A Comparison between Profit and Economic Value Added Optimization to Design a Supply Chain Network: A Case Study of Food Supply Chain in Vietnam

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Abstract— **The research field of food supply chain network design and optimization has expanded significantly. However, most recent studies have focused only on minimizing costs or maximizing profits, neglecting other important financial factors that affect the overall prosperity of the chain. This study generates two scenarios in the design of the supply chain network, comparing the maximization of profit and Economic Value Added (EVA) to assess their effectiveness in real-world situations. The comparison is based on supplier and potential distribution center selection, along with considerations of production level, production capacity, and the sizes of the plant, distribution centers, and retailers. The methodology considered in this research is based on Mixed-Integer Linear Programming (MILP) under deterministic parameters. The study provides computational results and managerial insights based on a case study of the food supply chain in Southern Vietnam. The findings indicate that the EVA maximization model offers a more precise evaluation of company wealth as compared to the profit maximization model as it can determine more suitable operating supply chain's decision variables leading to a significant decrease of 11.1% in the invested capital.**

Index Terms— **Economic Value Added (EVA), Food Supply Chain Network Design (FSCND), Mixed Integer Linear Programming (MILP), Profit Maximization**

I. Introduction

The strategic design of the food supply chain network plays a pivotal role in addressing the fundamental needs of humanity, encompassing a diverse range of activities, including production, transportation, processing, distribution, and consumption [1]. However, real-world challenges, such as high logistics costs and limited investment funds to meet customer demand, hinder the practical implementation of the food supply chain [2].

The complexity of the food supply chain planning problem arises due to its vast scale, involving numerous interconnected echelons and variables that need careful consideration and strategic management [3]. For instance, the decision of selecting suitable suppliers or establishing distribution centers becomes increasingly intricate. In the field of food supply chain network design, challenges such as cost considerations, regulatory compliance, or transportation logistics may also necessitate adjustments to ordering quantities and facilities capacities or even the need for new centers in the case of much extra capacity being required. Burgess et al. [4] generated alternative food networks to enhance processes, meet customer needs, and elevate the overall quality of the supply chain. Gholian-Jouybari et al. [5] concentrated on designing a closed-loop agri-food supply chain network design for the soybean industry while Gholian-Jouybari et al. [6] developed policies in the agri-food supply chain coconut industry to provide fresh, healthy products to their societies.

Southern Vietnam, with its tropical climate and abundant agricultural products, holds great potential for strategically planning a food supply chain that can cater to the entire nation. This region plays a vital role as a key contributor to the economic market. According to Insights [7] on the food industry in Vietnam, the revenue surged from 64.86 billion USD in 2018 to 94.37 billion USD in 2023, as Fig. 1. The market is expected to grow annually by 7.46% (CAGR 2024-2028). To ensure adequate consumption, the Vietnamese government has prioritized the promotion of the supply chain network. This includes a focus on effectively and sustainably managing all members while taking into account the economic value. Traditionally, the primary goal of planning in the food supply chain has been to maximize the profit or minimize total costs across the chain, aiming to design the most cost-effective strategy for the production, storage, and transportation of goods. It is essential to include the relevant costs in managing the supply chain, such as purchasing, transportation, holding, and production.

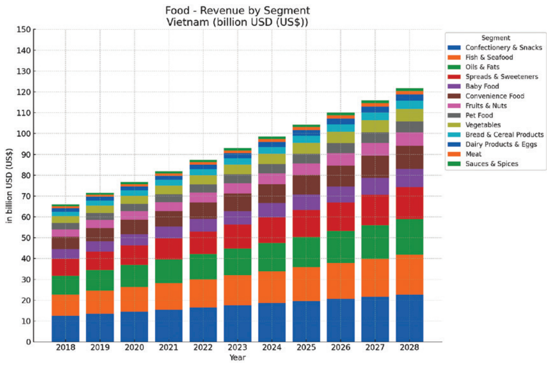

Fig. 1. Revenue of the food industry in Vietnam (2018-2028)

However, for a more practical and sustainable approach, it is important to evaluate the overall wealth of the company. In order to make decisions that involve such an investment, Economic Value Added (EVA) incorporates both operational and investment expenditures. It helps showcase the business performance based on the total costs invested, including both operating and fixed capital [3]. This financial resource allocation plays a vital role in the decision-making process of supply chain management [8]. Therefore, making the right decisions can save a business a significant amount of financial resources. For instance, instead of opening a new distribution center, a more cost-effective approach might involve allocating less amount of resources to expand the current distribution center. In some cases, the assessment and selection of potential facilities face limitations. For example, focusing solely on profit optimization may lead decision-makers to choose partners with low transportation expenses. However, a more detailed analysis could reveal that the cost savings in delivery would require more investment in the fixed assets. This is not, however, considered in the profit calculation. Therefore, this aspect deserves attention when framing a supply chain management problem and should be considered in the decision-making processes.

As a result, this study aims to suggest a shift in the perspective within the supply chain, particularly in the private food supply chain, moving from the traditional focus on maximizing profit to a more holistic approach that prioritizes economic income. Encouraging asset optimization, as highlighted by Economic Value Added (EVA), underscores how businesses can effectively use their assets to create value while simultaneously reducing capital costs [9]. The structure of this paper is set as follows. Section 2 presents the literature review. Section 3 introduces the methodology. In section 4, the mathematical models are formulated based on both scenarios (profit and EVA maximization). In section 5, a case study is presented to illustrate the methodology. Section 6 presents the results and discussion. Finally, section 7 summarizes the conclusion and outlines future studies.

II. Literature Review

A. Supply Chain Network Design and Optimization

Supply chain networks are complex structures that span the globe, encompassing a range of interconnected entities such as suppliers, production centers, distribution centers, retailers, and customers [8]. These entities engage in diverse activities, including raw material procurement, transportation, manufacturing, and product distribution to meet customer demands. The operations within these networks require careful consideration of several factors (strategic, tactical, operational), the type of product (single or multiple), and the studied periods (single or multiple). For instance, Nagurney [10] highlighted that the modeling framework developed in the study included many echelons (manufacturers, two-level distribution centers, and retailers), and the solution of the model yielded optimal product flows, capacity investments, and demand satisfaction with the minimum total costs. Kashanian and Ryan [11] proposed a sustainable supply chain network design for chemicals from biomass, which incorporated green electrochemistry to minimize annual costs with the three-echelon network (supplier, facility, and customer). Ala et al. [12] designed a blood collection and distribution network to optimize fixed and mobile facilities and supply points, considering the short-term and long-term aspects from donation places to hospitals through temporary and permanent centers. Nagurney [10] proposed a framework for the supply chain network design and redesign that minimized the total costs with two main factors determining the level of capacity in various nodes and operational flows, subject to customer satisfaction. Based on the aforementioned reviews, it was found that most discussions regarding the supply chain network design have focused mainly on maximizing the profit or minimizing the operational costs, without considering investment funds and the costs of capital. These funds could reflect the chain's capital, which constitutes authentic economic profitability.

