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Integration of Liability Payment and New Funding Entries in the Optimal Design of a Supply Chain Network

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ABSTRACT

In recent years, the supply chain network design (SCND) problems that integrate financial issues have attracted the attention of managers and researchers. In this paper, in order to address an SCND problem, a mixed-integer nonlinear programming (MINLP) model developed that considers operational and financial decisions simultaneously for designing a deterministic multi-echelon, multi-product, and multi-period supply chain network. The developed model provides the possibility of opening or closing facilities at every time period to adapt to market fluctuations. The model also considers bank loans, liability repayment, and new capital from shareholders as decision variables, therefore, it provides an accounts payable policy for the company managers. In addition to common operational objectives(profit/cost) and constraints, we also applied the economic value added (EVA) index to measure the financial performance of supply chain and lower and/or upper limit value for financial ratios to ensure the company's financial health, while making decisions at strategic and tactical levels. To show the model applicability, data of a case study in the literature employed and solved using BARON solver in GAMS software. The results clearly show an improvement in the total value created for the company compared to the base model, so it can be applied as an effective decision tool.

1 Introduction

More than seventy percent of a company's 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 [2]. Managers should be aware of how their operational actions can impact supply chain performance [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 to create value for the shareholders [4]. 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 mathematical

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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 [4]. 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 net 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 [5] and is defined as the difference between return of the capital and the cost of that capital [6]. Fig. 1 shows how logistics influence EVA.

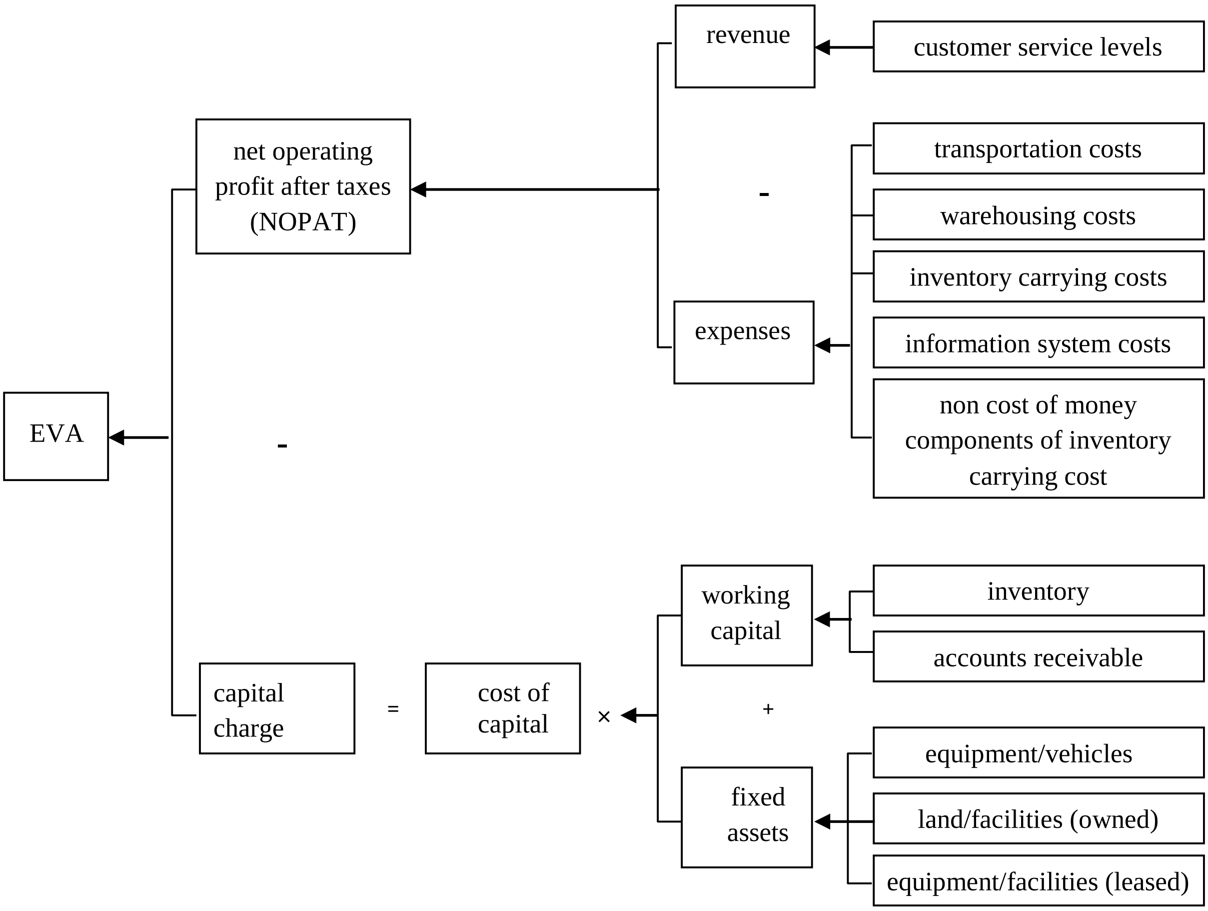

Fig. 1: Logistics Impacts on EVA [6]

The major contributions of this study that distinguish this research from the other mentioned works in the 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 deals 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 the 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 decisions and considerations.
- Developing a mixed-integer nonlinear programming (MINLP) model 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 the efficiency of the proposed model with the data as reported in the 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, some conclusions are given in Section 5.

2 Literature Review

As mentioned in the previous section, the available published studies on supply chain network design which simultaneously take into account operations and financial dimensions is still rare. This section presents an overview of selected studies that consider financial issues in the supply chain planning models. Vidal et al. [7] suggested a model for a global supply chain to maximize the profit of a company. In their study, allocation of transportation costs and pricing of transfer were considered as decision variables. Wang et al. [8] developed a model in order to minimize the interval to deliver customers' goods. They considered budget limitations to make a decision to either open or close a facility. Hugo and Pistikopoulos [9] presented a bi-objective model to minimize environmental effects and maximize NPV (Net Present Value). Their study surveyed the integration of mid-term and long-term decisions during life cycle of products with financial consideration. Puigianer et al. [10] considered both financial and environmental aspects in a dynamic simulation model for a chemical supply chain.

