the lack of liquidity with a short repayment period of less than one year. In this research, the goal is to

determine the optimal percentage of facilities to pay facilities from the bank to the suppliers in order to reduce the cost of receiving facilities for the suppliers and also to provide the desired profit of the bank.

### Debt Purchase Facility

This method of providing facilities is to guarantee short-term financing by the bank by mortgaging the sellers' claims in the supply chain. By pledging a receivable, members of the supply chain transfer the rights related to future cash receipts to the bank at a lower price and solve their liquidity shortage problem with the cash they currently receive from the bank.

In this method, the bank will first deduct the cost of returned defective goods and the amount of discount from the nominal value of the receivables. After determining the actual value of the receivables, the bank will provide a percentage of the actual value to the seller in the supply chain based on its acceptable profit, which in this research, the goal is to determine the optimal percentage of debt purchase or discount and after that, the appropriate amount of sales Documents that must be provided to the bank.

### Calculation of Return on Investment

Return on assets (ROA) is an indicator of how profitable a company is relative to its total assets. ROA gives us an idea of efficient management in relation to the use of assets to generate profit, which is calculated by dividing annual profit by the company's total assets. This rate gives investors an idea of how successful the company has been in converting the money it has invested into net profit. This rate is determined using the financial flows of the production chain.

To analyze the data, mean-variance, semi-variance, and statistical indicators were used along with metaheuristic models such as taboo search algorithms and simulated annealing, etc., using Matlab software, etc., to provide the best model for risk management. Metaheuristic algorithms or metaheuristics are a type of random algorithm that is used to find the optimal answer.

### Findings

Based on the results reported in the previous section, the two designed algorithms were examined and compared based on the four indicators explained earlier. Also, the average of the four criteria of

quantity, quality, the degree of balance in achieving the goals simultaneously, and the diversity of Pareto answers obtained from each presented algorithm is presented. As can be seen, the NSGAI algorithm has performed better than NPGA in all four performance indicators.

### Presenting a Three-Stage Multi-Objective Mathematical Model for Financing the Production Chain

To present the mathematical model of the problem, we first recall the assumptions of the problem:

- The problem is a single-product, multi-period, and three-layer model.
- The location and number of suppliers, producers, and customer centers are specified.
- The level of equipment in production centers is considered the same.
- The product is divided into  $q$  categories in terms of quality. In this way, the product with quality level one will be a first-class product and has the best quality, and the product with quality level  $q$  is the product with the worst quality.
- Raw materials with quality level one have the least impurities and with quality level  $L$  have the most impurities.
- The human force of skill level 1 is a professional force, and the human force of level  $k$  is a trainee.
- The fact that the product of degree  $q$  can be prepared with what level of manpower and with what level of raw materials has been determined by experts in the industry according to past experiences.

Sets

S: Set of suppliers  $s=1,2,\dots,S$

L: Quality level of raw materials  $l=1,2,\dots,L$

K: Skill level of human resources  $K=1,2,\dots,K$

q: Final product quality level  $q=1,2,\dots,q$

C: Set of customers/retailers  $c=1,2,\dots,C$

J: Set of producers  $j=1,2,\dots,J$

T: Period  $t=1,2,\dots,T$

### Parameters

- ✓  $D_{ct}$  : Customer  $c$ 's demand in period  $t$

- ✓  $C_s^l$  : The cost of purchasing one unit of raw material from supplier  $s$  with quality level  $l$
- ✓  $C_j^q$  : The cost of producing one unit of the final product with quality level  $q$  in factory  $j$
- ✓  $Tc_{sj}$  : The cost of transporting raw materials from supplier  $s$  to producer  $j$  per unit
- ✓  $Tc_{jc}$  : The cost of transporting the product from producer  $j$  to customer  $c$  per unit
- ✓  $Mw_{kjt}$  : The cost of an operator with skill level  $k$  in period  $t$  in factory  $j$
- ✓  $Fw_{kjt}$  : The cost of firing an operator of level  $k$  from factory  $j$  in period  $t$
- ✓  $Hw_{kjt}$  : The cost of hiring an operator of level  $k$  in factory  $j$  in period  $t$
- ✓  $Tw_{kk'jt}$  : The cost of training the operator from skill level  $k$  to skill level  $k'$  in factory  $j$  in period  $t$
- ✓  $tp_{kk'}$  : }
- ✓  $A_{kjt}$  : Time available in factory  $j$  for operator level  $k$  in period  $t$   
0 other wise
- ✓  $a_{jt}^{kl}$  : The number of workers required at level  $k$  if working on level  $l$  materials to produce a product in factory  $j$  in period  $t$
- ✓  $ic_j$  : The cost of storing one unit of product in factory  $j$
- ✓  $Cap_{st}^l$  : Maximum capacity to provide raw materials of type  $l$  supplied from supplier  $s$  in period  $t$
- ✓  $M$  : Big number
- ✓  $b_{jlk}$  : Production time of one unit of product in factory  $j$  by operator level  $k$  and raw material level  $l$