B. Economic Value Added (EVA) as a Financial Metric for Decision-Making

EVA as present in Equation (1) is a performance metric that calculates the creation of shareholder value. It distinguishes itself from traditional financial performance metrics, such as net profit. EVA is the calculation of what profits remain after the costs of a company's capital are deducted from the operating profit [13].

$$EVA = NOPAT - (WACC \times IC) \quad (1)$$

Where:

- *NOPAT* is the net operating profit after tax.
- *WACC* is the weighted average cost of capital.
- *IC* is the invested capital.

Operating profit, obtained by subtracting Cost of Goods Sold (COGS), operating expenses, and depreciation from revenue, excludes interest and taxes. After-tax deductions, it becomes the Net Operating Profit After Tax (NOPAT), which represents the company's profit from core operations [5]. For investors, the Weighted Average Cost of Capital (WACC) is an important tool in assessing a company's potential for profitability. A lower WACC often indicates a robust business capable of securing capital from investors at a lower expense, whereas a higher WACC tends to signal riskier ventures necessitating higher returns to attract investors. Hence, within the complex framework of supply chain management, a nuanced comprehension of WACC emerges as crucial for guiding pivotal investment determinations, as proposed by Ashayeri and Lemmes [14]. Invested capital, in the context of EVA, refers to the total capital invested in a business to generate profits, usually calculated by the sum of all company-held assets.

In essence, EVA emerges as an indispensable tool, offering a nuanced and comprehensive framework for navigating the multifaceted landscape of corporate investments with precision and insight, offering benefits such as making more informed investment decisions considering the cost of capital, considering simultaneously the total expenses, and revenue, and facilitating decisions for long-term planning horizons. This EVA not only outweighs projected costs but also indicates the project's financial viability, and emphasizes parameters crucial to financial considerations such as capital investment and accounts payables/receivables. Longinidis and Georgiadis [9] presented an explanation of how physical network planning and financial formulation can be integrated to calculate the EVA. They focused on calculating the current fixed assets with a depreciation rate and considered both debt and equity as the cost of capital. Li et al. [15] simultaneously took into account three values: operating costs, capital expenditures, and revenues when proposing an effective supply chain network. They highlighted the significance of investing in sustainable resources and fixed assets when planning capital expenditures for the optimal design of a supply chain network.

C. Linear Programming Model in Supply Chain Network Design

Mixed Integer Linear Programming (MILP) is the most commonly used optimization technique for designing complex supply chain networks. Purnomo et al. [16] employed the MILP to minimize the total costs, encompassing production, traceability, transport, inventory, and emission costs within a supply chain, serving multiple customers over various periods. Kazancoglu et al. [17] proposed the MILP to investigate the optimal selection of echelons and transportation alternatives in a closed-loop supply chain network. Moretti et al. [18] proposed the MILP model to choose the strategy of advanced biofuel supply chains including the distribution of network nodes and the efficient planning of logistics activities. Kumar and Kumar [19] employed the MILP to maintain the balanced flow across all stages of the network and optimize the usage of raw materials in production while minimizing both production costs and greenhouse gas emissions.

The MILP commonly serves as an optimization model, which is typically geared towards achieving either cost or revenue objectives. However, this study endeavors to illuminate another dimension within supply chain networks by broadening the scope to encompass the economic value realized through investment. A comprehensive understanding of this issue necessitates a holistic examination of real-world supply chains, influenced by myriad factors including long-term investment capacity and size, potential facility relocations, which may be variable, and pertinent financial metrics such as taxes, cost of capital, and asset depreciation. Notably, this investigation advocates for replacing the singular profit objective with a comprehensive assessment, thereby facilitating strategic, long-term investment decisions concerning asset capacity.

According to the aforementioned literature, it was found that there could be several research gaps, as shown in Table I. To fill these gaps, this study can be contributed as follows:

1) Introduction of EVA as a key factor in the supply chain network design to determine suppliers and prospective distribution centers, production level and production capacity at the plant, and the sizes of the plant, distribution centers, and retailers, as compared to the profit maximization through Mixed Integer Linear Programming (MILP).

2) Through the comparative analysis between Economic Value Added (EVA) and the profit maximization, it can highlight the key advantages at each member in the supply chain when maximizing EVA over the profit under the long-term planning.

III. Methodology

In the context of food supply chain network design, two models have been developed under deterministic conditions under Mixed-Integer Linear Programming (MILP). The primary objective is to demonstrate the advantages of maximizing Economic Value Added (EVA) over the conventional profit maximization approach. Both models are based on identical datasets and follow the same methodological steps, as shown in Fig. 2.

1. The first step involves defining the objective either maximizing profit or Economic Value Added (EVA). A mathematical model is formulated using deterministic input parameters such as selling prices, purchasing costs, customer demand, and transportation costs. These inputs are integrated into a MILP model, which defines the objective function and includes indices, parameters, constraints, and required decision variables. The goal is to derive optimal solutions for potential suppliers, distribution centers, production levels, capacities, material flows, facility sizes, and inventory levels, aligned with the chosen objective.

2. The second step applies the developed models to a practical scenario specifically, the food supply chain in Southern Vietnam. This application serves to test the models' real-world viability and effectiveness.

3. The final step involves a thorough analysis and comparison of the results obtained from the case study. This analysis focuses on evaluating the performance of the profit maximization model against the EVA maximization model. By comparing the outcomes, stakeholders can discern the long-term economic income from EVA and the short-term profit maximization.

