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Developing a Value-based Optimization Model for Designing a Multi-echelon Supply Chain Network

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Abstract: This study developed a mathematical programming model in order to consider an SCND problem. In this model, the operational and financial decisions are simultaneously considered to design a supply chain network. It also paves the way for opening or closing facilities in order to adapt to fluctuations at market. Furthermore, an accounts payable policy is provided for the company managers because bank loans, liability repayment and new capital from shareholders are considered as decision variables in this model. The economic value added (EVA) index was also used besides the common operational objectives and constraints in order that the financial performance of supply chain and lower and / or upper limit value for financial rations to be measured. To demonstrate the efficiency of the proposed model, a test problem from the recent literature is used. And also, sensitivity analyses to evaluate the results are provided to obtain better insight and access to different aspects of the problem. The results illustrate that with appropriate financial decisions, creating more value for the company and its shareholders is achievable since the total created value by the proposed model with a new financial approach is able to improve the total created shareholder value as much as 21.05% and convince the decision-makers to apply it as an effective decision tool.

***Keywords**: Supply chain network design, Financial supply chain model, Mathematical programming, Economic value added (EVA).*

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1. Introduction

More than seventy percent of a company cost is due to supply chain activities which shows the importance of supply chain management on the overall improvement of financial performance [1]. Operational and financial aspects of a supply chain have been traditionally considered and modeled as separate issues. Most of the previous studies consider only the physical logistic operations and ignore the financial aspects of the chain. Managers should be aware of how their operational actions can impact supply chain performance [2,3]. Traditionally, most of the previous studies on supply chain planning have been done to seek cost minimization. Recently, researchers have extended their studies to support the company profitability and create value for shareholders [4-6].

SCND includes making decisions at both strategic and tactical levels. These two groups of decisions are connected to each other because tactical decisions are influenced by the strategic decisions, thus, they should be considered at the same time, despite the fact that most of the previous studies considered these two decision levels separately.

This study addresses a deterministic multi-echelon, multi-period, and multi-product supply chain network design that considers the strategic and tactical decisions simultaneously. The proposed

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mathematical model has the ability to adapt with market fluctuations, since it allows the configuration of network to be changed during the planning horizon, instead of only at the beginning of the process.

Many previous studies have indicated that financial factors such as income taxes, exchange rate, transfer pricing, and tariffs have significant effects on the network of supply chain . In addition, durability and development of the supply chain depend on financial operations, because they support production and distribution operations. Therefore, the objective of the proposed model is to maximize the company's created value, rather than traditional approaches like minimizing cost or maximizing profit. The company's created value is measured by Economic Value Added (EVA) which is one the most popular measures of a company financial performance and is defined as the difference between return of capital and cost of that capital [7]. The major contributions of this study that distinguish it from other mentioned works in literature can be summarized as follows:

1. Providing the possibility of relocation facilities (opening or closing), since our model is capable of changing the network configuration in order to deal with market fluctuations at any time period of the planning horizon.
2. The proposed model considers the amount of loan, bank repayment and new capital from shareholders as decision variables; therefore, it provides an accounts payable policy for the company managers instead of considering that all payments should be paid in cash.
3. Using accounting principles with less assumptions: for example, we use net liabilities in the analysis of financial statements that balances bank loans and payments, determining the exact value of deprecation by knowing the lifetime of each asset in each time period, applying real cash value instead of pre-determined proportion of profit.
4. Regarding the constraints in addition to common operational constraints, we also consider lower limit and/or upper limit values for performance ratios, efficiency ratios, liquidity ratios and leverage ratios in order to support the financial health of the corporation.

The main steps of this study can be outlined as follows:

- Addressing a supply chain network design problem that simultaneously considers operations and financial considerations.
- Developing a mixed-integer nonlinear programming (MINLP) to model the problem.
- Integrating new financial considerations in the developed model to ensure financial health of the company and growth.
- Testing the applicability and efficiency of the proposed model with the data as reported in literature.
- Comparing the results obtained by the proposed model with the base model through different criteria to show its applicability and advantages.

The rest of the paper is structured as follows: Section 2 reviews the related work in the literature. Section 3 presents the proposed mathematical model. Section 4 tests the validity of the model using the case study from the literature, then results are reported and compared with the original work. Finally, conclusions are given in Section 5.

2. Literature Review

As mentioned in the previous section, the available studies on supply chain network design which simultaneously take operations and financial dimensions into account are still rare. This section presents an overview of the selected studies that consider financial issues in the supply chain planning models.

Longinidis et al. [8] introduced an (MINLP) SCN design model that integrates the sale and leaseback (SLB) technique to find the optimal configuration of an SCN, under uncertainty in product demand. Their model's financial objectives are maximizing net operating profits after taxes (NOPAT) and unearned profit on SLB (UPSLB).

Ramezani et al. [9] presented a financial approach to model a supply chain network design that considers financial and physical flows for long-term and mid-term decisions. They applied the change in a company equity as the objective function instead of traditional approaches such as maximizing profit or minimizing cost.

Mussawi and Jaber [10] formulated a nonlinear program to find the optimal order amounts and the payment time of the supplier by using cash management integration. In their model, maximizing cash level and loan amount are financial decisions that need to be made to minimize inventory and financial costs.

Badri et al. [11] proposed a stochastic MILP programming model for a value-based supply chain network design. In their model, to maximize the company value (EVA), decisions on financial flow and physical flow (raw materials and finished products) are integrated.

Mohammadi et al. [12] developed an MILP model to consider financial and physical flows in mid and long-term decisions. The objective functions of their study are maximizing the economic value added (EVA), shareholders' equity, and corporate value. Saberi et al. [13] considered a trade-off between funding and its effect on environment in order to optimize NPV in a forward supply chain. Steinrücke and Albrecht [14] developed a mathematical model for maximizing payments to investors via the SCND with financial planning. Alavi and Jabbarzadeh [15] presented a robust stochastic optimization model in order to maximize expected supply chain profit under demand uncertainty. They also considered accounting for financial resources of trade credit and bank credit. In order to solve the model, they developed a solution method based on the Lagrangian relaxation method.