Bertel et al. [11] presented a MILP model with physical and financial flows of production planning. They applied a new algorithm to solve their problem. Sodhi et al. [12] developed different mathematical models to analyze the results of property – liability management in planning of a supply chain. Gupta and Dutta [13] addressed the cash flow optimization problem between the partners of supply chain. The aim of their study was to plan all payments. Loginidis et al. [14] used a nonlinear and bi-objective model to integrate financial performance and credit solvency within a supply chain network design problem. In their study, a concept of economic value was added and Z-score was also applied to manage the trade-offs between financial performance and credit solvency. Ramezani et al. [15] introduced a method to incorporate the financial aspects (i.e., current and fixed assets and liabilities) into a set of constraints relevant to the budget through balances of cash, debt, securities, payment delays, and discounts in supply chain planning. To show the advantage of using the financial model, the financial and traditional approaches were compared. The results of their study indicated that the traditional model leads to lower change in equity than the financial model. Feng et al. [16] investigated the effect of budget limitation on buyback and income sharing contracts. Cardoso et al. [17] presented a mathematical model for minimizing the financial risk and maximizing the anticipated value in the planning of a closed-loop supply chain. Mohammadi et al. [18] developed a model with three different objective functions in order to measure the value creation of a company. Saberi et al. [19] considered a trade-off between funding and its effect on environment, in order to optimize NPV in a forward supply chain.

Steinrücke and Albrecht [20] developed a mathematical model for maximizing payments to investors via the SCND with financial planning. Arani and Torabi [21] suggested a bi-objective model to maximize the manufacture and the supplier's net cash flow. Polo et al. [22] proposed a MINLP model in order to maximize EVA in the robust design of a closed-loop supply chain. Yousefi and Pishvaee [23] developed a MIP model considering the operational and financial aspects of a global supply chain. They also considered economic value added index to measure the financial performance of the global supply chain. Alavi and Jabbarzadeh [24] presented a stochastic robust 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 and developed a solution method based on the Lagrangian relaxation technique to solve the model. Kees et al. [25] 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. Their problem was formulated as a mixed-integer linear programming (MILP) model. They also addressed the lack of certainty in data through fuzzy constraints and considering two conflicting objectives: the total cost and the total product shortage. To deal with a multi-criteria optimization, they applied fuzzy mixed-integer goal programming (FMIGP). Liu and Rezaei [26] proposed a model for designing a multi-level supply chain utilizing an integrated model involving various decisions at different levels.

Paz and Escobar [27] considered a problem of designing a global supply chain of consumer products by considering decisions regarding the location of facilities, transfer pricing, plant capacities, the 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 considering the determination of global revenues in the different facilities and their division over the chain. The problem was solved by using a mixed-integer linear programming model. Tsao et al. [28] considered a supply chain network under an advance-cash-credit payment. Their study investigated the effect of payment schemes on the supply chain network design problem and determines the optimum location, allocation, as well as inventory cycle time with the objective function of minimizing total cost. Wang and Huang [29] proposed a general framework to design a flexible capital-constrained global supply chain (CCGSC), which coordinated both the material flow and the 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. Yang et al. [30] presented a closed-loop supply chain design with financial management problem, which was tackled as a stochastic programming model with ambiguity demand set. Zhang and Wang [31] 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. They also considered the influence of transfer price on the global supply chain. Brahmi et al. [32] presented a new approach to address the problem of joint planning of physical and financial flows. Their study integrated supply chain contracts and also focused on supply chain tactical planning in an uncertain and disrupted environment, taking into account budgetary and contractual constraints. 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. Escobar et al. [33] considered are design problem of a supply chain for mass consumer products, considering financial criteria and scenarios of demand. 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: the maximization of the net present value (NPV) of the supply chain and the minimization of the financial risk. Gupta and Chutani [34] studied a financing problem in a supply chain (SC) consisting of one supplier and one buyer under supply disruption. They modeled this problem as a Stackelberg game, where the supplier as the leader announces the wholesale price and the retailer responds by deciding its optimal order quantity given stochastic demand and an exogenous fixed retail price.

Hong and Najmi [35] explored which financial performance indicators (FPIs) evaluate the level of supply chain capability (SCC) that explicitly touches all of the business functions and processes within and beyond the company. The authors investigated nine FPIs that were selected from the financial statements of 155 companies within nine industries from 2011 to 2017 using Morningstar financial database and Gartner's report. Jamal et al. [36] applied a contingency theory approach to present and test a conceptual model that investigated relationships between supply chain management and management accounting practices and their individual or combined effects on both supply chain and overall organizational performance. Their findings also showed a positive and direct relationship between these two sets of practices and supply chain performance. Seiler et al. [37] investigated how the network position of organizations in an extended supply chain network impacts their financial performance. Their study argued that performance measurement tools should incorporate a network (external, connectedness) perspective in addition to an internal financial perspective. Steglich [38] in his study presented a new approach for simultaneous investment, financial and operating planning. His approach was under uncertainty and considered different scenarios with given probabilities taking into account individual risk preferences. It contained the choice of different investment alternatives and their disinvestment, different financing alternatives as well as the determination of the sales and production quantities on the basis of mixed-integer linear programming with the aim of maximizing the net present value (NPV) of periodical project dividends.

Wang and Fei [39] developed a mixed-integer stochastic programming model for production decisions of manufacturing/remanufacturing. Their model integrated physical and financial operations based on scenario analysis, which took the downward substitution between new and remanufactured products into account and selects financial performance indicators, i.e., economic value-added, as the optimal objective function. Yan et al. [40] focused on an agricultural supply chain model for a situation where the small and medium-sized enterprises' initial capital is constrained and cannot fully cover the cost of the optimal operation strategy without a capital constraint. Their study analyzed the financing strategies adopted by a fresh agricultural supply chain and obtained optimal operational and financing strategies in different situations. Yazdi Moghaddam [41] presented a mathematical model that integrated the strategic and tactical aspects of a supply chain as well as financial flows. His study compared a traditional approach (maximize profit) with a new approach (maximize change in equity). The results showed that the new approach leads to move change in equity. Goli et al. [42] developed a mathematical model with three objective functions: maximize the cash flow, reliability of consumed raw materials, and also maximize the total created occupations in a supply chain. Motevalli-Taher and Paydar [43] addressed an integrated supply chain master problem. They developed a mathematical model with three objectives: maximizing the NPV of producing centers, maximizing cash flow of suppliers and minimizing the product price in market. Mohammadi et al. [44] presented a multi-product, multi-stage, and multi-objective programming model to design a sustainable plastic closed-loop supply chain network integrating financial decisions such as loans to take and investments to make. Yousefi et al. [45] developed a MILP model that simultaneously considers financial and physical flows and evaluates the financial performance by EVA and some financial ratios. They also applied fuzzy mathematical programming in order to handle the uncertainty of exchange rate, quality, and quantity of return products parameters. Baabaker et al. [46] proposed a system view to link supply chain (SC) strategy to a company's financial performance by developing a scenario approach. They applied five scenarios under differing financial performance contexts to analyze the relationship between supply chain performance and the overall financial performance. Benbouja et al. [47] presented an integrated planning model for a multi-echelon supply chain within mass customization. Their research viewed collaborative management through an integrated procurement, production, and distribution mixed-integer linear programming (MILP) as a planning modeling approach for a multi-echelon and multi-site supply chain within the tactical decision level.