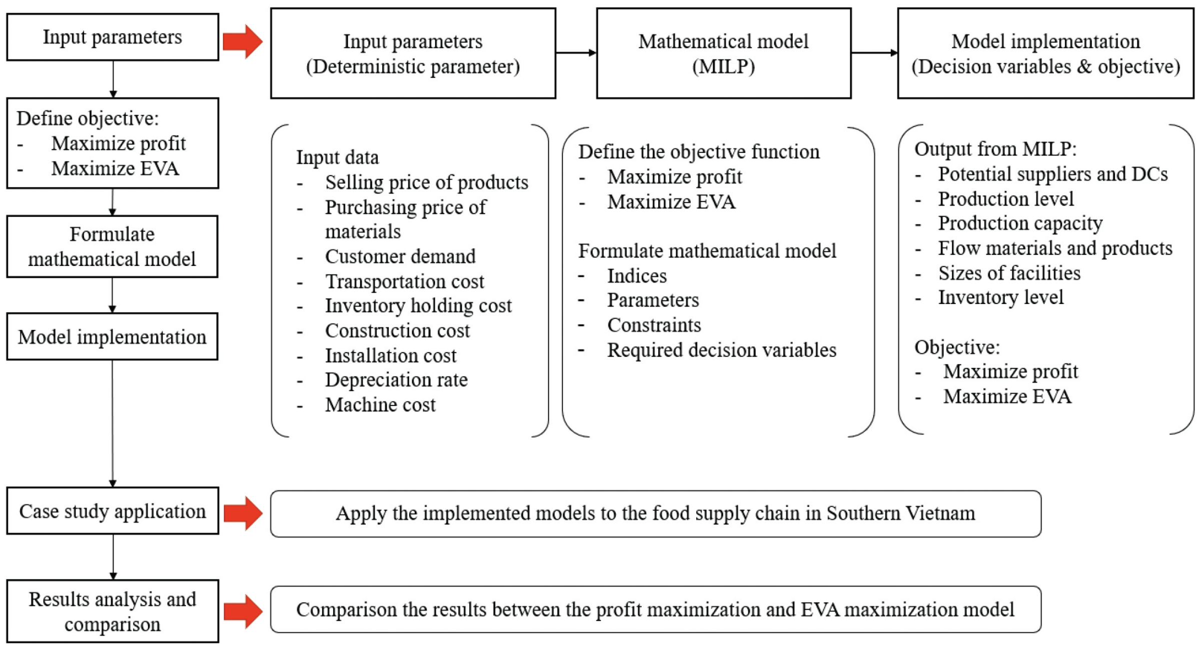

Fig. 2. Procedures of MILP model formulation of the proposed three-step approach

IV. Mathematical Formulation

All optimization models were implemented and solved using the IBM, ILOG, CPLEX, and Optimization Studio on a Windows 10 Pro 64-bit system with an Intel Core i7-8565U CPU running @ 2.0 GHz and 8.0 GB of memory. The supply chain configuration used in this study is illustrated in Fig. 3.

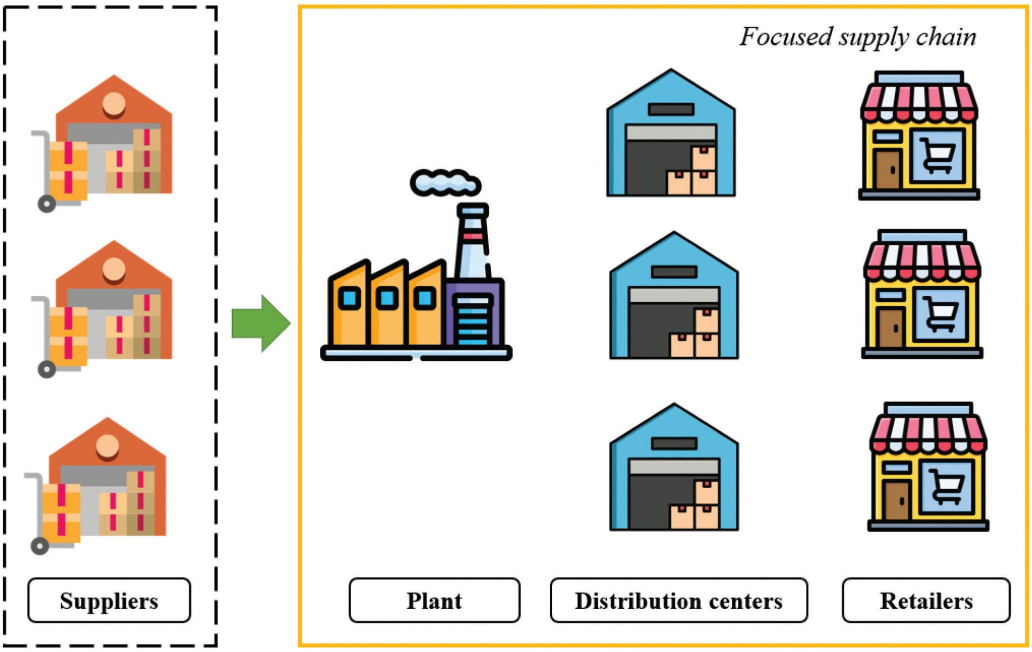

Fig. 3. The supply chain configuration

TABLE I
Summary of Previous Literature Reviews

References	Number of Echelons	Planning Period		Type of Systems	Objectives	Model Types	Solving Tool
		S	L				
Duffuaa et al., 2024 [20]	4	-	x	SCND	Min cost	MILP	CPLEX
Moretti et al., 2021 [18]	2	-	x	SCND	Min cost	MILP	CPLEX
Li et al., 2020 [15]	4	x	-	SCND	Min cost	MILP	CPLEX
Kumar and Kumar, 2024 [19]	4	-	x	SCND	Min cost	MILP	LINGO
Khalifehzadeh et al., 2015 [21]	4	-	x	SCND	Min cost Max reliability	MILP	LINGO
Sheibani and Niroomand, 2024 [22]	4	x	x	SCND	Min cost Min CO_2 Max social effects	MINLP	CPLEX
Ji and Chiadamrong, 2019 [23]	2	x	-	SCNL	Max profit	MILP	CPLEX
Martins et al., 2017 [24]	3	-	x	SCNR	Min cost	MIP	CPLEX
Aqlan and Lam, 2016 [25]	4	-	x	SCRM	Max profit Min lead time	LP	CPLEX
De Keizer et al., 2015 [26]	3	x	x	SCND	Min cost	MILP	CPLEX
Longinidis and Georgiadis, 2011 [9]	4	-	x	SCND	Max EVA	MILP	CPLEX
Badakhshan and Ball, 2022 [8]	4	x	x	SCND	Max EVA	MILP	CPLEX
This paper	4	x	x	SCND	Max EVA	MILP	CPLEX

Abbreviations: S=Short-term Planning, L=Long-term Planning, SCND=Supply Chain Network, SCNR=Supply Chain Network Redesign, SCRM=Supply Chain Risk Management, SCNL=Supply Chain Network Planning, MINLP=Mixed Integer Non-Linear Programming, MILP=Mixed Integer Linear Programming, MIP=Mixed Integer Programming, LP=Linear Programming

A. Mathematical Notations

Indices

S	Set of the suppliers, $I \in S$
D	Set of the distribution centers, $k \in D$
R	Set of the retailers, $l \in R$
T	Set of the periods, $t \in T$