Yousefi and Pishvaee [16] developed an MIP model considering the operational and financial aspects of a global supply chain. They also considered the economic value added index to measure the financial performance of the global supply chain. Polo et al. [17] proposed an MINLP model in order to maximize EVA in the robust design of a closed-loop supply chain. Paz and Escobar [18] considered the problem of designing a global supply chain of consumer products by considering decisions regarding the location of facilities, transfer pricing, plant capacities, flow of products, and transfer pricing through a supply chain. The objective function of the proposed mathematical model was to maximize the total profit after tax by determining of global revenues in different facilities and their division over the chain. The problem was solved by using a mixed-integer linear programming model.

Wang and Huang [19] proposed a general framework to design a flexible capital-constrained global supply chain (CCGSC), which coordinated both the material flow and cash flow. They also applied a scenario-based mix-integer linear programming model to maximize the quasi-shareholder value (QSC) of a CCGSC under uncertain demand and exchange rates.

Kees et al. [20] developed a novel multi-period approach that provides an alternative framework to determine managerial strategies, integrating financial aspects with logistic decisions in a public hospital supply chain. They also addressed the lack of certainty in data through fuzzy constraints and considered two conflicting objectives: the total cost and total product shortage. To deal with a multi-criteria optimization, they applied fuzzy mixed-integer goal programming (FMIGP). Zhang and Wang [21] presented a model that simultaneously focused on multinational enterprises with a global supply chain network design using transfer pricing strategy to achieve the objective of after-tax income maximization of the whole global supply chain. The effect of transfer price over the global supply chain was also studied.

Azari Marhabi et al. [22] presentd a structure that empowers designing supervisory groups to survey the estimation of real options in the projects of enormous scale. Specific options writing is done using a methodology of planning the design and making prior decisions regarding the arrangements of specific options, with a recreation-based value measure designed to be near-current construction rehearsals and to resolve financial problems in particular cases. The physical and financial flow and their disturbance are simultaneously modulated. In order to complete the financial flows, financial ratios are also entered into the model.

Alinezahd [23] proposed a deterministic model for a multi-period, multi-product closed-loop supply chain. The model includes four layers in the forward flow (suppliers, manufacturing centers, distribution centers, and customer zone) and three layers in the reverse flow (collection center,inspection center, and disposal centers). The model objective is to maximize the chain profit with considering economic characteristics.

Brahm et al. [24] presented a new approach to address the problem of joint planning of physical and financial flows. In their research, supply chain contracts were combined and supply chain tactical planning was also considered within an uncertain condition; budgetary, environmental and contractual constraints were also incorporated. They also developed and implemented a planning model on a rolling horizon basis in order to minimize the effect of disturbances due to existing uncertainties.

Yazdimoghaddam [25] presented a mathematical model that integrated strategic and tactical aspects of a supply chain as well as financial flows. His study compared the traditional approach (maximize profit) with a new approach (maximize the change in equity). The results showed that the new approach leads to a change in equity.

Goli et al. [26] addressed a closed-loop supply chain network design with uncertain parameters. They developed a mathematical model to incorporate the financial flow, constraints of debts, and employment under fuzzy uncertainty with three objective functions: maximize the cash flow, maximize the reliability of consumed raw materials, and maximize the total gobs created in a supply chain.

Wang and Fei [27] developed a stochastic programming model for production decisions of manufacturing/remanufacturing. Their model integrated physical and financial operations based on scenario analysis, which took downward substitution between new and remanufactured products into account and selected financial performance indicators, i.e. economic value-added, as the optimal objective function.

Haghighatpanah et al. [28] proposed a scenario-based optimization model to deal with the SCND problem by considering sale and leaseback (SLB) transactions. The model is formulated based on accounting standards of sales to maximize the supply chain's benefit after tax.

Mohammadi et al. [29] presented a multi-product, multi-stage, and multi-objective programming model to design a sustainable plastic closed-loop supply chain network.

Escobar et al. [30] considered the design problem of a supply chain for mass-consumer products, taking financial criteria and scenarios of demand into account. An established supply chain was adopted as the starting point. The central problem lied in determining the closure and consolidation of distribution centers. The problem was solved using a multi-objective, mixed-integer linear programming model, considering two objective functions: maximization of net present value (NPV) of the supply chain and minimization of financial risk. Yousefi et al. [31] developed an MILP model which considers financial and physical flows and evaluates the financial performance of EVA and some financial ratios simultaneously. In order to handle the uncertainty of exchange rate, quality, and quantity of return products, fuzzy mathematical programming is applied. Tsao et al. [32] applied an approximation approach that examined the impacts of dynamic discounting regarding credit payment on a supply chain network design problem.

Badakhshan and Ball [33] developed an MILP model and simulation-based model to consider the financial and physical flows in a supply chain planning problem under economic uncertainty. They applied the economic value added (EVA) index to measure the financial performance of the supply chain.

Babaee Tirkolaee and Serhan Aydin [34] designed a bi-level DSS to configure supply chain and transportation networks and address the sustainable development of the problem by developing two MILP models. They applied a fuzzy weighted goal programming approach to deal with multiobjectiveness. Alinezhad et. al [35] developed a multi-product, multi-period problem which is formulated by a bi-objective mixed-integer linear programming model with fuzzy demand and return rate . The objectives of their model are to maximize the supply chain profit and customer satisfaction at the same time. Moreover, the carbon footprint is included in the first objective function in terms of cost (tax) to affect the total profit and treat the environmental aspect. They applied the fuzzy linear programming and Lp-metric method to deal with the uncertainty and bi-objectiveness of the model, respectively.

Babaeinesami et al. [36] addressed a closed-loop supply chain (CLSC) network design considering suppliers, assembly centers, retailers, customers, collection centers, refurbishing centers, disassembly centers and disposal centers to design a distribution network based on customers needs and simultaneously minimize the total cost and total $CO2$ emission. To tackle the complexity of the problem, a self-adaptive, non-dominated sorting genetic algorithm II (NSGA-II) algorithm is designed, which is then evaluated against the ε-constraint method. Sadeghi Darvazeh et al. [35] proposed a hybrid methodology to expose the process of this problem which helps managers learn how they can determine the optimal number of suppliers. They addressed this gap by developing an integrated approach based on multi-criteria decision-making (MCDM) comprising best-worst method (BWM), simple additive weighting (SAW), and a technique for order preference by similarity to ideal solution (TOPSIS), and simulation to determine the optimal number of suppliers.