Izadikhah [48] applied the modified ERM model to evaluate 15 private bank branches in Markazi province. For this purpose, His study followed the primary goal that was maximizing the shareholders' satisfaction level and chose two financial bank efficiency measurement approaches, i.e., the production approach and the user cost approach. The approaches led to finding four regions for all branch performances. Ehtesham Rasi [49] provided a bi-objective mathematical model for designing SSC network economic-based competition and optimize by using meta-heuristic algorithms. He integrated a mathematical model and formulated objectives and constraints-based multi-echelon supply chain network. Izadikhah [50] proposed a new variant of two stage DEA models and further evaluates the banks and financial institutes in Tehran stock exchange by considering the financial ratios. Based on the above-mentioned works, this study suggests a mathematical model 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 to 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 the 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. 2. The supply chain consists of plans, warehouses, distribution centers and customer's 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 (opening or closing) in the possible given locations and the supply routes among them for each time period.
- Tactical operation 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 maximum and minimum 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.

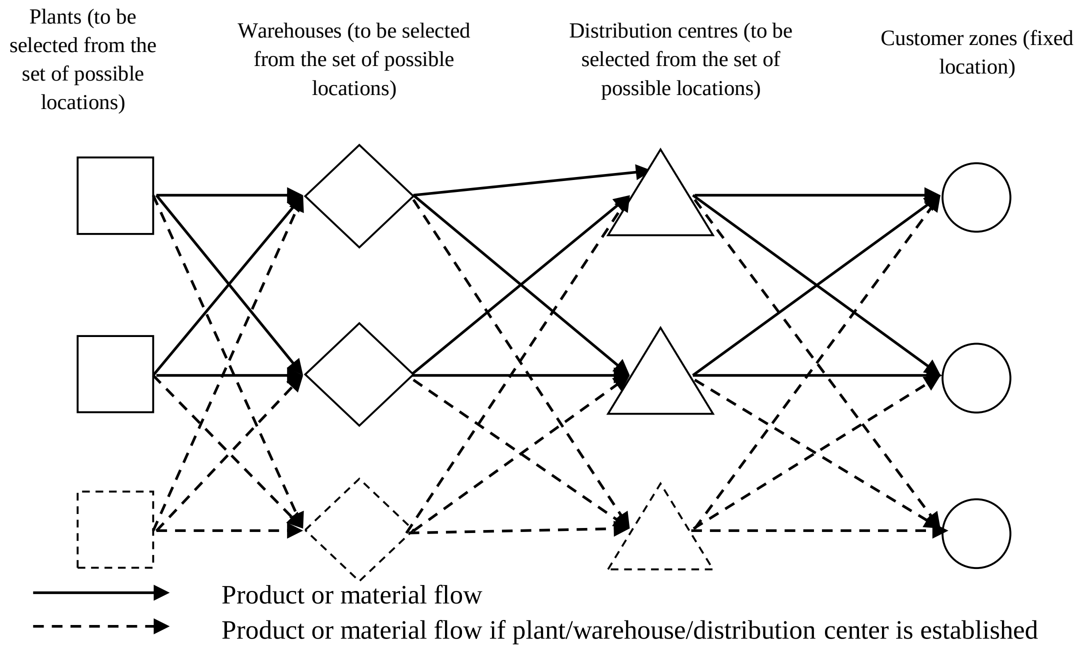

Fig. 2: The Semantic Supply Chain Structure of This Study

These three kinds of decisions were made for maximizing the value of company at the end of planning horizon that was measured by EVA as an indicator of profitability. That shows how well the company utilizes its properties in order to create value [29]. 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 no 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.

3.1 Mathematical Formulation

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

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, and 3-distribution centre, 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}: the highest capacity of product $i \in I$in plant $j \in J_1$;

P_{ij}^{min}: the least capacity of product $i \in I$in plant $j \in J_1$;

I_{ijt}^{max}: the highest capacity of storage $i \in I$ in plant $j \in J_1$ in the 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}: the highest capacity of storage at facility$j \in J_1$, $(l = 2,3)$;

S_j^{min}: the least capacity of storage at facility $j \in J_1$, $(l = 2,3)$;

Q_{jk}: the highest 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}: the establishment cost of a facility at possible location $j \in J_1$, $(l = 1,2,3)$ in duration $t \in \mathcal{T}$;

FPC_{ijt}: fixed cost of production$i \in$ I at plant j $\in \mathrm{J}_1$ in period t $\in \mathcal{T}$;

VPC_{ijt}: production variable cost of product $i \in I$ at plant $j \in J_1$in duration$t \in \mathcal{T}$;

FTC_{ijkt}: the fixed cost of transportation of product $i \in I$ from facility j $\in \mathrm{J}_1$ to facility $k \in J_{l+1}$, $(l = 1,2,3)$, in period $t \in \mathcal{T}$;

VTC_{ijkt}: the transportation variable cost of product $i \in I$from facility j $\in \mathrm{J}_1$to facility $k \in J_{l+1}$, $(l = 1,2,3)$, in period $t \in \mathcal{T}$;

IC_{ijt}: the cost of inventory for each unit of product $i \in I$ at facility j $\in \mathrm{J}_1$, $(l = 1,2,3)$, in duration $t \in \mathcal{T}$;

r_t: capital rate cost at the end of duration$t \in \mathcal{T}$;

TR_t : rate of tax at the end of duration$t \in \mathcal{T}$;

IR_t: rate of long-term interest at the end of duration $t \in \mathcal{T}$;

DPR_{st}: rate of devaluation at the end of duration $t = s,\ s\ and\ t\ \in T$;

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 duration $t \in \mathcal{T}$;

CUR_t: lower bound for current ratio at the end of duration$t \in \mathcal{T}$;

ROA_t: lower bound for return on assets ratio at the end of duration $t \in \mathcal{T}$;

ROE_t: lower bound for return on equity ratio at the end of duration $t \in \mathcal{T}$;

ATR_t: lower bound for assets turnover ratio at the end of duration $t \in \mathcal{T}$;

PMR_t: lower bound forprofit margin ratio at the end of duration $t \in \mathcal{T}$;

QR_t: lower bound for quick ratio at the end of duration $t \in \mathcal{T}$;
$LTDR_t$: 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 duration $t \in \mathcal{T}$;
α_t: unpaid incomes coefficient at the end of duration $t \in \mathcal{T}$;
μ_t: unpaid payables coefficient at the end of duration $t \in \mathcal{T}$;