Deterministic Parameters

C_t^P	Production cost of products at the plant in period t (\$/ton)
C_{it}^S	Purchasing cost of raw materials at supplier i in period t (\$/ton)
C_t^{HP}	Inventory holding cost of products at the plant in period t (\$/ton)
C_{kt}^{HD}	Inventory holding cost of products at distribution center k in period t (\$/ton)
C_{lt}^{HR}	Inventory holding cost of products at retailer l in period t (\$/ton)
C_{it}^{TR}	Transportation cost of materials from supplier i to the plant in period t (\$/ton)
C_{kt}^{TR}	Transportation cost of products from the plant to distribution center k in period t (\$/ton)
C_{klt}^{TR}	Transportation cost of products from distribution center k to retailer l in period t (\$/ton)
C_{kt}^{O}	Installation cost of distribution center k in period t (\$/ton)
PR_t^{mac}	Production rate per machine at the plant in period t (tons/machine)
$Cost_{mac}$	Purchasing cost of a machine at the plant (\$/machine)
$Price_{lt}$	Price of products at retailer l in period t (\$/ton)
$Penalty_{lt}$	Penalty cost of lost sales at retailer l in period t (\$/ton)
$FAPV_t$	Construction cost at the plant in period t (\$/m^2)
$FADV_{kt}$	Construction cost at distribution center k in period t (\$/m^2)
$FARV_{lt}$	Construction cost at retailer l in period t (\$/m^2)
dr	Depreciate rate (%)
$WACC$	Weighted average cost of capital (%)
D_{lt}	Customer demands at retailer l in period t (tons)
Q_t^{max}	Maximum capacity at supplier i to provide raw materials in period t (tons)
$size_t$	Size of the plant in period t (m^2/ton)
$size_{kt}$	Size of distribution center k in period t (m^2/ton)
$size_{lt}$	Size of retailer l in period t (m^2/ton)
FAP_t	Fixed asset value of the plant at the beginning of period t (\$)
FAD_{kt}	Fixed asset value of distribution center k at the beginning of period t (\$)
FAR_{lt}	Fixed asset value of retailer l at the beginning of period t (\$)
$investP_t$	Investment value for the extra space and machine capacity at the plant in period t (\$)
$investD_{kt}$	Investment value for the extra space of distribution center k in period t (\$)
$investR_{lt}$	Investment value for the extra space of retailer l in period t (\$)
Rev_t	Total revenue received from selling products at all retailers in period t (\$)
$Profit_t$	Total net profit calculated by subtracting total costs from the revenue in period t (\$)
TC_t^{Profit}	Summation of all costs in the profit maximization in period t (\$)
TC_t^{EVA}	Summation of all costs in the EVA maximization in period t (\$)
PC_t	Production cost at the plant in period t (\$)
RMC_t	Raw material cost transferred from supplier i to the plant in period t (\$)
HC_t	Total inventory holding cost at the plant, at all distribution centers, and at all retailers in period t (\$)
TLS_t	Total penalty cost of all retailers in period t (\$)
DPR_t	Total depreciation cost of all fixed assets at the end of period t (\$)
IC_t	Total invested capital of the plant, all distribution centers, and all retailers in period t (\$)
FDC_t	Total installation cost of all distribution centers in period t (\$)
$PROFIT$	Total net income in all periods (\$)
EVA	Total economic value added in all periods (\$)

Binary Decision Variables

Y_{it}	1 if supplier i is established, otherwise 0 in period t
Y_{kt}	1 if distribution center k is established, otherwise 0 in period t
L_{klt}	1 if the connection from distribution center k to retailer l is established, otherwise 0 in period t

A. Mathematical Notations (Con.)

Decision Variables

PR_t	Production level at the plant in period *t* (tons)
M_t^{int}	Integer number of machines at the plant in period *t* (machines)
M_t^{dec}	Decimal number of machines at the plant in period *t* (machines)
Cap_t	Size of the plant in period *t* (tons)
Cap_{kt}	Size of distribution center *k* in period *t* (tons)
Cap_{lt}	Size of retailer *l* in period *t* (tons)
S_{lt}	Amount of shortages at retailer *l* in period *t* (tons)
Q_{it}	Amount of materials transferred from supplier *i* to the plant in period *t* (tons)
Q_{kt}	Amount of products transferred from the plant to distribution center *k* in period *t* (tons)
Q_{klt}	Amount of products transferred from distribution center *k* to retailer *l* in period *t* (tons)
I_t	Inventory level of products at the plant at the end of period *t* (tons)
I_{kt}	Inventory level of products at distribution center *k* at the end of period *t* (tons)
I_{lt}	Inventory level of products at retailer *l* at the end of period *t* (tons)

B. Mathematical Notations

Objective Function

Two scenarios are considered: One focuses on the traditional profit metric, while the other delves into the assessment of Economic Value Added (EVA). With profit maximization, its objective function as presented in Equation (2) aims to maximize the profit by satisfying customer demand, subject to the total costs including the installation cost, the purchasing raw material cost, the transportation cost, the inventory holding cost, the production cost, and the shortage cost. The calculation of the maximization of Economic Value Added (EVA), as outlined in Equation (3), is calculated by subtracting the capital charge (WACC multiplied by invested capital) from the company's profit. In essence, it is a measure of how much value a company is generating above and beyond the cost of the capital that it employs in its operations.

$$PROFIT = \sum_{t=1}^{T}(Rev_t - TC_t^{Profit}) \tag{2}$$

$$EVA = \sum_{t=1}^{T}(Profit_t - WACC \times IC_t) \tag{3}$$

where:

$$Profit_t = \sum_{t=1}^{T}(Rev_t - TC_t^{EVA}) \tag{4}$$

Constraints

1) Revenue generated from the demand satisfaction is calculated by subtracting the revenue lost due to unmet demand (shortages) from all initial demands at the retailers and then multiplying with the selling price per ton, as expressed in Equation (5).

$$Profit_t = \sum_{l=1}^{R}(D_{lt} - S_{lt}) \times price_{lt}, \forall t \tag{5}$$

2) In the context of the profit maximization, the ordinary total costs encompass all associated expenses related to production, transportation, inventory holding, material procurement, installation of distribution centers, and shortage penalties, as stated in Equation (6). Additionally, the depreciation of all fixed assets has been included within the framework of maximizing Economic Value Added (EVA), as expressed in Equation (7).

$$TC_t^{Profit} = PC_t + TRC_t + HC_t + RMC_t + FDC_t + TLS_t, \forall t \tag{6}$$

$$TC_t^{EVA} = PC_t + TRC_t + HC_t + RMC_t + FDC_t + TLS_t + DPR_t, \forall t \tag{7}$$

3) The production cost at the plant is calculated by multiplying the units of products produced at the plant by the production cost per ton, as shown in Equation (8).