Babaee Tirkolaee et al. [38] developed a novel mixed-integer linear programming (MILP) model for MSW management. The objectives were to simultaneously minimize the total cost and total environmental emission, maximize citizenship satisfaction and minimize the workload deviation. To treat the problem efficiently, a hybrid multi-objective optimization algorithm, namely, MOSA-MOIWOA is designed based on the multi-objective simulated annealing algorithm (MOSA) and multi-objective invasive weed optimization algorithm (MOIWOA).

Table 1 presented an overview of studies which integrate the financial aspect in supply change management.

Table 1. Overview of financial studies in supply chain

Paper	Period		Finished product		Parameters		Objective function		Financial futures				
	Single	Multiple	Single	Multiple	Deterministic	Stochastic	Profit/cost	Change in equity	EVA	Financial ratios	Financing(Loan, cash. . .)	Tax	Payment-Reception planning
Longinidis et al. [8]		✓		✓		✓			✓	✓		✓	
Ramezani et al. [9]	✓		✓		✓			✓				✓	✓
Badri et al. [11]		✓		✓	✓				✓			✓	
Jin et al. [39]		✓		✓	✓				✓	✓	✓	✓	
Mohammadi et al. [12]	✓			✓	✓	✓		✓	✓	✓		✓	✓
Steinrücke and Albrecht [14]		✓	✓		✓			✓	✓				

Alavi and Jabbarzadeh [15]		✓		✓		✓	✓				✓		
Yousefi and Pishvaee [16]		✓	✓		✓		✓	✓	✓				✓
Polo et al. [17]		✓		✓		✓			✓			✓	
Paz and Escobar [18]	✓			✓		✓						✓	
Zhang and Wang [19]		✓		✓	✓		✓					✓	
Brahmi et al. [22]		✓		✓		✓	✓				✓		
Yazdimoghaddam [23]	✓		✓		✓			✓				✓	
Goli et al. [24]		✓		✓		✓					✓		
Wang and Fei [25]		✓		✓	✓		✓		✓			✓	
Haghighatpanah et al. [26]		✓		✓			✓					✓	
Mohammadi et al. [27]		✓		✓		✓	✓						
Escobar et al. [28]		✓		✓		✓	✓					✓	
Yousefi et al. [29]		✓		✓		✓			✓	✓	✓	✓	
Tsao et al. [30]	✓		✓			✓						✓	
Badakhshan and Ball [31]	✓					✓			✓			✓	
This study		✓		✓	✓			✓	✓	✓	✓	✓	✓

Based on the above-mentioned works, this study suggests a mathematical model and simultaneously considers physical and financial aspects in a supply chain planning problem. We develop a deterministic Mixed Integer Nonlinear Programming (MINLP) model to specify the number and location of facilities and the links between them. The model also determines the quantities to be produced, stored and transported in order to meet customers demands as well as maximize EVA. As financial decisions, we consider the amount to invest, the source of the money needed (cash, bank loan, or new capital from shareholders), and repayments to the bank.

3. Problem statement

In this study, a multi-echelon, multi-period, and multi-product supply chain was discussed. Its semantic structure is shown in Fig. 1. The supply chain consists of plans, warehouses, distribution centers and customers zones. Our aim was to specify the overall manufacturing and distribution for a firm. The problem incorporates operational and financial decisions simultaneously, therefore, the mathematical formulation needs some proper variables and parameters. The goals of the proposed model were to determine:

- Strategic decisions about the facilities (plants, warehouses and distribution centers) to be constituted in the possible given locations and supply routes among them for each time period.
- Tactical, operational decisions regarding the quantity produced for each product at each manufactory, the materials flow between facilities and the levels of inventory that consist of maximum inventory at plants, products safety stock and maximal and minimal inventory of products at warehouses and distribution centers.

Financial decisions for determining the amount of bank loans, new capital entries and total investments to establish the network and the quantity of repayments to the bank for each time period.

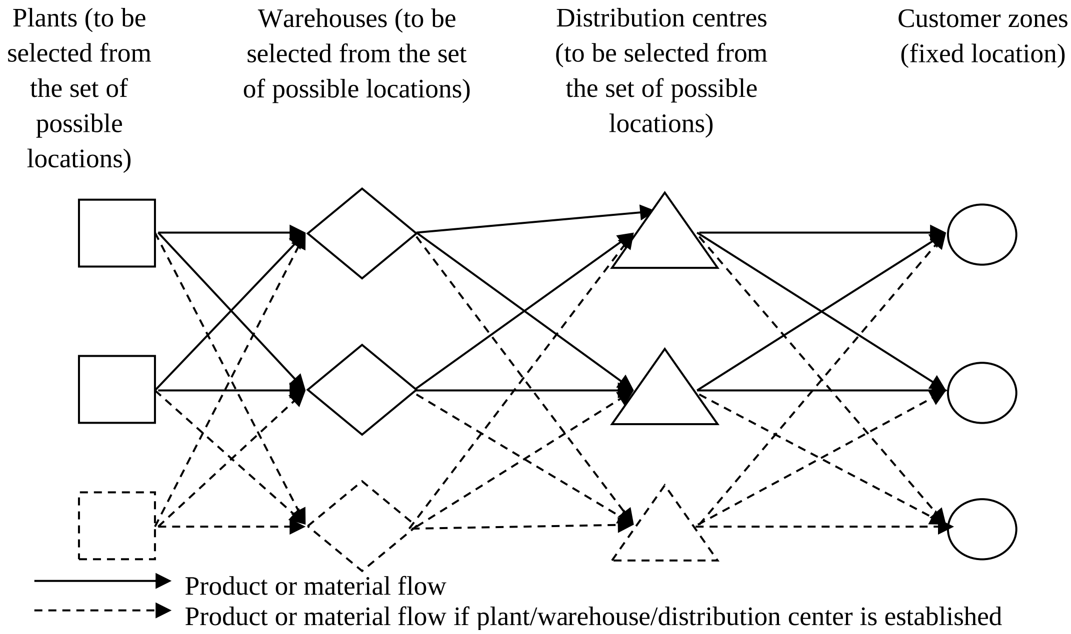

Figure 1. The semantic supply chain structure of this study

These three kinds of decisions were made for maximizing the value of company at the end of planning horizon measured by EVA as an indicator of profitability. That shows how well the company utilizes its properties in order to create value [7]. The considered assumptions of the proposed model in this study can be summarized as follows:

- In each duration, the demand of each customer zone is clear.
- To satisfy customers' demands, the company can decide what kind of facilities to be involved at a particular time.
- Products can be kept at the company as inventory or distributed among warehouses.
- There is not any back-order.
- The transportation of products among various kinds of facilities has capacity limitation.
- Cost and revenue are derived from the operation of the firm.
- Fixed and variable expenses are related to transportation and production.
- The establishment of facilities has fixed costs.
- Financial considerations are defined regarding to capital cost, financial ratios, tax and depreciation rates and long-term borrowing.

1.1. Mathematical formulation

The indices, parameters and decision variables used in the mathematical model of this study are defined as follows in Table 2.

Table 2: Notations

Sets and Indices	
E	Resources of production indexed by e
I	Products, indexed by i
J_l	Possible locations for facilities type l (1-plant, 2-warehouse, 3-distribution centre and 4-customer), indexed by $j. k$ and m
$\mathcal{T}$	Time periods, indexed by s and t
Parameters	
O_{ijt}	Demand of product i from customer zone j in time period t
R_{je}	Resource availability in plantj $\in J_1$and e $\in E$
ρ_{ije}	Peripheral needs for product i of resource e at plant $j \in J_1$
P_{ij}^{max}	Maximum capacity of product $i \in I$in plant $j \in J_1$
P_{ij}^{min}	Minimum capacity of product $i \in I$in plant $j \in J_1$
I_{ijt}^{max}	Maximum capacity of storage $i \in I$ in plant $j \in J_1$ in period $t \in \mathcal{T}$
SS_{ijt}	Safety storage of product $i \in I$ at facility $j \in J_1$,$(l = 2.3)$ at the end of period $t \in \mathcal{T}$
S_j^{max}	Maximum capacity of storage at facility$j \in J_1$, $(l = 2.3)$
S_j^{min}	Minimum capacity of storage at facility $j \in J_1$, $(l = 2.3)$
Q_{jk}	Maximum quantity of transportation from facility $j \in J_1$to facility $k \in J_{l+1}$, $(l = 2.3)$
SP_{ijt}	Selling fee of product $i \in I$for customer zone $j \in J_4$ in the period $t \in \mathcal{T}$
C_{jt}	Cost of establishing a facility at possible location $j \in J_1$, $(l = 1.2.3)$ in period $t \in \mathcal{T}$
FPC_{ijt}	Fixed cost of production$i \in$ I at plant j $\in J_1$ in period t $\in \mathcal{T}$
VPC_{ijt}	Variable production cost of product $i \in I$ at plant $j \in J_1$in period $t \in \mathcal{T}$
FTC_{ijkt}	Fixed transportation cost of product $i \in I$ from facility j $\in J_1$ to facility $k \in J_{l+1}$, $(l = 1.2.3)$, in period $t \in \mathcal{T}$
VTC_{ijkt}	Variable transportation cost of product $i \in I$from facility j $\in J_1$to facility $k \in J_{l+1}$, $(l = 1.2.3)$, in period $t \in \mathcal{T}$
IC_{ijt}	Inventory cost per unit of product $i \in I$ at facility j $\in J_1$, $(l = 1.2.3)$, in period $t \in \mathcal{T}$
r_t	Capital rate cost at the end of period $t \in \mathcal{T}$
TR_t	Tax rate at the end of period $t \in \mathcal{T}$
IR_t	long-term interest rate at the end of period $t \in \mathcal{T}$
DPR_{st}	Devaluation rate at the end of period $t = s.\ s\ and\ t \in T$
CR_t	Lower bound for cash ratio at the end of period $t \in \mathcal{T}$
CCR_t	Lower bound for cash coverage ratio at the end of period $t \in \mathcal{T}$
CUR_t	Lower bound for current ratio at the end of period $t \in \mathcal{T}$
ROA_t	Lower bound for return on assets ratio at the end of period $t \in \mathcal{T}$
ROE_t	Lower bound for return on equity ratio at the end of period $t \in \mathcal{T}$
ATR_t	Lower bound for assets turnover ratio at the end of period $t \in \mathcal{T}$
PMR_t	Lower bound for profit margin ratio at the end of period $t \in \mathcal{T}$
QR_t	Lower bound for quick ratio at the end of period $t \in \mathcal{T}$
$LTDR_t$	Upper bound for long-term debt ratio at the end of period $t \in \mathcal{T}$
CP_t	Upper bound for new capital from shareholders at the end of period $t \in \mathcal{T}$
α_t	Unpaid incomes coefficient at the end of period $t \in \mathcal{T}$
μ_t	Unpaid payables coefficient at the end of period n. $t \in \mathcal{T}$
Decision Variables	
P_{ijt}	Quantity of product $i \in I$ manufactured in plant j $\in J_1$ in period $t \in \mathcal{T}$

x_{ijkt}	Quantity of product $i \in I$ shipped from facility j ∈ J_1 to facility k ∈ J_{l+1}, (l=1,2,3), in period $t \in \mathcal{T}$
q_{ijt}	Quantity of inventory of product $i \in I$ holding in facility j ∈ J_1, (l = 1,2,3), in the period $t \in \mathcal{T}$
b_t	Amount of loans borrowed in period $t \in \mathcal{T}$
rp_t	Repaid amount to the bank in period $t \in \mathcal{T}$
ncP_t	Amount of new capital from shareholders in period $t \in \mathcal{T}$
Binary Variables	
y_{it}	Taking the value 1 if facility j ∈ J_1, (l =1,2,3), is to be established in the period $t \in \mathcal{T}$ and 0 otherwise
w_{jst}	Taking the value 1 if facility j ∈ J_1, ($l = 1.2.3$), was established in the period $s \in \mathcal{T}$ and is yet open in the period $t \in \{s. \cdots . T\}$ and 0 otherwise
u_{ijt}	Taking the value 1 if product $i \in I$ is manufactured at plant j ∈ J_1in the period $t \in \mathcal{T}$ and 0 otherwise
$\mathcal{Z}_{ikt}$	Taking the value 1 if there is shipping from facility j ∈ $J_1$to facility k ∈ J_{l+1}, (l = 1.2.3), in period $t \in \mathcal{T}$