**Variables**

- ✓  $Q_{jt}^q$  The amount of product produced in factory  $j$  in period  $t$  with quality level  $q$

- ✓  $X_{sjt}^l$  The amount of raw materials with quality  $l$  transported from supplier  $s$  to producer  $j$  in period  $t$
- ✓  $X_{jt}^{lk}$  The amount of product produced with skill level  $k$  and raw material level  $l$  in factory  $j$  in period  $t$
- ✓  $Y_{jct}^q$  The amount of product transferred from producer  $j$  to customer  $c$  in period  $t$  with quality level  $q$
- ✓  $I_{jt}^q$  The amount of product inventory in factory  $j$  in period  $t$  with quality  $q$
- ✓  $L_{kjt}$  The number of human resources needed from skill level  $k$  in factory  $j$  in period  $t$
- ✓  $Fl_{kjt}$  The number of employees with skill level  $k$  in factory  $j$  who are fired in period  $t$
- ✓  $Hl_{kjt}$  The number of employees with skill level  $k$  in factory  $j$  who are hired in period  $t$
- ✓  $Tl_{kk'jt}$  The number of employees with skill level  $k$  who are trained to skill level  $k'$  in factory  $j$  in period  $t$

**Objective Functions of the Problem**

**First objective function:**

Minimize costs = cost of purchasing raw materials + cost of transporting raw materials + production costs + cost of transporting the product to the customer + inventory cost + human resources cost + human resources firing cost + human resources hiring cost + human resources training cost

(F-1)

Min  $Z_1 =$

$$\sum_s \sum_j \sum_l \sum_t X_{sjt}^l C_s^l + \sum_s \sum_j \sum_l \sum_t Tc_{sj} X_{sjt}^l + \sum_j \sum_q \sum_t C_j^q Q_{jt}^q + \sum_j \sum_c \sum_q \sum_t Tc_{jc} Y_{jct}^q + \sum_j \sum_q \sum_t ic_j I_{jt}^q + \sum_k \sum_j \sum_t Mw_{kj} L_{kjt} + \sum_k \sum_j \sum_t Fw_{kj} Fl_{kjt} + \sum_k \sum_j \sum_t Hw_{kj} Hl_{kjt} + \sum_k \sum_{k'} \sum_j \sum_t Tw_{kj} Tl_{kk'jt}$$

**Second objective function:**

Maximum total production value, which is equal to maximizing quality

(F-2)

$$Max Z_2 = \sum_j \sum_t \sum_q w_q Q_{jt}^q$$

**Model Constraints**

$$(f-3) I_{jt}^q = I_{j(t-1)}^q + Q_{jt}^q - \sum_c Y_{jct}^q \quad \forall q, j, t$$

(f-4)

$$L_{kjt} = L_{kj(t-1)} + HL_{kjt} - FL_{kjt} + \sum_{k'} TL_{k'kjt} - \sum_{k'} TL_{kk'jt} \quad \forall k, j, t$$

(f-5)

$$\sum_L a_{jt}^{kl} x_{jt}^{kl} \leq L_{kjt} \quad \forall k, j, t$$

$$(f-6) \sum_k A_{tkj} L_{tkj} \geq \sum_k \sum_L b_{jlk} X_{jt}^{LK} \quad \forall j, t$$