$$PC_t = \sum_{l=1}^{R} PR_t \times C_t^P, \forall t \tag{8}$$

4) Transportation cost comprises the cost of transporting materials from suppliers to the plant, products from the plant to distribution centers, and products from distribution centers to retailers, multiplied by the respective transportation cost per ton, as shown in Equation (9).

$$TRC_t = \sum_{i=1}^{S} C_{it}^{TR} \times Q_{it} + C_{kt}^{TR} \times Q_{kt} + \sum_{k=1}^{D} C_{klt}^{TR} \times Q_{klt}, \forall t, k, l \tag{9}$$

5) Inventory holding cost, representing the expenses incurred in storing products at the plant, distribution centers, and retailers, is calculated by multiplying their respective inventory holding cost per ton, as specified in Equation (10).

$$HC_t = \frac{I_{t-1} + I_t}{2} \times C_t^{HP} + \sum_{k=1}^{D} C_{kt}^{HD} \times \frac{I_{k(t-1)} + I_{kt}}{2} + \sum_{l=1}^{R} C_{lt}^{HR} \times \frac{I_{l(t-1)} + I_{lt}}{2}, \forall t \tag{10}$$

6) Raw material cost transferred from suppliers to the plant is determined by multiplying the quantity of raw materials by their respective purchasing price, as shown in Equation (11).

$$RMC_t = \sum_{i=1}^{S} C_{it}^{S} \times Q_{it}, \forall t \tag{11}$$

7) The installation cost is charged in each period when a distribution center operates, as detailed in Equation (12).

$$FDC_t = \sum_{k=1}^{D} C^{O}_{kt} \times Y_{kt}, \forall t \quad (12)$$

8) Depreciation cost is determined by multiplying all fixed asset values by the Depreciation rate (*dr*) at the end of period *t*, as detailed in Equation (13).

$$DPR_t = (FAP_t + \sum_{k=1}^{D} FAD_{kt} + \sum_{l=1}^{R} FAR_{lt}) \times dr, \forall t \quad (13)$$

9) Fixed asset values, encompassing the existing fixed asset values plus new invested values of facilities such as the production capacity, space of potential new distribution centers, and retailers, are represented in Equations (14) - (16).

$$FAP_t = FAP_{(t-1)} \times (1-dr) + investP_t, \forall t \quad (14)$$

$$FAD_{kt} = FAD_{k(t-1)} \times (1-dr) + investD_{kt}, \forall t,k \quad (15)$$

$$FAR_{lt} = FAR_{l(t-1)} \times (1-dr) + investR_{lt}, \forall t,l \quad (16)$$

Where:

$$investP_t = [Cap_t - Cap_{(t-1)}] \times FAPV_t \times size_t + M_t^{int} \times cost_{mac}, \forall t \quad (17)$$

$$investD_t = [Cap_{kt} - Cap_{k(t-1)}] \times FADV_t \times size_{kt}, \forall t \quad (18)$$

$$investR_t = [Cap_{lt} - Cap_{l(t-1)}] \times FARV_t \times size_{lt}, \forall t \quad (19)$$

Equation (17) determines the total plant investment, encompassing production machine capacity (assumed to be $100,000 for a machine) and the space investment cost within a specific period. This equation suggests additional capacity and space when the customer demand rises, with no investment required for constant or decreasing customer demands. Equations (18) - (19) calculate the space investment cost at the distribution centers and retailers. Facility sizing is estimated using a simplified assumption of one square meter of storage per one ton of product.

10) The capital investment is determined by summing the total fixed asset values at the plant, distribution centers, and retailers at the beginning of the period, as stated in Equation (20).

$$IC_t = FAP_t + FAD_{kt} + FAR_{lt}, \forall t,k,l \quad (20)$$

11) Each supplier has the maximum capacity of 20,000 tons to supply raw materials to the plant, as shown in Equation (21).

$$Q_{it} \le Q_t^{max} \times Y_{it}, \forall t,i \quad (21)$$

12) In each period, at least one supplier and one distribution center must be established as expressed in Equations (22) - (23). Furthermore, all retailers must be linked with at least one distribution center during each period, as shown in Equation (24). The connection between each distribution center and retailers is established, as shown in Equation (25). Lastly, it is imperative to ensure the continuity of distribution center operations throughout the designated design period, as shown in Equation (26).

$$\sum_{i=1}^{S} Y_{it} \ge 1, \forall t \quad (22)$$

$$\sum_{k=1}^{D} Y_{kt} \ge 1, \forall t \quad (23)$$

$$\sum_{k=1}^{D} L_{klt} \ge 1, \forall t, l \quad (24)$$

$$L_{klt} \le Y_{kt}, \forall t, k, l \quad (25)$$

$$L_{kt} \ge Y_{k(t-1)}, \forall t, k \quad (26)$$

13) Inventory balance at each node in the supply chain is calculated as the sum of the products that flow into the facility, adding the remaining products from the previous period, and then subtracting the products that flow out of the facility, as shown in Equations (27) - (29).

$$I_t = I_{j(t-1)} + PR_t - \sum_{k=1}^{D} Q_{kt}, \forall t \quad (27)$$

$$I_{kt} = I_{k(t-1)} + Q_{kt} - \sum_{l=1}^{R} Q_{klt}, \forall t,k \quad (28)$$

$$I_{lt} = I_{l(t-1)} + \sum_{k=1}^{D} Q_{klt} - (D_{lt} - LS_{lt}), \forall t,l \quad (29)$$

14) Suppliers are assumed to supply the raw materials immediately to the plant when it receives the order from the plant, as expressed in Equation (30).

$$PR_t = \sum_{i=1}^{S} Q_{it}, \forall t \quad (30)$$

15) The machine capacity at the plant, representing the required number of machines, is determined by dividing the production level in each period by the production rate per machine, which is set at 2,000 tons per machine per period (year), as stated in Equation (31). However, since the number of machines must be an integer, as described in Equations (32) - (35), several constraints are imposed. Equation (32) ensures that the minimum number of machines needed in each period is at least equal to the total production level divided by the production rate per machine. To prevent underestimation, Equation (33) sets an upper limit on the number of machines required by adding one extra machine to the calculation. Additionally, Equation (34) safeguards against reducing the required number of machines, even in the event of a decrease in customer demands. These equations collectively ensure sufficient machine capacity while accommodating variations in production levels and customer demands.

$$M_t^{dec} = \frac{PR_t}{PR_t^{mac}}, \forall t \quad (31)$$

$$M_t^{int} \geq M_t^{dec}, \forall t \quad (32)$$

$$M_t^{int} \leq M_t^{dec} + 1, \forall t \quad (33)$$

$$M_t^{\text{int}} \geq M_{t-1}^{int}, \forall t \quad (34)$$

16) Equation (35) specifies that the size of the plant must not decrease as compared to the previous period. Likewise, similar constraints are applied to the sizes allocated for the distribution centers and the retailers, as depicted in Equations (36) - (37).