1.2. Objective Function

As we know, strategic decisions can have a significant effect on the value created for the company and its shareholders. Consequently, we conducted EVA to evaluate the value generated for the company that is accounted by aggregation of net operating profit after taxes (NOPAT) of the invested cost over the planning horizon. Therefore, the objective of our model is to maximize the value created with the network configuration using EVA as given by equation (1).

$$Maximize \sum_{t \in \mathcal{T}} (NOPAT_t - r_t CI_t) \quad (1)$$

Next, we explain how these terms, $NOPAT_t$and CI_t were calculated, as well as the components involved to obtain them. In any period of time, the NOPAT, as shown in Equation (1) can be calculated with Equation (2) by subtracting sales costs (manufacturing, shipping, inventory holding and costs of inventory changing), devaluation costs in the period (the operational facilities devaluation) and the company's long-term debt (LTD_t) from the income gained from the purchased products.

$$NOPAT_t = \left(\sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt} - \left(CS_t + \sum_{l=1}^{3} \sum_{j \in J_l} \sum_{s=1}^{t} DPR_{st} C_{js} w_{jst} + IR_t LTD_t\right)\right)(1 - TR_t)\ , t \in \mathcal{T} \quad (2)$$

where $CS_t = PC_t + TC_t + IC_t - (IV_t - IV_{t-1})$ (see equations. (3)-(6) and $LTD_t = LTD_{t-1} + b_t - rp_t$

$$PC_t = \sum_{i \in I} \sum_{j \in J_1} \left(FPC_{ijt} u_{ijt} + VPC_{ijt} p_{ijt}\right).\ t \in \mathcal{T} \quad (3)$$

$$TC_t = \sum_{l=1}^{3} \sum_{j \in J_1} \sum_{k \in J_{l+1}} \left(FTC_{jkt} \mathcal{Z}_{jkt} + \sum_{i \in I} VTC_{ijkt} x_{ijkt} \right) . t \in \mathcal{T}$$	(4)
$$IC_t = \sum_{l=1}^{3} \sum_{j \in J_1} \sum_{i \in I} IC_{ijt} \frac{q_{ijt} + q_{ijt-1}}{2} \ . t \in \mathcal{T}$$	(5)
$$IV_t - IV_{t-1} = \sum_{i \in I} \left(\frac{\sum_{j \in J_1} VPC_{ijt}}{\lvert J_1 \rvert} \sum_{l=1}^{3} \sum_{j \in J_1} \left(q_{ijt} - q_{ijt-1} \right) \right) . t \in \mathcal{T}$$	(6)
$CI_t = E_t + LTD_t$ where $E_t = E_{t-1} + NOPAT_t + ncp_t$, with $t \in \mathcal{T}$	(7)

In equations (1) and (7), the capital invested (CI_t) refers to the amount of money that has to be paid or spent in the project. As shown in equation (7), equity (E_t) is the residul interest of the financier in assets. It is equal to the equity in the previous period, NOPAT of the current period and new capital from shareholders. It should be noted that in our model, all profits stay in the company and there is not dividend distribution during the planning horizon.

1.3. Model constraints

Constraints of the model can be categorized into two groups of operational and financial constraints.

3.3.1 Operational constraints

These constraints are related to the process operations and include strategic or structural constraints:

Opening/closing facilities, tactical constraints: quantities should be produced at plants and transported between facilities and inventory levels.

Equation (8) displays that the total flow from distribution centers to customer zones has to be equal to the market demand.

$$\sum_{j \in J_3} x_{ijkt} = O_{ikt} \qquad \forall i \in I, k \in J_4, t \in \mathcal{T}$$	(8)

Equations (9) and (10) force the product quantities to be in a pre-specified range in each plant and each time period.

$$\sum_{j \in J_3} x_{ijkt} = O_{ikt} \qquad \forall i \in I, k \in J_4, t \in \mathcal{T}$$	(9)
$$p_{ijt} \geq P_{ij}^{min} \sum_{s=1}^{t} y_{js} \quad \forall i \in I, j \in J_1 \ , t \in \mathcal{T}$$	(10)

$$p_{ijt} \leq P_{ij}^{max} \sum_{s=1}^{t} y_{js} \qquad \forall i \in I\,, j \in J_1, t \in \mathcal{T} \tag{11}$$

Equation (11) also shows the accessible quantity of each resource in each plant and each time duration.

$$\sum_{i \in I} \rho_{ije} P_{ijt} \leq R_e \qquad \forall j \in J_1, e \in E, t \in \mathcal{T} \tag{12}$$

Equations (12) to (15) represent that quantities of stored product in facilities should be within a pre-specified range.

$$q_{ijt} \leq I_{ijt}^{max} \sum_{s=1}^{t} y_{js} \qquad \forall i \in I, j \in J_1, t \in \mathcal{T} \tag{13}$$

$$\sum_{i \in I} q_{ijt} \geq S_j^{min} \sum_{s=1}^{t} y_{js} \qquad \forall l = 2{,}3\; j \in J_l\,, t \in \mathcal{T} \tag{14}$$

$$\sum_{i \in I} q_{ijt} \leq S_j^{max} \sum_{s=1}^{t} y_{js} \qquad \forall j = J_l, t \in \mathcal{T} \tag{15}$$

$$q_{ijt} \geq SS_{ij} \sum_{s=1}^{t} y_{js} \quad \forall i \in I, l = 2{,}3 \quad j \in J_l,\; t \in \mathcal{T} \tag{16}$$