Decision Variables:
P_{ijt}: amount of product $i \in I$ manufactured in plant $j \in J_1$ in duration $t \in \mathcal{T}$;
x_{ijkt}: amount of product $i \in I$ shipped from facility $j \in J_1$ to facility $k \in J_{l+1}$, (l=1,2,3), in duration $t \in \mathcal{T}$;
q_{ijt}: amount of inventory of product $i \in I$ holding in facility $j \in J_1$, (l = 1,2,3), in the duration $t \in \mathcal{T}$;
b_t: amount of loans borrowed in duration $t \in \mathcal{T}$;
rp_t: repaid amount to the bank in duration $t \in \mathcal{T}$;
ncP_t: amount of new capital from shareholders in duration $t \in \mathcal{T}$;

Binary Variables
y_{it}: taking the value 1 if facility $j \in J_1$, (l =1,2,3), is to be established in the duration $t \in \mathcal{T}$ and 0 otherwise;
w_{jst}: taking the value 1 if facility $j \in J_1$, ($l = 1,2,3$), was established in the duration $s \in \mathcal{T}$ and is yet open in the duration $t \in \{s, \cdots, T\}$ and 0 otherwise;
u_{ijt}: taking the value 1 if product $i \in I$ is manufactured at plant $j \in J_1$ in the duration $t \in \mathcal{T}$ and 0 otherwise;
$\mathcal{Z}_{ikt}$: taking the value 1 if there is shipping from facility $j \in J_1$ to facility $k \in J_{l+1}$, ($l = 1,2,3$), in duration $t \in \mathcal{T}$.

3.2 Objective Function

Supply chain strategic decisions affect company finances and therefore, affect 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 the 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 the EVA as given by Eq. (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 Eq. (1) can be calculated with Eq. (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 Eqs. (3)-(6) and $LTD_t = LTD_{t-1} + b_t - rp_t$

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

$$TC_t = \sum_{l=1}^{3}\sum_{j\in J_1}\sum_{k\in J_{l+1}}\left(FTC_{jkt}z_{jkt} + \sum_{i\in I} VTC_{ijkt}x_{ijkt}\right).t \in \mathcal{T} \quad (4)$$

$$IC_t = \sum_{l=1}^{3}\sum_{j\in J_1}\sum_{i\in I} IC_{ijt}\frac{q_{ijt} + q_{ijt-1}}{2}\ .t \in \mathcal{T} \quad (5)$$

$$IV_t - IV_{t-1} = \sum_{i\in I}\left(\frac{\sum_{j\in J_1} VPC_{ijt}}{|J_1|}\sum_{l=1}^{3}\sum_{j\in J_1}\left(q_{ijt} - q_{ijt-1}\right)\right).t \in \mathcal{T} \quad (6)$$

$CI_t = E_t + LTD_t$ where$E_t = E_{t-1} + NOPAT_t + ncp_t$, with $t \in \mathcal{T}$ (7)

In Eqs. (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 Eq. (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 it was assumed that all profits stay in the company in order to finance and there is no any dividend distribution during the planning horizon.

3.3 The Model Constraints

Constraints of the model can be categorized into two groups that should be satisfied as operational and financial constraints.

3.3.1 The 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. Eq. (8) shows that the total flow of each product received by each customer zone from distribution centers has to be equal to the market demand.

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

Eqs. (9) and (10) force the quantities of production for each product in each plant and each time duration to be into a pre-specified range.

$$p_{ijt} \geq P_{ij}^{min}\sum_{s=1}^{t} y_{js} \forall i \in I, j \in J_1, t \in \mathcal{T} \quad (9)$$

$$p_{ijt} \leq P_{ij}^{max}\sum_{s=1}^{t} y_{js} \forall i \in I, j \in J_1, t \in \mathcal{T} \quad (10)$$

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

$$\sum_{i\in I} \rho_{ije}P_{ijt} \leq R_e \forall j \in J_1, e \in E, t \in \mathcal{T} \quad (11)$$

Eqs. (12) to (15) represent stored quantities in each facility for each product to be required within a pre-specified range, in each time period.

$$q_{ijt} \leq I_{ijt}^{max}\sum_{s=1}^{t} y_{js} \forall i \in I, j \in J_1, t \in \mathcal{T} \quad (12)$$

$$\sum_{i\in I} q_{ijt} \geq S_j^{min} \sum_{s=1}^{t} y_{js} \forall l = 2{,}3\ j \in J_l\ , t \in \mathcal{T} \tag{13}$$

$$\sum_{i\in I} q_{ijt} \leq S_j^{max} \sum_{s=1}^{t} y_{js} \forall j = J_l, t \in \mathcal{T} \tag{14}$$

$$q_{ijt} \geq SS_{ij} \sum_{s=1}^{t} y_{js} \forall i \in I, l = 2{,}3\ \ j \in J_l, t \in \mathcal{T} \tag{15}$$

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

$$q_{ijt-1} + p_{ijt} - \sum_{k\in J_2} x_{ijkt} - q_{ijt} = 0 \qquad \forall i \in I, j \in J_1\ , t \in \mathcal{T} \tag{16}$$

As the case for plants, inventories at warehouses and distribution centers satisfy flow preservation constraints, hence, in each time duration, 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 Eq. (17).

$$q_{ijt-1} + \sum_{m\in J_{l-1}} x_{imit} - \sum_{k\in J_{l+1}} x_{ijkt} - q_{ijt} = 0 \qquad \forall i \in I, l = 2{,}3,\ \ j \in J_1, t \in \mathcal{T} \tag{17}$$

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

$$\sum_{i\in I} x_{ijkt} \leq Q_{jk} \mathcal{Z}_{jkt} \forall l = 1{,}2{,}3, \qquad j \in J_l k \in J_{l+1}, t \in \mathcal{T} \tag{18}$$

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

$$\sum_{t=1}^{T} y_{is} \leq 1 \qquad \forall l = 1{,}2{,}3\ \ , j \in J_l \tag{19}$$

Eq. (20) is a logical constraint forcing opening facility to be opened.

$$w_{jst} = y_{js} \forall l = 1{,}2{,}3, j \in J_l, s, t \in \mathcal{T}, t \geq s \tag{19}$$

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

$$\sum_{i\in I} \sum_{k\in J_{l+1}} x_{ijkt} \leq M \sum_{s=1}^{t} y_{js} \quad \forall l = 1{,}2{,}3, j \in J_l, t \in \mathcal{T} \tag{21}$$

$$\sum_{i\in I} \sum_{j\in J_l} x_{ijkt} \leq M \sum_{s=1}^{t} y_{js} \quad \forall l = 1{,}2, k \in J_{l+1}, t \in \mathcal{T}) \tag{22}$$

$$p_{ijt} \leq M u_{ijt} \forall i \in I, J \in J_1, t \in \mathcal{T} \tag{23}$$