$$Cap_t = max\left[PR_t, Cap_{t-1}\right], \forall t \quad (35)$$

$$Cap_{kt} = max\left[Q_{kt}, Cap_{k(t-1)}\right], \forall t, k \quad (36)$$

$$Cap_{lt} = max\left[\sum_k^D Q_{klt}, Cap_{l(t-1)}\right], \forall t, l \quad (37)$$

17) The penalty of shortages incurred due to the lost sales is calculated by multiplying the number of tons shortage by the shortage penalty cost per ton, as shown in Equation (38).

$$TLS_t = \sum_{l=1}^R S_{lt} \times penalty_{lt}, \forall t \quad (38)$$

18) The maximum size of each distribution center is limited to 20,000 tons, as indicated in Equation (39).

$$Cap_{kt} \leq 20,000, \forall t, k \quad (39)$$

19) Customer Service Level (CSL) ensures that all retailers must distribute a minimum quantity of products to their customers in each period. The study guarantees at least a 90% service level at all retailers, as expressed in Equation (40).

$$\sum_{k=1}^D Q_{klt} \geq 0.9 * D_{lt}, \forall t, l \quad (40)$$

20) Equation (41) ensures that the production level at the plant does not exceed the total customer demands for a given period, thereby aligning the production level with the customer demands.

$$PR_t \geq \sum_{l=1}^R D_{lt}, \forall t \quad (41)$$

21) Equations (42) - (47) are established to ensure that the values of all decision variables are non-negative, with some constraints to be integer or binary.

$$Q_{it}, Q_{kt}, Q_{klt} \geq 0, \forall i, k, l, t \quad (42)$$

$$I_t, I_{kt}, I_{lt} \geq 0, \forall k, l, t \quad (43)$$

$$PR_t, M_t^{int} \geq 0, \forall t \quad (44)$$

$$Y_{it}, Y_{kt}, Y_{klt} \in \{0,1\}, \forall i, k, l, t \quad (45)$$

$$S_{lt} \geq 0, \forall t, l \quad (46)$$

$$Cap_t, Cap_{kt}, Cap_{lt} \geq 0, \forall t, k, l \quad (47)$$

V. Case Study

A. Problem Description

A case study is constructed to illustrate and evaluate the effectiveness of the proposed MILP decision-making model in addressing a FSCND (Food Supply Chain Network Design) problem within a small-sized food industry in the Southern Region of Vietnam. The model aims to demonstrate the advantages of utilizing EVA over profit maximization. Following sorting at the supplier level, the raw materials are then transferred to the plant for processing. Here, they undergo a series of essential steps including washing, sorting, cutting, packaging, and labeling. Having been processed, the products are dispatched to Distribution Centers (DCs) for additional quality assessments and sorting, then distributed to retailers, who display and sell them to consumers.

In this study, seven districts in southern Vietnam are considered in the supply chain network. These districts comprise one plant located in Dong Thap, three distribution centers situated in Can Tho, Tien Giang, and Ho Chi Minh, and three retailers located in Tay Ninh, Binh Duong, and Soc Trang. The investigation focuses on the planning horizon of the proposed model, from January 2019 to December 2023, comprising five years. This location provides access to an abundant amount of food-based agriculture resources. There are three qualified suppliers, who supply raw materials at varying prices based on the quality. They consistently fulfill the requirements of the plant. Additionally, there are three potential distribution centers, and three retailers with varying demand levels across different locations, as depicted in Fig. 4.

This supply chain network structure can be segmented into three distinct stages. In the initial stage, the suppliers provide raw materials to the plant for product fabrication. Subsequently, in the second stage, products are requested from the plant by the distribution centers and then dispatched to the retailers in the third stage. Operations within this framework entail making numerous decisions throughout the supply chain network in both strategic and operational planning. These decisions encompass identifying the suppliers, and the potential distribution centers, determining the production level and the production capacity at the plant, as well as managing the sizes of the plant, distribution centers, and retailers.

B. Input Data and Cost Structure

The objective of this study is to examine the benefits of maximizing the Economic Value Added

(EVA) of the FSCND (Food Supply Chain Network Design) instead of solely focusing on maximizing the profit. Major costs are influenced by the supply chain network decisions, including raw material cost, production cost at the plant, transportation cost, inventory holding cost, installation cost of all potential distribution centers, penalty cost of shortages, and depreciation cost of the plant, distribution centers, and retailer's buildings and machines in FSCND. Total revenue is generated at all retailers by selling the products to customers. It is also assumed that shortages are permitted with the penalty cost, requiring all supply chain members to balance between enlarging the sizes of facilities and risking shortages to achieve optimal profitability while considering investment capital.

All data have been scaled with a common factor and presented on an average basis. There is one plant (P) that manufactures the products from raw materials supplied by three suppliers (S1, S2, S3). These products are intended to reach three retailers (R1, R2, R3) located in different locations to meet customer demands, facilitated through a network of three potential distribution centers (DC1, DC2, DC3). The problem entails finding the optimal three echelons in the FSCND configuration illustrated in Fig. 3, in a planning horizon of 5 periods (years). The requisite data for evaluating the model are provided in Tables II-VI. They display the transportation costs associated with deliveries from suppliers to the plant, from the plant to potential distribution centers, and from potential distribution centers to retailers. Transportation costs can vary depending on the distance between facilities while maintaining the assumption that these costs remain constant throughout the planning horizon. Table V shows the purchasing cost of raw materials at the supplier, while Table VI presents the customer demands at the retailers measured in tons per period across five distinct years. It shows that the fluctuation in the customer demands occurs from year to year, and there is a significant peak upward trend in the third year, followed by a decline and subsequent stabilization in the later years.