(f-7)

$$Q_{jt}^q \geq \sum_c Y_{jct}^q \quad \forall q, j, t$$

(f-8)

$$\sum_j X_{sjt}^L \leq Cap_{st}^L \quad \forall L, s, t$$

(f-9)

$$\sum_k X_{jt}^{kL} = \sum_s X_{sjt}^L \quad \forall L, j, t$$

(f-10)

$$FL_{kjt} + \sum_{k'} TL_{kk'jt} \leq L_{kj(t-1)} \quad \forall k, j, t$$

(f-11)

$$D_{ct} = \sum_j \sum_q Y_{jct}^q \quad \forall c, t$$

(f-12)

$$\sum_{k'} TL_{kk'jt} FL_{kjt} = 0 \quad \forall k, j, t$$

(f-13)

$$TL_{k'kjt} \leq M T p_{kk'} \quad \forall k, k', j, t$$

$$\sum_k (FL_{kjt} + HL_{kjt}) \leq \alpha_{(t-1)} \sum_k L_{kj(t-1)} \quad \forall j, t$$

(f-14)

$$\begin{cases} x_{11jt} + x_{12jt} = Q_{jt}^1 \\ x_{21jt} + x_{22jt} = Q_{jt}^2 \quad \forall j, t \quad (f-15) \\ x_{31jt} + x_{32jt} + x_{33jt} + x_{23jt} + x_{13jt} = Q_{jt}^3 \end{cases}$$

(f-16)

$$Q_{jt}^q, X_{sjt}^L, X_{jt}^{lk}, Y_{jct}^q, I_{jt}^q, L_{kjt}, FL_{kjt}, HL_{kjt}, TL_{kk'jt} \geq 0$$

Constraint (3-4) shows the inventory level in each period, which is determined according to the inventory of the previous period, production, and shipments of the period. Constraint (4-4) shows the number of workers with skill k in each factory and in each period. Constraint (4-5) guarantees the consideration of the number of workers required in each period according to the production of the product with different quality levels. Constraint (4-6) guarantees taking into account the available time of each worker. Constraint (4-7) expresses the balance between the production of goods and sending them to the customer. Constraint (4-8) ensures that in each period, the amount of semi-finished product received from the suppliers should not exceed the supplier's capacity. Constraint (4-9) expresses the balance between the production of the product and the materials that enter the factory. Constraint (4-10) states that layoffs and training should not be more than the available human resources. Constraint (4-11) implies that all product demand in each period must be met. Constraint (4-12) ensures that an operator who is trained in one period should not be fired in that period. Constraint (4-13) indicates the possibility or impossibility of training in each period. Constraint (4-14) shows that in each period we can make a certain amount of change in human resources. Constraint (4-15) expresses the possibility of producing any product of any quality level with different operators and raw materials. Equation (4-16) expresses the non-negative constraints of the decision variables.

**Linearization of a Non-Linear Function**

Since there is a multiplication of two decision variables in constraint (4-12), the presented model is nonlinear. To linearize the model, it is necessary to consider a new variable that is zero and one as follows:

(f-17)

$$\begin{cases} \sum_{k'} TL_{kk'jt} \leq M Y_{kjt} \\ FL_{kjt} \leq M (1 - Y_{kjt}) \\ Y_{kjt} \in \{0,1\} \end{cases}$$

The following constraints are incorporated into the model. In Equation (4-17),  $(M \setminus)$  represents a large real number. Consequently, the Integer Linear Programming (ILP) model is formulated as follows:

(F-18)

$$\begin{aligned} \text{Min } Z_1 = & \sum_s \sum_j \sum_l \sum_t X_{sjt}^l C_s^l + \sum_s \sum_j \sum_l \sum_t Tc_{sj} X_{sjt}^l + \\ & \sum_j \sum_q \sum_t C_j^q Q_{jt}^q + \sum_j \sum_c \sum_q \sum_t Tc_{jc} Y_{jct}^q + \\ & \sum_j \sum_q \sum_t ic_j I_{jt}^q + \sum_k \sum_j \sum_t Mw_{kj} L_{kjt} + \\ & \sum_k \sum_j \sum_t Fw_{kj} Fl_{kjt} + \sum_k \sum_j \sum_t Hw_{kj} Hl_{kjt} + \\ & \sum_k \sum_{k'} \sum_j \sum_t Tw_{kj} Tl_{kk'jt} \end{aligned}$$