3.3.2 Financial Constraints

One of the beneficial parts of financial statements is financial ratios that prepare standard tools for measuring a company's performance, efficiency, liquidity, and leverage. The financial constrains force financial ratios in order to support the financial health of the corporation. This study used the ratios categories defined by Breally et al. [48] and sets upper/lower limits value 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). Eqs. (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 after taxes (NOPAT) by net fixed assets (NFA_t) and current assets (CA_t); their calculations are given by Eqs. (25) to (28).

$$\frac{NOPAT_t}{E_t} \geq ROE_t \forall t \in \mathcal{T} \tag{24}$$

$$\frac{NOPAT_t}{NFA_t + CA_t} \geq ROA_t \forall t \in \mathcal{T} \tag{25}$$

$$NFA_t = NFA_{t-1} + \sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} - DPR_t \text{ , } t \in \mathcal{T} \tag{26}$$

$$CA_t = C_t + \alpha_t \sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} + IV_t \text{ , } t \in \mathcal{T} \tag{27}$$

$$\begin{aligned} C_t = C_{t-1} + \alpha_{t-1} \sum_{i \in 1} \sum_{j \in J_4} SP_{ijt} O_{ijt} + (1 - \alpha_t) \sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt} + ncp_t + b_t \\ -\mu_{t-1}(PC_{t-1} + TC_{t-1} + IC_{t-1}) - (1 - \mu_t)(PC_t + TC_t + IC_t) \\ -TR_{t-1}(EBIT_{t-1} - IR_{t-1} LTD_{t-1}) - \sum_{l=1}^{3} \sum_{j \in J_l} C_{jt} y_{jt} + IR_t LTD_t - rp_t \text{ , } t \in \mathcal{T} \end{aligned} \tag{28}$$

3.3.2.2 Efficiency Ratios

Efficiency ratios measure how well the company utilizes its many 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 (PMR)**

Profit margin measures the proportion of sales that finds its way into profits. 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 Eq. (29).

$$\frac{NOPAT_t}{\sum_{i \in I} \sum_{j \in J_4} SP_{ijt} O_{ijt}} \geq PMR_t \forall t \in \mathcal{T} \tag{29}$$

- **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. Eq. (30) shows asset turnover ratios.

$$\frac{\sum_{i\in I}\sum_{j\in J_4} SP_{ijt}O_{ijt}}{NFA_t + CA_t} \geq ATR_t \forall t \in \mathcal{T} \quad (30)$$

3.3.2.3 Liquidity Ratios

Liquidity ratios determine how quickly assets can be converted into cash. The liquidity ratios analysis helps the company to 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). Eq. (31) shows current ratio constraint.

$$\frac{CA_t}{STD_t} \geq CUR_t \forall t \in \mathcal{T} \quad (31)$$

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

$$STD_t = \mu_t(PC_t + TC_t + IC_t) + (EBIT_t - IR_t LTD_1)TR_t \, .t \in \mathcal{T} \quad (32)$$

- **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:

$$\frac{C_t + \alpha_t \sum_{i\in I}\sum_{j\in J_4} SP_{ijt}O_{ijt}}{STD_t} \geq QR_t \forall t \in \mathcal{T} \quad (33)$$

- **Cash Ratio (CR)**

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

$$\frac{C_t}{STD_t} \geq CR_t \forall t \in \mathcal{T} \quad (34)$$

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:

$$\frac{LTD_t}{E_t + LTD_t} \leq LTDR_t \forall t \in \mathcal{T} \quad (35)$$

- **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:

$$\frac{EBIT_t + DPR_t}{IR_t LTD_t} \geq CCR_t \forall t \in \mathcal{T} \quad (36)$$

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

$$EBIT_t = \sum_{i\in I}\sum_{j\in J_4} SP_{ijt}O_{ijt} - CS_t - \sum_{l=1}^{3}\sum_{j\in J_l}\sum_{s=1}^{t} DPR_{st}C_{js}w_{jst} t \in \mathcal{T} \quad (37)$$

3.3.2.5 Other Financial Constrains

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

$$\sum_{l=1}^{3}\sum_{j\in J_l} C_{jt}y_{jt} = ncp_t + b_t \forall t \in \mathcal{T} \quad (38)$$

Eq. (39) shows new capital entries are limited to the quantity that company participants desire to invest in the company

$$ncp_t \leq CP_t \forall t \in \mathcal{T} \quad (39)$$

Commonly, banks constrain the repayment (rp_t) to be at least the interest costs, to barricade a growing debt:

$$rp_t \geq IR_t LTD_t \forall t \in \mathcal{T} \quad (40)$$

Eventually, Eqs. (41) to (43) show the type of the variables.

$$b_t . rp_t . ncp_t \geq 0 \qquad \forall i \in I, t \in \mathcal{T} \quad (41)$$

$$p_{ijt} . q_{ijt} . x_{ijkt} \geq 0 \quad \forall i \in I, l = 1,2,3, \qquad j \in J_l, k \in J_{l+1}, t \in \mathcal{T} \quad (42)$$

$$y_{it} . w_{sjt} . u_{ijt} . \mathcal{Z}_{jkt} \in \{0.1\} \forall i \in I, l = 1,2,3, j \in J_l, k \in J_{l+1}, s, t \in \mathcal{T}, s \leq t \quad (43)$$