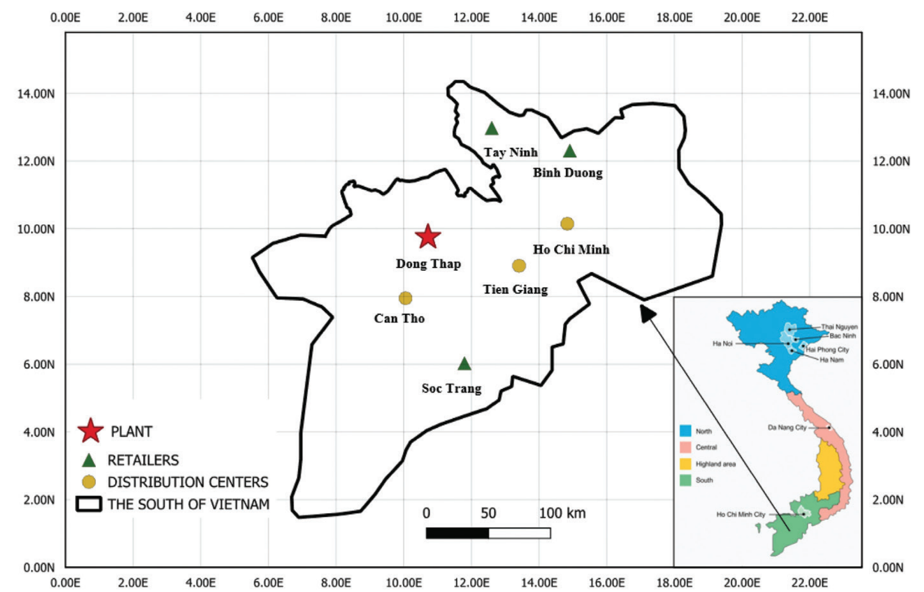

Fig. 4. The location of facilities in the southern region of Vietnam (QGIS)

TABLE II

Transportation Cost (C_l^{TR}) of Raw Materials from Suppliers to The Plant ($/ton)

Plant	Suppliers		
	S1	S2	S3
P	88.0	110.0	154.0

TABLE III

Transportation Cost (C_{kt}^{TR}) of Products from The Plant to Distribution Centers ($/ton)

Plant	Distribution Centers		
	DC1	DC2	DC3
P	176.0	154.0	110.0

TABLE IV

Transportation Cost of Products from Distribution Centers to Retailers (C_{lt}^{TR}) ($/tons)

Distribution Centers	Retailers		
	R1	R2	R3
DC1	176.0	167.2	173.8
DC2	154.0	165.0	132.0
DC3	121.0	110.0	88.0

TABLE V
PURCHASING COST OF RAW MATERIALS (C_{it}^{S}) AT SUPPLIERS ($/TON)

Suppliers		
S1	S2	S3
330	341	352

TABLE VI
CUSTOMER DEMAND (D_{lt}) AT EACH RETAILER PER YEAR (TONS/YEAR)

Retailers	Years				
	1	2	3	4	5
R1	6,500	7,700	8,500	7,000	7,000
R2	5,300	6,300	7,500	7,500	6,600
R3	5,000	6,000	7,000	6,000	6,500

TABLE VII
OTHER PARAMETERS (%)

Other Parameters	Rate
Weighted Average Cost of Capital *(WACC)*	0.1
Depreciation Rate *(dr)*	0.1
Customer Service Level *(CSL)*	0.9

Table VII outlines important parameters expressed as percentages. The Weighted Average Cost of Capital (WACC) signifies the average rate of return expected to be paid to investors for financing assets, indicated as 10%. The depreciation rate noted as 0.1, indicates a 10% fixed asset depreciated value annually. Additionally, Customer Service Level (CSL) of 0.9 represents the target to fulfill at least 90% of the customer demands promptly and satisfactorily within the supply chain operation.

The selling price ($price_{lt}$) is set at $2,200 per ton, with a corresponding shortage penalty cost the same as the selling price ($lostsale_{lt}$). The production cost is estimated at 18% of the selling price (C_t^P = $396) per ton, while the inventory holding cost is estimated at 20% of the selling price ($C_t^{HP} = C_{kt}^{HD} = C_{lt}^{HR}$ = $440) per ton per year. The installation cost (C_{kt}^{O}) would be incurred at any distribution center upon its opening at $600,000 per year. Acknowledging the importance of plant, distribution center, and retailer sizes in the capital investment and depreciation cost determination, this study has standardized the building construction cost for each member in the chain ($FAPV_t = FAPV_{kt} = FAPV_{lt}$ = $500 per square meter) with one ton per one square meter at the plant ($size_t$), distribution centers ($size_{kt}$), and retailers ($size_{lt}$).

VI. RESULTS AND DISCUSSIONS

The section is divided into two segments. The first segment outlines the outcomes resulting from the application of the previously described methodology to both models, within the framework of the case study conducted in the southern region of Vietnam. The second segment commences with a discourse on the disparities between profit and Economic Value Added (EVA) maximization. These differences are comprehensively illustrated in Tables VIII - XVII.

A. Profit and EVA Maximization

TABLE VIII
BINARY DECISION VARIABLES FOR SUPPLIERS SELECTION (Y_{it}) IN THE PROFIT AND EVA MAXIMIZATION

Suppliers	PROFIT			EVA		
	S1	S2	S3	S1	S2	S3
Year 1	1	0	0	1	0	0
Year 2	1	0	0	1	0	0
Year 3	1	1	0	1	0	0
Year 4	1	1	0	1	0	0
Year 5	1	1	0	1	0	0

Close=0, Open=1

TABLE IX
BINARY DECISION VARIABLES FOR POTENTIAL DISTRIBUTION CENTERS SELECTION (Y_{kt}) IN THE PROFIT AND EVA MAXIMIZATION

Distribution Centers	PROFIT			EVA		
	DC1	DC2	DC3	DC1	DC2	DC3
Year 1	0	0	1	0	0	1
Year 2	0	0	1	0	0	1
Year 3	0	1	1	0	0	1
Year 4	0	1	1	0	0	1
Year 5	0	1	1	0	0	1

Close=0, Open=1

During the five-year planning horizon, Supplier 1 (S1) emerges as the preferred choice across both models due to its combination of lower raw material price per ton and transportation expenses compared to Supplier 2 (S2) and Supplier 3 (S3), as indicated in Table VIII. For both models, each supplier's annual capacity is capped at 20,000 tons, as shown in Equation (17). Therefore, S2 will continue to supply raw materials once the plant's orders exceed S1's maximum capacity. As shown in Table VIII, S2 is selected in years 3, 4, and 5 for the case of profit maximization, but not for EVA maximization.

According to Table IX, DC3 consistently emerges as the preferred choice in both optimization models throughout the planning period. However, for the profit maximization, DC2 is chosen to open in years 3, 4, and 5. Conversely, for Economic Value Added (EVA) maximization, only DC3 is selected.

The decision to open DC2 for profit maximization reflects a focus on maximizing sales to drive profitability. It prioritizes the avoidance of shortages at the retailers by adding another distribution center to meet all demands. In contrast, for EVA maximization, the emphasis remains solely on DC3, possibly due to factors such as cost efficiency and overall fixed asset utilization in the long term, thereby ensuring optimal economic performance throughout the whole planning horizon.