Equation (16) is for inventory balance at plants and shows the accessible inventory is specified by the inventory available in the previous period, plus the amount produced in the current period subtracting the amount sent to warehouses.

$$q_{ijt-1} + p_{ijt} - \sum_{k \in J_2} x_{ijkt} - q_{ijt} = 0 \qquad \forall i \in I, j \in J_1\,, t \in \mathcal{T} \tag{17}$$

As the case for plants, inventories at warehouses and distribution centers satisfy flow preservation constraints, hence, in each time period, the accessible inventory is specified by the inventory available in the previous period, plus the amount produced in the current period, minus the quantity sent to distribution centers. These constraints, which are applied to distribution centers too, are shown in equation (17).

$$q_{ijt-1} + \sum_{m \in J_{l-1}} x_{imit} - \sum_{k \in J_{l+1}} x_{ijkt} - q_{ijt} = 0 \qquad \forall i \in I, l = 2{,}3, \;\; j \in J_1, t \in \mathcal{T} \tag{18}$$

Equation (18) shows the quantity sent by each plant to each warehouse and the quantity sent by each warehouse to each distribution center in each period time must convince the transportation capacity.

$\sum_{i \in I} x_{ijkt} \le Q_{jk} \mathcal{Z}_{jkt} \quad \forall l = 1,2,3, \qquad j \in J_l k \in J_{l+1}, t \in \mathcal{T}$	(19)

Equation (19) also displays a facility that can just be opened at most once within the entire planning duration.

$\sum_{t=1}^{T} y_{is} \le 1 \qquad \forall l = 1,2,3 \ , j \in J_l$	(20)

Equation (20) is a logical constraint forcing an opening facility to stay open.

$w_{jst} = y_{js} \ \forall l = 1,2,3, \ j \in J_l, s, \qquad t \in \mathcal{T}, t \ge s$	(21)

Equations (21) and (22) force the facilities to send and receive all or part of products.

$\sum_{i \in I} \sum_{k \in J_{l+1}} x_{ijkt} \le M \sum_{s=1}^{t} y_{js} \quad \forall l = 1,2,3, j \in J_l, t \in \mathcal{T}$	(22)
$\sum_{i \in I} \sum_{j \in J_l} x_{ijkt} \le M \sum_{s=1}^{t} y_{js} \quad \forall l = 1,2, k \in J_{l+1}, t \in \mathcal{T})$	(23)
$p_{ijt} \le M u_{ijt} \forall i \in I, J \in J_1, t \in \mathcal{T}$	(24)

3.3.2. Financial constraints

Financial ratios are one of the useful parts of each financial statement that prepare standard tools for measuring a company's performance, efficiency, liquidity, and leverage. In order to support the financial health of corporations, financial constraints force financial ratios. This study applied the ratios categories defined by Brealy et al. [40] and considered upper/lower limits values for them.

3.3.2.1. Performance ratios

Performance ratios measure the financial performance of the company. In this study, we considered two common measures, that is, return on equity (ROE) and return on assets (ROA). Equations (24) and (25) present the least values of ROE_t and ROA_t that have to be satisfied in each time duration. Note that, ROE_t illustrates the marginal investment income of shareholders and is calculated by dividing the net income by shareholders' equity and ROA_t is marginal income accessible to liability and equity investors from the company's total properties. It is calculated by dividing the net operating profit after taxes (NOPAT) by net fixed assets (NFA_t) and current assets (CA_t); their calculations are given by Equations (25) to (28).

$$\frac{NOPAT_t}{E_t} \geq ROE_t \qquad \forall t \in \mathcal{T}$$	(25)
$$\frac{NOPAT_t}{NFA_t + CA_t} \geq ROA_t \qquad \forall t \in \mathcal{T}$$	(26)
$$NFA_t = NFA_{t-1} + \sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} - DPR_t\ , \qquad t \in \mathcal{T}$$	(27)
$$CA_t = C_t + \alpha_t \sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} + IV_t\ , t \in \mathcal{T}$$	(28)
$$C_t = C_{t-1} + \alpha_{t-1} \sum_{i \in 1} \sum_{j \in J_4} SP_{ijt} O_{ijt} + (1 - \alpha_t) \sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt} + ncp_t + b_t$$ $$-\mu_{t-1}(PC_{t-1} + TC_{t-1} + IC_{t-1}) - (1 - \mu_t)(PC_t + TC_t + IC_t)$$ $$-TR_{t-1}(EBIT_{t-1} - IR_{t-1} LTD_{t-1}) - \sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} + IR_t LTD_t - rp_t\ , t \in \mathcal{T}$$	(29)

3.3.2.2. Efficiency ratios

Efficiency ratios measure how well the company utilizes its different kinds of assets. These ratios allow the company to evaluate its efficiency. In this study, we considered profit margin (PMR) and asset turnover (ATR) as efficiency ratios.

- **Profit margin ratio (PMR)**

Profit margin is the ratio that measures the profit remaining from sales after all expenses have been paid. It is defined as the ratio of net income to sales and must attain a minimum value at each time duration (PMR_t); its ratios are given by Equation (30).

$$\frac{NOPAT_t}{\sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt}} \geq PMR_t \qquad \forall t \in \mathcal{T}$$	(30)

- **Asset turnover (ATR)**

Asset turnover displays the incomes generated per monetary unit of total assets, measuring how hard the firm's assets are working. It is given by the ratio of sales revenue to total assets at turn period t. Equation (31) shows asset turnover ratios.

$$\frac{\sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt}}{NFA_t + CA_t} \geq ATR_t \qquad \forall t \in \mathcal{T}$$	(31)

3.3.2.3. Liquidity ratios

Liquidity ratios determine how quickly assets can be converted into cash. The liquidity ratios analysis helps the company evaluate its ability to keep more liquid assets.