(F-19)

$$\text{Max } Z_2 = \sum_j \sum_t \sum_q W_q Q_{jt}^q$$

(F-20)

$$I_{jt}^q = I_{j(t-1)}^q + Q_{jt}^q - \sum_c Y_{jct}^q \quad \forall q, j, t$$

(F-21)

$$\begin{aligned} L_{kjt} = & L_{kj(t-1)} + Hl_{kjt} - Fl_{kjt} \\ & + \sum_{k'} Tl_{k'kjt} - \sum_{k'} Tl_{kk'jt} \quad \forall k, j, t \end{aligned}$$

(F-22)

$$\sum_l a_{jt}^{kl} x_{jt}^{kl} \leq L_{kjt} \quad \forall k, j, t$$

(F-23)

$$\sum_k A_{tkj} L_{tkj} \geq \sum_k \sum_l b_{jlk} X_{jt}^{LK} \quad \forall j, t$$

(F-24)

$$Q_{jt}^q \geq \sum_c Y_{jct}^q \quad \forall q, j, t$$

(F-25)

$$\sum_j X_{sjt}^l \leq Cap_{st}^L \quad \forall L, s, t$$

(F-26)

$$\sum_k X_{jt}^{kL} = \sum_s X_{sjt}^L \quad \forall L, j, t$$

(F-27)

$$Fl_{kjt} + \sum_{k'} Tl_{kk'jt} \leq L_{kj(t-1)} \quad \forall k, j, t$$

(F-28)

$$\sum_{k'} Tl_{kk'jt} \leq M Y_{kjt}$$

(F-29)

$$Fl_{kjt} \leq M (1 - Y_{kjt})$$

$$Y_{kjt} \in \{0,1\}$$

(F-30)

$$D_{ct} = \sum_j \sum_q Y_{jct}^q \quad \forall c, t$$

(F-31)

$$Tl_{k'kjt} \leq M Tpk_{k'} \quad \forall k, k', j, t$$

(F-32)

$$\sum_k (Fl_{kjt} + Hl_{kjt}) \leq \alpha_{(t-1)} \sum_k L_{kj(t-1)} \quad \forall j, t$$

$$\begin{cases} x_{11jt} + x_{21jt} = Q_{jt}^1 & (F-33) \\ x_{12jt} + x_{22jt} = Q_{jt}^2 \quad \forall j, t \\ x_{31jt} + x_{32jt} + x_{33jt} + x_{23jt} + x_{13jt} = Q_{jt}^3 \end{cases}$$

(F-34)

$$Q_{jt}^q, X_{sjt}^L, X_{jt}^{lk}, Y_{jct}^q, I_{jt}^q, L_{kjt}, Fl_{kjt}, Hl_{kjt}, Tl_{kk'jt} \geq 0$$

### Model Validation

To test the validity and correctness of the proposed model, a small-scale problem is solved by Lingo software. Then, the presented mathematical model is solved by Lingo 9 software, which is an operations research software, and the proposed model is examined with an example. In this model, considering the various cost factors, we are looking to minimize the total cost of the chain and maximize the total production value or maximum quality. In this way, the costs in the chain include the cost of purchasing and transporting raw materials with different quality levels, the cost of producing the final product with different quality levels, the costs related to human resources, the cost of transporting the product from the producer to the customer, and the cost of storing the final product in the producer's warehouse. And finally, the outputs of the model and the value of the objective function are presented. The numerical solution includes 2 periods and 2 suppliers of raw materials, 2 manufacturing plants, 3 retail centers or customers, 3 levels of human resources that are classified according

to work experience, 3 levels of raw materials that are classified according to the percentage of impurities and 3 quality levels are considered for the final product.