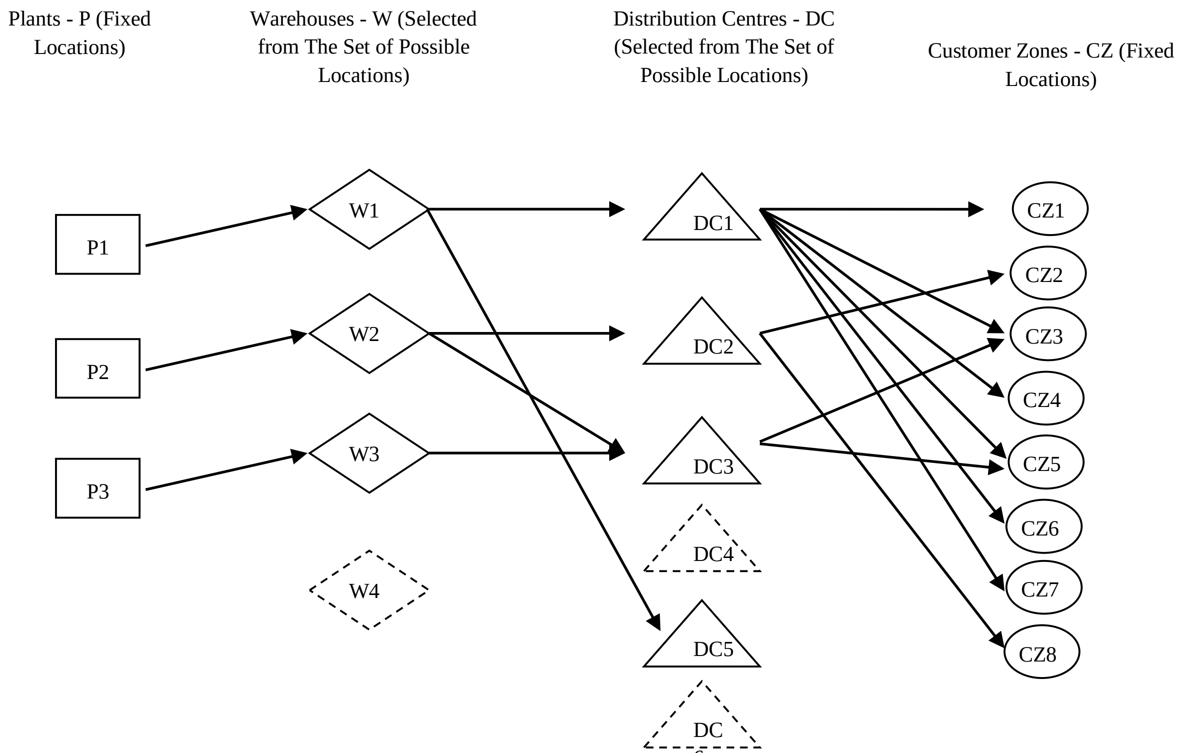

Fig. 3: The Optimal Network Configuration of Supply Chain and Flows of Products During the First Time Period

4 Computational Results

In order to show the applicability and the efficiency of the proposed model, we applied the data of Loginidis et al. [1]. The scale of the studied company is as follows: this 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 centers have an upper and lower bound handling capacity and need 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 (See the appendix for more details). 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. Fig. 3 displays the optimal configuration of the supply chain network includes tree plants, tree warehouses and four distribution centers that are selected to be opened in the first year.

The optimal networks for other time periods are shown in Figs. 4 and 5 (see appendix). 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 1: Total Flows Transported from the Plants to the Warehouses. (a) Achieved by our Model. (b) Obtained by the Base-Model [11]

Our Model	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 2: Total Aggregated Flows Transported from the Warehouses to the Distribution Centres. (a) Obtained by our Model. (b) Obtained by the Base-Model [11]

(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 3: Total Aggregated Flows Transported from the Distribution Centres to the Customer Zones. (a) Obtained by our Model. (b) Obtained by the Base-Model [11]

(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 are decisions to be adopted. Our model also provides a balance between debt, repayments and new capital in order to maintain company's financial condition well. 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, 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 4.

Table 4: 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 4 shows that since the company has enough cash, it does not need bank loans. It also captures all the capital entries from shareholders. In addition, due to the 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 money units whereas the proposed model with a new financial approach is able to create 2,125,210 money 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.

5 Conclusions

A firm's managers should make decisions that secure the firm's future sustainability through the maximization of long-term firm value. Therefore, in the decision-making process involving each division and business unit, financial and SC decisions affect each other, and these aspects should be included in modelling of such decision procedures. In modelling business activities, the integration of SC operations and the financial aspects of a company has recently drawn a considerable amount of research attention. However, published works on supply chain network design (SCND) incorporating financial decisions are scarce. The major contributions of this study can be summarized as follows:

- This study presents a mathematical model to solve a supply chain network design problem that considers tactical, strategic and financial decisions at the same time.
- The model determines the locations of facilities, amount of production, inventory for each product at each facility, flows of products (distribution) for both strategical and financial levels.
- The proposed model also considers new capital from shareholders, bank repayment and amount borrowed as decision variables, but in previous works the capital entries were considered as a parameter.
- Besides, the usual operational limitations, the model imposes upper and/or lower bound for leverage ratio, efficiency ratios, liquidity ratios and preference ratios that led together to a greater value creation for the company. In order to retain a better financial performance, the proposed model provides a balance among new capital entries, loans and repayment. With consideration of large cost

of new capital entries, the model imposes upper bound on it and to avoid an ever-increasing debt, it considers lower bound for bank repayments. Besides, these benefits our model provides for manager an accounts payable guideline.

- We modified depreciation calculation because the life time of each asset was determined and we can calculate the exact depreciation values in any period of time. We also used real value of the cash instead of considered percentage of profit and financial ratios instead of total value of fixed assets. This study provides a connection between supply chain performance and financial decision that can be used as supportive tools for decision making and also helps manager improve the company performance.

By comparing results obtained by the proposed model and results obtained by the base model, we have shown that our model is more effective in terms of increasing the overall value of the company measured by economic value-added index (EVA) as well as providing target values for the financial ratios set by the company's managers and shareholders.

Our work can be extended in the following directions: First, by using the financial ratios as objective functions in our model, we can look for ways to increase and improve the firm's soundness and its optimal results through experiments. Second, including uncertainty into some parameters like price, cost, demand, interest rate in order to get a solution approach closer to reality. Third, another research direction for our model can be the green supply chain with a closed-loop structure or sustainability that considers technological, environmental, social and economic aspects that should be incorporated in the supply chain network design; with these developments the problem would become more complicated. Accordingly, tracking other kinds of solutions, such as metaheuristics, in order to solve the problem may be another suggestion for future studies. Finally, the results of our model can be different by changing the target values. To observe in detail how such changes affect the objective function of our model, sensitivity analysis can be performed in future work.

Appendix A

To verify the practical applicability of the proposed optimization model and solution approach, we test them with the data of Loginidis et al. [1] (Tables 5-21).

Table 5: Highest Capacity of Production

Products	Plants		
	Plant 1	Plant 2	Plant 3
Product 1	157	0	971
Product 2	2267	1412	779
Product 3	1702	1057	606
Product 4	1511	1327	541
Product 5	0	997	0
Product 6	811	665	415
Product 7	641	665	415

Table 6: Coefficient of Utilization of Resources

Plant	Resource	Products							Resource Availability (h/year)
		P 1	P 2	P 3	P 4	P 5	P 6	P 7	
Plant 1	E1	0.2382	0	0	0	0.7935	0	0	120
	E2	0	0.0462	0.0616	0.0693	0	0	0	106
	E3	0	0	0	0	0	0	0.1633	106

Table 6: Coefficient of Utilization of Resources

Plant	Resource	Products							Resource Availability (h/year)
		P 1	P 2	P 3	P 4	P 5	P 6	P 7	
Plant 1	E1	0.2177	0	0.3743	0	0	0	0	106
	E2	0	0	0	0.0792	0.1053	0.1581	0.1583	106
	E3	0	0.073	0.1	0	0	0	0	106
Plant 1	E1	0	0	0.1975	0.223	0	0	0	106
	E2	0	0	0	0	0.7788	0.3967	0.3967	165
	E3	0.1200	0.1542	0	0	0	0	0	120