- **Current ratio (CR)**

Current ratio is the ratio of current assets to its current liabilities and must attain a minimum value (CUR_t). Equation (32) shows current ratio constraint.

$$\frac{CA_t}{STD_t} \geq CUR_t \quad \forall t \in \mathcal{T} \tag{32}$$

As in our model, short-term loans are negligible, thus short-term debt (STD_t) is due to accounts payable and taxes, as follows:

$$STD_t = \mu_t(PC_t + TC_t + IC_t) + (EBIT_t - IR_t LTD_1)TR_t\,, t \in \mathcal{T} \tag{33}$$

- **Quick ratio (QR)**

QR is the ratio of current assets (except inventory) to its current liabilities which must satisfy a threshold value (QR_t), as follows:

$$\frac{C_t + \alpha_t \sum_{i\in I}\sum_{j\in J_4} SP_{ijt}O_{ijt}}{STD_t} \geq QR_{\ t} \ \ \forall t \in \mathcal{T} \tag{34}$$

- **Cash ratio (CR)**

Cash ratio is the ratio of its current liabilities which must satisfy a threshold value (CR_t), as follows:

$$\frac{C_t}{STD_t} \geq CR_t \quad \forall t \in \mathcal{T} \tag{35}$$

3.3.2.4. Leverage ratios

Leverage ratios assess the firm's ability to meet financial obligations.

- **Long-term debt to equity ratio (LTDR):** It provides an indication on how much debt a company is using to finance its assets. This ratio must be below a given limit:

$$\frac{LTD_t}{E_t + LTD_t} \leq LTDR_t \quad \forall t \in \mathcal{T} \tag{36}$$

- **Cash coverage ratio (CCR)**

Cash coverage ratio measures the firm's capacity to meet interest payments in cash, thus it must satisfy a given lower limit:

$$\frac{EBIT_t + DPR_t}{IR_t LTD_t} \geq CCR_t \quad \forall t \in \mathcal{T} \tag{37}$$

where $EBIT_t$ is the earnings before interst and taxes in each time duration:

$$EBIT_t = \sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt} - CS_t - \sum_{l=1}^{3} \sum_{j \in J_l} \sum_{s=1}^{t} DPR_{st} C_{js} w_{jst} \qquad t \in \mathcal{T} \tag{38}$$

3.3.2.4. Other financial constrains

In each time period, total funds of investments were provided from new capital and loans from bank:

$$\sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} = ncp_t + b_t \qquad \forall t \in \mathcal{T} \tag{39}$$

Equation (40) shows that new capital entries are limited to the quantity that company participants desire to invest in the company.

$$ncp_t \leq CP_t \qquad \forall t \in \mathcal{T} \tag{40}$$

Commonly, banks constrain the repayment (rp_t) to be at least the interest costs to barricade a growing debt. Eventually, equations. (41) to (43) show type of variables.

$$rp_t \geq IR_t LTD_t \qquad \forall t \in \mathcal{T} \tag{41}$$

$$b_t . rp_t . ncp_t \geq 0 \qquad \forall i \in I, t \in \mathcal{T} \tag{42}$$

$$p_{ijt} . q_{ijt} . x_{ijkt} \geq 0 \quad \forall i \in I, l = 1,2,3, \qquad j \in J_l, k \in J_{l+1}, t \in \mathcal{T} \tag{43}$$

$$y_{it} . w_{sjt} . u_{ijt} . \mathcal{Z}_{jkt} \in \{0.1\} \ \forall i \in I, l = 1,2,3, j \in J_l, k \in J_{l+1}, s, t \in \mathcal{T}, s \leq t \tag{44}$$

4. Computational results

In order to show the applicability and efficiency of the proposed model, we applied the data of Loginidis et al. [7]. The studied company has three plants and four possible locations for warehouses and six potential locations for distribution centers. Each plant is able to produce six of seven products within its limitations of production capacity. Each plant also holds about two times the average annual demand as initial inventories. In each time duration, each warehouse and distribution center has an upper and lower bound handling capacity and needs safety stock. Product flows between plants, warehouses, distribution centers and customer zones have upper bounds. Prices and demands of products in each customer zones are known. The mentioned company has a 4-year planning horizon .

The problem was solved by Branch and Reduce Optimization Navigator (BARON) solver in GAMS software on personal computer with core i5 CPU 2.50 GHz and 8 GB of RAM on windows 8. During the 4-year planning horizon, the network configuration remains the same because decisions for opening have not been made, although plant 2 was considered in the first year. This represents that decisions for closing facilities should be noticed. Regardless of flows value between facilities, there are some differences in the used flows, but not much. The most changes happen between the first and second years because most flows are held for the rest of periods. Tables 1, 2 and 3 show the total flows value transported among the supply chain network regardless of the kind of the product during the planning horizon (four years).

Table 3. Total flows transported from the plants to the warehouses. (a) achieved by our model. (b) obtained by the base-model [7]

(a)	Warehouse1	Warehouse2	Warehouse3	Warehouse4
Plant1	7540			
Plant2		2173		
Plant3			2760	

(b)	Warehouse1	Warehouse2	Warehouse3	Warehouse4
1	1684	970	1680	1785
2	480	1037	525	1384
3	420	745	946	1020

Table 4. Total flows transported from the warehouses to the distribution centres. (a) obtained by our model. (b) obtained by The base-model [7]

(a)	DC1	DC2	DC3	DC4	DC5	DC6
w1	6500				941	
w2		1760	410			
w3			2714			
w4						

(b)	DC1	DC2	DC3	DC4	DC5	DC6
1		1210			1348	
2		875			1819	
3		1820			1262	
4	1580	894			1607	

Table 5. Total flows transported from the distribution centres to the customer zones. (a) obtained by our model. (b) obtained by the base-model [7]

(a)	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
DC1	1350		101	2018	108	1415	1443	
DC2		1516						
DC3			1531		202			
DC4								
DC5					930			
DC6								

(b)	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
1								1543
2				2018	1238		1442	
3								
4								
5	1350	1517	1620			1417		
6								

In comparison with the base model regarding the financial approach, we consider the amount of repayment to bank and new capital from shareholders as decisions to be adopted. Our model also provides a balance between debt, repayments and new capital in order to maintain the company's financial condition. As it can be seen, among funding options for the company, new capital from shareholders has large costs; therefore, the model imposes upper bound on it. The model also prevents ever increasing liability and considers a lower limit on repayments to bank. All in all, the proposed model provides an accounts payable policy for the company managers, as shown in Table 6.