**Table 4-1. The cost of purchasing one unit of raw material from supplier s with quality level L. )C<sub>s</sub><sup>l</sup>(**

	S <sub>1</sub>	S <sub>2</sub>
L <sub>1</sub>	30	34
L <sub>2</sub>	26	22
L <sub>2</sub>	13	10

**Table 4-2- The cost of producing a product with quality level q in the factory )C<sub>j</sub><sup>q</sup>(**

	Q <sub>1</sub>	Q <sub>2</sub>	Q <sub>3</sub>
J <sub>1</sub>	118	62	38
J <sub>2</sub>	110	70	12

**Table 4-3- The cost of transporting raw materials from supplier S to producer j per unit )Tc<sub>sj</sub>(**

	J <sub>1</sub>	J <sub>2</sub>
S <sub>1</sub>	2	3
S <sub>2</sub>	2	2

**Table 4-4- The cost of transporting raw materials from supplier S to producer j per unit )Tc<sub>jc</sub>(**

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
J <sub>1</sub>	8	7	1
J <sub>2</sub>	2	9	5

**Table 4-5- The cost of storing one unit of product in factory j )ic<sub>j</sub>(**

	J <sub>1</sub>	J <sub>2</sub>
	6	4

**Table 4-6- The cost of an operator with skill level k in period t in factory j )Mw<sub>kjt</sub>(**

T=1	J <sub>1</sub>	J <sub>2</sub>
K <sub>1</sub>	1645	1664
K <sub>2</sub>	805	823
K <sub>3</sub>	500	594
T=2	J <sub>1</sub>	J <sub>2</sub>
K <sub>1</sub>	1689	1666
K <sub>2</sub>	817	822
K <sub>3</sub>	565	522

**Table 4-7- The cost of firing an operator of level k from factory j in period t )Fw<sub>kjt</sub>(**

T=1	J <sub>1</sub>	J <sub>2</sub>
K <sub>1</sub>	766	715
K <sub>2</sub>	436	448
K <sub>3</sub>	239	282
T=2	J <sub>1</sub>	J <sub>2</sub>

K <sub>1</sub>	693	630
K <sub>2</sub>	399	411
K <sub>3</sub>	305	173

**Table 4-8- The cost of hiring an operator of level k in factory j in period t )  $Hw_{kjt}$  (**

T=1		J <sub>1</sub>	J <sub>2</sub>
K <sub>1</sub>		381	308
K <sub>2</sub>		187	205
K <sub>3</sub>		131	118
T=2		J <sub>1</sub>	J <sub>2</sub>
K <sub>1</sub>		397	311
K <sub>2</sub>		207	220
K <sub>3</sub>		131	131

**Table 4-9- The cost of training the operator from level k' to level k in factory j in period t)  $TL_{k'kjt}$  (**

		J <sub>1</sub>			J <sub>2</sub>		
T <sub>1</sub>	0	0	0	0	0	0	
	184	0	0	160	0	0	
	281	164	0	295	158	0	
T <sub>2</sub>	0	0	0	0	0	0	
	158	0	0	162	0	0	
	254	193	0	265	153	0	

**Table 4-10- Possibility of training )  $TP_{kk'}$  (**

	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>
K <sub>1</sub>	0	0	0
K <sub>2</sub>	1	0	0
K <sub>3</sub>	1	1	0

**Table 4-11- Customer c's demand in period t)  $D_{ct}$  (**

	T <sub>1</sub>	T <sub>2</sub>
C1	87	98
C2	71	90
C3	43	94

**Table 4-12- Maximum capacity to provide raw materials of type r with quality L supplied from supplier s in period t**

		) $Cap_{st}^l$ (	
T=1		S <sub>1</sub>	S <sub>2</sub>
L <sub>1</sub>		76	69
L <sub>2</sub>		58	51
L <sub>3</sub>		78	56
T=2		S <sub>1</sub>	S <sub>2</sub>
L <sub>1</sub>		73	75
L <sub>2</sub>		68	68
L <sub>3</sub>		60	59

**Table 4-13- The number of workers required at level k if working on materials at level L to produce a product in factory j in period t )a<sub>jt</sub><sup>kl</sup>(**

J=1	K <sub>1</sub>	K <sub>2</sub>	K <sub>3</sub>
L <sub>1</sub>	0.05	0.06	0.08
L <sub>2</sub>	0.06	0.08	0.11
L <sub>3</sub>	0.08	0.11	0.14
J=2			
L <sub>1</sub>	0.05	0.06	0.08
L <sub>2</sub>	0.06	0.08	0.11
L <sub>3</sub>	0.08	0.11	0.14
J=1	K <sub>1</sub>	K <sub>2</sub>	K <sub>3</sub>
L <sub>1</sub>	0.05	0.06	0.08
L <sub>2</sub>	0.06	0.08	0.11
L <sub>3</sub>	0.08	0.11	0.14
J=2			
L <sub>1</sub>	0.05	0.06	0.08
L <sub>2</sub>	0.06	0.08	0.11
L <sub>3</sub>	0.08	0.11	0.14