Table 7: Quantities of Inventory at the Beginning of the Planning Horizon

	Plants		
	Plant 1	Plant 2	Plant3
Primary inventory	7091	6121	3728

Table 8: Demand by Product in Year 1

Demand, Year 1									
Products	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	Total
Product 1	50	0	0	115	0	0	0	0	165
Product 2	0	54	105	0	0	0	155	0	313
Product 3	187	114	0	306	310	0	0	0	918
Product 4	0	103	115	0	0	0	205	192	615
Product 5	0	76	0	0	0	0	0	0	76
Product 6	100	0	95	0	0	354	0	194	743
Product 7	0	30	89	80	0	0	0	0	199
Total	337	377	404	501	310	354	360	386	3029

Table 9: Demand by Product in Year 2

Demand, Year 2									
Product	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	Total
P1	50	0	0	115	0	0	0	0	165
P2	0	53	105	0	0	0	155	0	313
P3	187	116	0	308	310	0	0	0	922
P4	0	104	116	0	0	0	205	192	617
P5	0	76	0	0	0	0	0	0	76
P6	100	0	96	0	0	354	0	194	744
P7	0	30	89	80	0	0	0	0	199
Total	337	379	406	503	310	354	360	386	3036

Table 10: Demand by Product in Year 3

Demand, Year 3									
Product	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	Total
P1	50	0	0	116	0	0	0	0	166
P2	0	54	106	0	0	0	156	0	316
P3	188	117	0	308	309	0	0	0	922
P4	0	103	116	0	0	0	205	192	616
P5	0	77	0	0	0	0	0	0	77
P6	100	0	95	0	0	354	0	194	743
P7	0	30	90	80	0	0	0	0	200
Total	338	381	407	504	309	354	361	386	3040

Table 11: Demand by Product in Year 4

Demand, year 4									
Product	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	Total
P1	50	0	0	116	0	0	0	0	166
P2	0	53	106	0	0	0	156	0	313
P3	188	115	0	308	310	0	0	0	921
P4	0	103	115	0	0	0	206	192	616
P5	0	76	0	0	0	0	0	0	76
P6	100	0	95	0	0	354	0	194	743
P7	0	33	97	86	0	0	0	0	215
Total	338	379	413	510	310	354	362	386	3052

Table 12: Production and Storage Costs at Plants (Money Units Per Ton)

Products	Production		
	Plant 1	Plant 2	Plant 3
P1-P6	61.26	59.44	61.42
P7	256.91	268.49	270.79

Storage		
Plant 1	Plant 2	Plant 3
8.3	8.56	8.97
8.24	8.54	8.97

Table 13: Cost of Transportation from Plants to Warehouses (Money Units Per Ton)

Plant	Products	Warehouse			
		W 1	W 2	W 3	W 4
Plant 1	P1-P6	5.48	63.10	67.27	31.08
	P7	5.5	68.02	72.43	33.27
Plant 2	P1-P6	65.6	6.22	75.93	48.85
	P7	86.94	6.83	101.45	64.64
Plant 3	P1-P6	80.40	83.75	6.4	59.75
	P7	99.14	103.23	6.77	73.24

Table 14: Cost of Warehouses Infrastructure and Costs of Inventory (Relative Money Units Per Ton)

Warehouses	Cost of Infrastructure	Cost of Inventory
Warehouse 1	40,000	8.24
Warehouse 2	20,000	8.55
Warehouse 3	16,000	8.97
Warehouse 4	24,000	8.94

Table 15: Cost of Transportation from Warehouses to Distribution Centers (Money Units Per Ton)

Warehouses	Products	Distribution Centers					
		DC1	DC2	DC3	DC4	DC5	DC6
Warehouse 1	P1-P6	4.25	78.95	81.11	30.89	74.06	33.31
	P7	4.25	79.83	82.01	31.19	74.87	33.66
Warehouse 2	P1-P6	63.1	4.55	67.94	50.09	114.34	43.70
	P7	65.12	4.55	70.10	51.64	118.10	46.10
Warehouse 3	P1-P6	77.08	80.69	4.98	54.59	99.20	103.22
	P7	95.00	99.43	4.98	66.81	122.42	127.66
Warehouse 4	P1-P6	32.79	67.33	62.06	4.93	92.37	62.88
	P7	33.13	68.09	62.75	4.93	93.43	63.59

Table 16: Cost of Transportation from Distribution Centers to Customer Zones (Money Units Per Ton)

Distribution Center	Product	Customer Zone							
		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
DC 1	P1-P6	0.00	75.62	54.52	12.31	70.33	29.88	17.57	119.56
	P7	0.00	73.11	52.72	11.90	68.03	28.8	17.00	15.62
DC 2	P1-P6	73.54	0.00	8.67	73.54	136.40	87.24	83.82	118.03

Table 16: Cost of Transportation from Distribution Centers to Customer Zones (Money Units Per Ton)

Distribution Center	Product	Customer Zone							
		CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
	P7	73.21	0.00	78.30	73.21	136.20	86.83	83.41	117.46
DC 3	P1-P6	73.27	76.62	19.95	49.95	94.94	99.94	63.27	83.29
	P7	81.64	85.35	24.95	55.66	105.77	111.35	70.51	88.24
DC 4	P1-P6	26.57	58.46	53.15	3.28	81.52	54.94	30.11	79.22
	P7	24.75	54.47	49.54	3.88	75.94	51.17	28.05	72.45
DC 5	P1-P6	77.15	154.32	109.95	84.89	7.14	90.66	59.81	136.96
	P7	7751	155.03	110.46	85.26	7.97	91.08	60.07	137.59
DC 6	P1-P6	27.07	84.64	79.56	38.92	79.56	17.43	43.33	143.91
	P7	23.64	32.64	95.94	46.93	95.94	18.05	51.04	173.51

Table 17: Costs of Distribution Centers Infrastructure and Costs of Inventory (Money Units Per Ton)

Distribution centers	Cost of Infrastructure	Cost of Inventory
DC 1	40,000	8.25
DC 2	20,000	8.55
DC 3	16,000	8.98
DC 4	24,000	8.93
DC 5	26,000	8.85
DC 6	14,000	6.90