Table 6. Financial decisions for proposed model in each time period

	Financial decisions				
	Year 1	Year 2	Year 3	Year 4	Total
Loans	0	0	0	0	0
New capital entries	50,000	50,000	50,000	50,000	200,000
Investment	292,000	0	0	0	292,000
Repayments	450,000	225,000	112,500	56,250	843,750

Regarding financial decisions, Table 6 shows that since the company has enough cash, it does not need bank loans. It also captures all capital entries from shareholders. In addition, due to high levels of inventory (each plant holds about two times the average annual demand as initial inventories), production costs are low releasing money for investment. Therefore, this is an appropriate condition to make repayments to the bank, decreasing debt and maximizing the total value created for the company.

According to accounting principles, we consider better depreciation calculations since in each period, the life time of each asset is known, therefore, the exact value of depreciation is determinable. Moreover, we used real cash value instead of assumed percentage of profit. We also applied the net value of fixed assets rather than their total value.

The results of the proposed model illustrate that with appropriate financial decisions, creating more value for the company and its shareholders is achievable since the total created value by the base model is 1,755,626 monetary units whereas the proposed model with a new financial approach is able to create 2,125,210 monetary units and improve the total created shareholder value as much as 21.05% and convince the decision-makers to apply it as an effective decision tool. The value created by each model is reported in Table 6.

Table 20: Values obtained by each model (Objective functions)

Model	**Value created (monetary units)**
The basic model	1,755,626
The proposed model	2,125,210

4.1 Financial sensitivity analysis

In this section, we test the performance of the proposed models in several cases by changing some financial parameters. These parameters are important because they are suggestive of the economic environment and in many cases are accepted conditions that the company has no impact on them. The cost of capital rate at time period t (r_t) is an important parameter. Also, one of the important financial parameters affecting the company's wealth is the tax rate (Tr_t). Moreover, we selected the depreciation (DPR_{st}) rate as a financial parameter for the sensitivity test. Table 7 shows the effects on the developed model by changing these parameters from −15% to +15%. The results show that the developed model with new financial aspects was robust against changes in these financial parameters.

Table 7. Sensitivity analysis of the value created according to changes in financial parameters

Parameter	Change (%)							
	-15	-10	-5	-2	+2	+5	+10	+15
Cost of capital rate at time period t (r_t)	2,422,739	2,316,479	2,231,471	2,167,714	2,082,706	2,018,950	1,933,941	1,827,681

Tax rate (Tr_t)	2,295,226	2,231,470	2,188,966	2,146,462	2,103,957	2,061,453	2,018,949	1,955,193
Depreciation rate (DPR_{st})	2,157,088	2,146,462	2,135,836	2,129,460	2,120,959	2,114,583	2,103,957	2,093,331

4.2 Managerial insight

This study suggests a value-based optimization model that considers the physical and financial aspects of a supply chain planning problem simultaneously. We have developed a deterministic Mixed-Integer Nonlinear Programming (MINLP) model to specify the number and location of facilities and the links between them. The model also determines the quantities to be produced, stored, and transported in order to meet customers demands. According to financial decisions made by the model, managers are provided with an accounts payable policy since we consider the amount to invest, the source of the money needed (cash, bank loan, or new capital from shareholders), and repayments. It enables supply chain managers to take holistic decisions without underestimating the basic objective of a profit company, which is the creation of value for shareholders measured by the EVA index. This objective dictates a satisfactory financial status in order to guarantee new funds from shareholders and financial institutions that will allow financing of company operations.

5. Conclusions

In order to ensure the future sustainability of the firm, managers should make decisions to maximize the long-term firm value. Through the process of decision making, the financial and SC decisions influence each other and for modeling such a decision procedure, these aspects should be considered. The combination of SC operations and financial aspects has been dramatically considered in modeling business activities. Published articles regarding supply chain network design (SCND) are scarce, however. The main shares of this research are summarized as bellow:

- Present a mathematical model for solving a supply chain network design problem considering tactical, strategic and financial problems simultaneously.
- Determine such items as the locations of facilities, amount of production, inventory for each product at each facility, flows of products at both strategical and financial levels.
- Consider new capital from shareholders, bank repayment, and also borrowed amount as decision variables. The capital entries were considered as a parameter in previous works.
- The model imposes such items as upper and/or lower bound for leverage ratio, efficiency ratios, liquidity ratios and preference ratios, as well as usual operational limitations, which resulted in more value creation for the company. The suggested model offers a balance amongst new capital entries, loans and repayment to sustain a better financial performance. Through considering large cost of new capital entries, the model imposes upper bound and by considering lower bound for bank repayments, it avoids an ever-growing debt. Such benefits of the model offer an accounts payable guideline for managers.

- Modify the depreciation calculation in that the life time for each asset was specified and the exact depreciation values in any time period can be calculated. Instead of total value of fixed assets, the financial ratios and instead of considered percentage of profit, the real value of the cash, were used. In this research, a connection is discovered between the supply chain performance and financial decision which may be used for decision making and helping managers improve the performance of company.

Through comparing the results of the suggested model and the achieved results of the base model, it was shown that our model is considered effective regarding increase in company's overall value estimated through economic value-added index (EVA) and offering target values for financial ratios.

Our study may extend as follows: at first, it can be possible to strengthen the soundness of firm and also optimal results. Secondly, incorporating uncertainty in some parameters such as cost, price, demand and interest rate.

Then, the green supply chain with a closed-loop structure can be the other research trend for the model considering environmental, social, technological and economic facets; such facets can be included in the supply chain network design. The problem would get more complicated with such developments. Therefore, following other solutions such as metaheuristics, can be considered as the other suggestion for future studies.

Our model results will become different if we change the target values. The sensitivity analysis could be done in future studies to observe how these changes can influence the objective function in our model.

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