The method used to solve this two-objective problem in this article is the fuzzy ideal programming method, which is explained in detail in the method section, and a brief explanation is given here. This method, by introducing a concept called a membership function or desirability function for each of the functions, and then maximizing it for each of the goals, seeks to bring each of the goals closer to their optimal value. The membership function for a maximization problem is calculated as follows:

$$\mu_i(x) = \frac{f_i(x) - F_i^{Min}}{F_i^{Max} - F_i^{Min}}$$

In the above relation, fkmin and fkmax show the minimum and maximum values of the objective function fk(x), respectively. The membership function for a minimization problem is also calculated as follows:

(f-36)

$$\mu_i(x) = \frac{F_i^{Max} - f_i(x)}{F_i^{Max} - F_i^{Min}}$$

The fuzzy ideal programming mathematical model, which seeks to maximize various membership functions, is obtained as follows:

$$\begin{aligned} & \text{Max } \lambda \\ & \text{Subject to: (f-37)} \\ & \mu_i(x) \geq \lambda \\ & x \in X \\ & \lambda \geq 0 \end{aligned}$$

After solving the model using Lingo software, the value of λ is obtained as 0.7566, which is acceptable considering the conflict between the objective functions.

The results of the solution are as follows:

Table 4-14- The amount of product produced with quality q

J=1	T <sub>1</sub>	T <sub>2</sub>
q <sub>1</sub>	56	55
q <sub>2</sub>	29	31
q <sub>3</sub>	35	36
J=2		

q <sub>1</sub>	51	68
q <sub>2</sub>	8	61
q <sub>3</sub>	28	34

Table 4-15- The amount of raw materials transported with quality L in the first period

L=1	J <sub>1</sub>	J <sub>2</sub>
S <sub>1</sub>	69	0
S <sub>2</sub>	0	53
L=2		
S <sub>1</sub>	0	0
S <sub>2</sub>	39	9
L=3		
S <sub>1</sub>	0	0
S <sub>2</sub>	12	25

Table 4-16- The amount of raw materials transported with quality L in the second period

L=1	J <sub>1</sub>	J <sub>2</sub>
S <sub>1</sub>	87	5
S <sub>2</sub>	0	75
L=2		
S <sub>1</sub>	0	52
S <sub>2</sub>	32	18
L=3		
S <sub>1</sub>	0	0
S <sub>2</sub>	3	13

Table 4-17- The amount of product produced with operator level k and raw material level L in the second period

J=1	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>
K <sub>1</sub>	37	25	10
K <sub>2</sub>	19	4	1
K <sub>3</sub>	13	10	1
J=2			
K <sub>1</sub>	42	3	19
K <sub>2</sub>	9	5	5
K <sub>3</sub>	2	1	1

Table 4-18- The amount of product produced with operator level k and raw material level L in the second period

J=1	L <sub>1</sub>	L <sub>2</sub>	L <sub>3</sub>
K <sub>1</sub>	28	8	0
K <sub>2</sub>	27	23	3
K <sub>3</sub>	32	1	0
J=2			
K <sub>1</sub>	57	46	10
K <sub>2</sub>	11	15	2
K <sub>3</sub>	12	9	1

Table 4-19- The amount of product sent to the customer in the first period

q=1	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
J <sub>1</sub>	56	0	0
J <sub>2</sub>	0	8	43
q=2			
J <sub>1</sub>	29	0	0
J <sub>2</sub>	0	8	0
q=3			
J <sub>1</sub>	2	33	0
J <sub>2</sub>	0	22	0

Table 4-20- The amount of product sent to the customer in the second period

q=1	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
J <sub>1</sub>	36	0	0
J <sub>2</sub>	0	0	68
q=2			
J <sub>1</sub>	50	0	0
J <sub>2</sub>	12	23	26
q=3			
J <sub>1</sub>	0	33	0
J <sub>2</sub>	0	34	0