Table 18: Products Price (Money Units Per Ton) For Each Customer Zone

Product	Price								
	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	Total
Product 1	250	0	0	230	0	0	0	0	480
Product 2	0	240	230	0	0	0	270	0	740
Product 3	0	270	0	230	250	0	0	0	750
Product 4	440	430	460	0	0	0	410	440	2180
Product 5	0	230	0	0	0	0	0	0	230
Product 6	420	0	430	0	0	400	0	430	1680
Product 7	0	610	600	600	0	0	0	0	1810
Total	1110	1780	1720	1060	250	400	680	870	7870

Table 19: Balance Sheet at The Beginning of the Planning Period (Money Units Per Ton)

Account	Value
Assets	500,000
Tangible assets	500,000
Intangible assets	0,000
Current assets	1979,088
Cash	550,000
Receivable accounts	50,000
Inventory	1379,088
Total Assets	**2,479,088**
Equity	1129,088
Common stock	1129,088
Retained earning	0,000
Debt	1350,000
Short term liabilities	450,000
Long term liabilities	900,000
Total Debt and Equity	**2,479,088**

Table 20: Financial Cycle Parameters in Each Time Period

Financial Parameter	Year 1	Year 2	Year 3	Year 4
Rate Of Depreciation	0.250	0.250	0.250	0.250
Short term interest rate	0.035	0.040	0.045	0.050
Long term interest rate	0.070	0.075	0.080	0.085
Tax rate	0.200	0.225	0.250	0.275
Cost of capital rate	0.015	0.020	0.025	0.030

Table 21: Bounds for Financial Ratios**.**

Financial ratio	Bound
Current ratio	2.00
Quick ratio	1.25
Cash ratio	1.00
Fixed assets turnover ratio	1.10
Receivables turnover ratio	1.67
Total-debt ratio	0.60
Debt-equity ratio	1.50
Long term debt ratio	0.80
Cash coverage ratio	5.00
Profit margin ratio	0.05
Return on assets ratio	0.01
Return on equity ratio	0.02

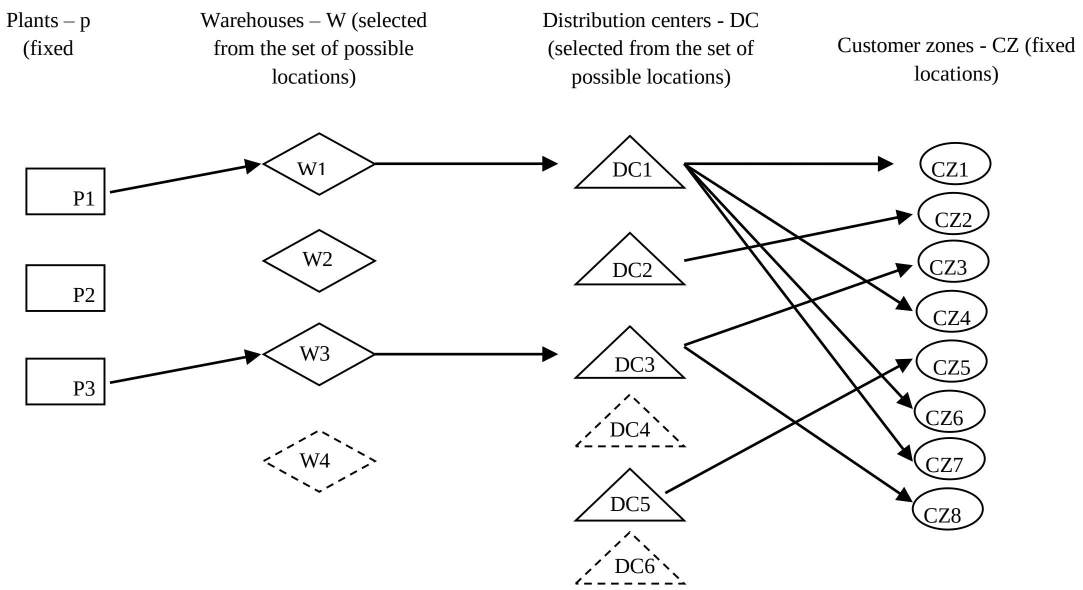

Fig. 4: The Optimal Network Configuration of Supply Chain and Flows of Products During the Second and Third Time Period

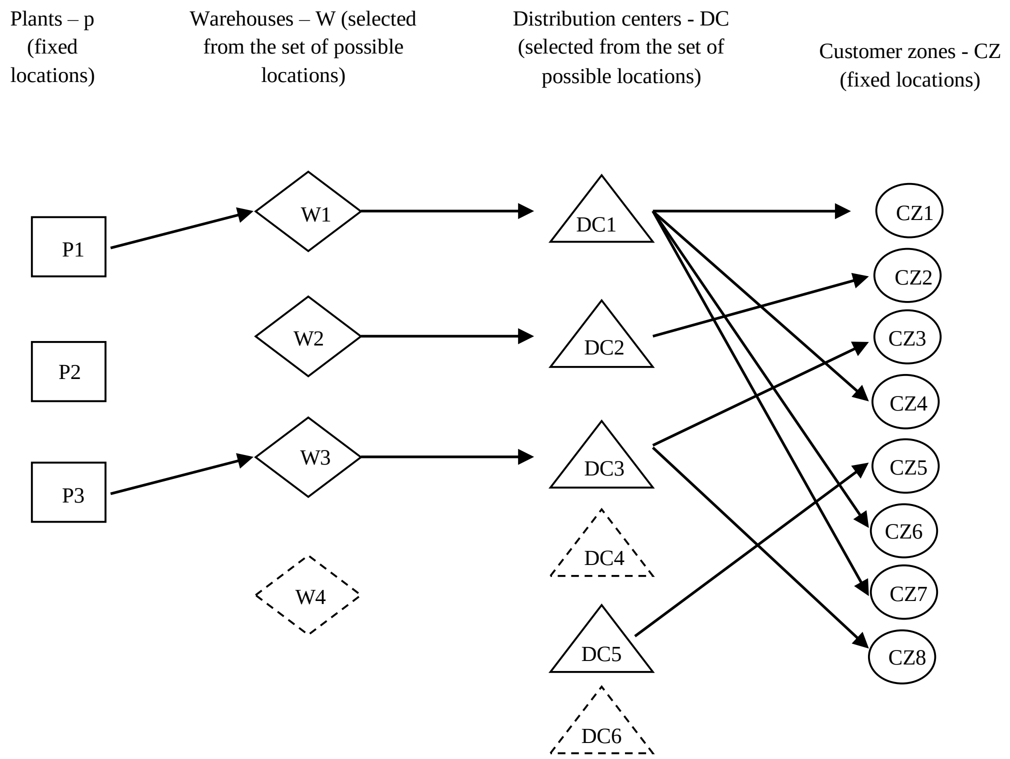

Fig. 5: The Optimal Network Configuration of Supply Chain and Flows of Products During the Fourth Time Period

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