Table 4-21- Human resource program obtained from solving the model

	Level k	Site j	Period t	
			1	2
L	1	1	5	2
		2	3	5
	2	1	3	4
		2	1	5
	3	1	2	3
		2	3	2
Firing labor	1	1	5	3
		2	2	0
	2	1	6	0
		2	6	0
	3	1	6	0
		2	9	0
Hiring labor	1	1	0	0
		2	0	1
	2	1	0	1
		2	0	4
	3	1	0	1
		2	0	0
Upgrading labor	3 → 1	2		1

**Discussion and Conclusion**

The structure of the production and supply chain affects the type of financing method, so there is a significant relationship between the independent variable and the control variables of the research with the dependent variable (financing) of the mentioned

companies in the time interval of the research. The results obtained in this research are consistent with the results obtained from the research of Lin et al. (2013) and Namazi and Kermani (2009) in all cases.

The complex and dynamic effects between the necessities (existences) of the supply chain lead to

uncertainty in planning. Uncertainty affects the increase and decrease of the supply chain. Davies (1993) identified three distinct sources of supply chain uncertainty - supply uncertainty, process uncertainty, and demand uncertainty. Supply uncertainty is caused by changes in supplier performance due to late delivery or delivery of defective goods. Process uncertainty arises from the unreliability of the production process due to machine failures. And finally, demand uncertainty, according to Davies (1993), is the most serious factor among the three, which arises from volatile demand or incorrect predictions. This author also discusses several metrics for measuring three types of uncertainty. Levy (1995) reported the results of a case study and a simulation model to show that demands related to the distributions of a multinational supply chain create necessary costs, including inventory holding, expediting, and fulfilling less demand.

However, considering the advantages of small and medium enterprises, including encouraging and encouraging entrepreneurship, dynamism and flexibility, the potential for rapid growth, high returns, and their wide spread and great impact on the gross national product of a country, these businesses are facing many problems in financing due to their newness and high risk (Talaghani Sayad Manesh & Kaviani, 2013).

On the other hand, many supply chains can consist of several small and medium-sized companies. However, these enterprises, due to their structural conditions, which require size and lack of sufficient capital, often face many problems in terms of financing, especially from banks, in order to grow and develop, and most of the attention or other financial institutions of the country is towards large and well-known companies.

The most important need that links the production flow of the supply chain to its financial flow is the supply chain financing (SCF) methods, which play a vital role in the production process by providing the necessary liquidity. In this regard, in this research, the issue of financing in the supply chain has been considered from three perspectives: internal resources, financing institutions through the supply chain, and financing through financial intermediaries. In this research, financial intermediaries are banks whose main task is to provide working capital, which is

considered short-term financing, and the goal of this research was also short-term financing.

The liquidity that banks inject into production units in the form of facilities has two main functions. The first function of liquidity stems from the fact that the flow of costs and revenues of a production process is not simultaneous, and in most cases, the flow of costs is realized sooner. This gap is either short-term and occurs in the production cycle, which banks can provide, or long-term and it is due to investment in creation and development projects, the task of financing which is correctly the responsibility of the capital market.

The second function of liquidity in production units is due to the difference in the amount of cost and income, in other words, the unprofitability of the production process. In general, these types of businesses are looking to attract liquidity despite being inefficient and use facilities as a cover to maintain their production level. If this problem becomes chronic and is transferred to later periods and accumulated, therefore, in this research, only the first case has been investigated and financing is only for covering the time gap between the flow of costs and income.

## Limitations

Little research has been done in the theoretical dimension regarding the relationship between the variables of this research. Therefore, it was not possible to review and compare the results of this research with other research. Therefore, this has caused limitations for this research.

## Suggestions

- The simulated model can also be used to design other scenarios. This is because it is possible to evaluate and analyze the short-term and long-term consequences of management decisions; For example: technical management of equipment by considering the downtime of workstations, helps the management to plan resources better.
- At a higher level, it is possible to provide a more appropriate sensitivity analysis by examining the behavior of the identified factors on the system so that the organization can focus more time and energy on more effective factors and achieve results faster.

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