TABLE X
DECISION VARIABLES FOR PRODUCTION LEVEL (PR_t) AT THE PLANT (TONS) IN THE PROFIT AND EVA MAXIMIZATION

Years	1	2	3	4	5
PR_t (PROFIT)	16,800	20,000	23,000	20,500	20,100
PR_t (EVA)	20,000	20,000	20,000	20,000	20,000

The Production level (PR) designated for each year in the profit maximization consistently aligns with the customer demand, as evidenced in Table X. The plant consistently meets the orders placed by the distribution centers, which receive orders from the retailers. This alignment between the production levels and the customer demands ensures that the supply chain operates efficiently and effectively, ultimately contributing to the maximization of profit.

In contrast, in the pursuit of Economic Value Added (EVA) maximization, the plant adheres to a different strategy, as presented in Table X. The plant is advised to manufacture quantities equal to or exceeding the orders from the distribution centers in the initial year, ensuring an inventory buffer for subsequent periods, as shown in Table XVII, considering the fluctuation and the trend of the demand predictions. This strategy empowers the plant to manage its production better during periods of heightened demand by leveraging prepared inventory from prior periods. Consequently, it minimizes the necessity for acquiring excessive machinery or expanding the space of the plant during peak periods, which would not be fully utilized when the demand recedes. Moreover, the production levels in each period are influenced by the selection of potential DCs and the sizes of these centers, as shown in Table XV.

TABLE XI
DECISION VARIABLES FOR MACHINE CAPACITY (M_t) AT THE PLANT (MACHINES) IN THE PROFIT AND EVA MAXIMIZATION

Years	1	2	3	4	5
M_t (PROFIT)	9	10	12	12	12
M_t (EVA)	10	10	10	10	10

In Table XI, the decision variables for the machine capacity are presented under both profit and EVA maximization scenarios across the five-year planning horizon. A comparison of machine capacity reveals notable differences between the two optimization objectives. Under the profit maximization, machine capacity fluctuates, reaching its peak in the third, fourth, and fifth years at 12 machines. In contrast, the EVA maximization maintains a constant machine capacity of 10 machines throughout the planning horizon. This divergence in machine capacity allocation underscores the strategic trade-offs between short-term profitability and long-term value creation. The decision to maintain a constant machine capacity under the EVA maximization suggests a focus on machine efficiency and avoidance of unnecessary capital expenditures.

TABLE XII
DECISION VARIABLES FOR AMOUNT TRANSFERRED FROM THE PLANT TO DISTRIBUTION CENTERS (TONS) (Q_{kt}) IN THE PROFIT MAXIMIZATION

	Plant (P)				
Years	1	2	3	4	5
DC1	-	-	-	-	-
DC2	-	-	3,000	500	100
DC3	16,800	20,000	20,000	20,000	20,000

TABLE XIII
DECISION VARIABLES FOR SIZES $(Cap_t, Cap_{kt}, Cap_{lt})$ AT THE PLANT, DISTRIBUTION CENTERS, AND RETAILERS (TONS) IN THE PROFIT MAXIMIZATION

Years	1	2	3	4	5
P	16,800	20,000	23,000	23,000	23,000
DC1	-	-	-	-	-
DC2	-	-	3,000	3,000	3,000
DC3	16,800	20,000	20,000	20,000	20,000
R1	6,500	7,700	8,500	8,500	8,500
R2	5,300	6,300	7,500	7,500	7,500
R3	5,000	6,000	7,000	7,000	7,000

TABLE XIV
DECISION VARIABLES FOR AMOUNT TRANSFERRED FROM THE PLANT TO DISTRIBUTION CENTERS (TONS) (Q_{kt}) IN THE EVA MAXIMIZATION

	Plant (P)				
Years	1	2	3	4	5
DC1	-	-	-	-	-
DC2	-	-	-	-	-
DC3	20,000	20,000	20,000	20,000	20,000

TABLE XV
DECISION VARIABLES FOR SIZES $(Cap_t, Cap_{kt}, Cap_{lt})$ AT THE PLANT, DISTRIBUTION CENTERS, AND RETAILERS (TONS) IN THE EVA MAXIMIZATION

Years	1	2	3	4	5
P	20,000	20,000	20,000	20,000	20,000
DC1	0	0	0	0	0
DC2	0	0	0	0	0
DC3	20,000	20,000	20,000	20,000	20,000
R1	6,500	7,700	8,200	8,200	8,200
R2	5,300	6,300	7,500	7,500	7,500
R3	5,000	6,000	7,000	7,000	7,000

TABLE XVI
DECISION VARIABLES FOR STORAGES (S_{lt})
AT RETAILERS (TONS)
IN THE PROFIT AND EVA MAXIMIZATION

Retailers	PROFIT			EVA		
	R1	R2	R3	R1	R2	R 3
Year 1	-	-	-	-	-	-
Year 2	-	-	-	-	-	-
Year 3	-	-	-	300	-	-
Year 4	-	-	-	-	-	-
Year 5	-	-	-	100	-	-

The size allocation within the supply chain network during the five years for profit maximization is illustrated in Table XIII, where the size at the Plant (P), Distribution Centers (DC1, DC2, DC3), and Retailers (R1, R2, R3) are detailed.

The capacities are adjusted to increase when the demand increases and remain the same when the demand drops. The significant observation lies in the size management of Distribution Center 2 (DC2). Despite the gradual decrease in the quantity stored in this center since its first year of operation (year 3) as indicated in Table XIII, attributed to a decline in total customer demands, it is noteworthy that the center still maintains a size of 3,000 tons.

The size allocation within the supply chain network during five years for EVA maximization is illustrated in Table XV. The size at the Plant (P), Distribution Centers (DC1, DC2, DC3), and Retailers (R1, R2, R3) are presented.

There is a notable disparity compared to the profit maximization, where DC3 consistently operates at the maximum size and the plant remains stable at a size of 20,000 tons regardless of fluctuations in total customer demands at the retailers.

The profit maximization model focuses solely on maximizing the profit, disregarding investment and depreciation costs. As demonstrated in Tables XVI-XVII, this model does not consider the necessity for holding remaining inventory or allowing shortages. Conversely, EVA maximization model indicates the potential for some shortages when the size of DC3 reaches its limitation. Adding a new distribution center might not always be beneficial, since the additional costs could outweigh the gains.

TABLE XVII
DECISION VARIABLES FOR INVENTORY HOLDING (I_t, I_{kt}, I_{lt}) (TONS)
IN THE PROFIT AND EVA MAXIMIZATION

	Plant		Distribution Centers						Retailers					
	PROFIT	EVA	PROFIT			EVA			PROFIT			EVA		
	P	P	DC1	DC2	DC3	DC1	DC2	DC3	R1	R2	R3	R1	R2	R3
Year 1	-	-	-	-	-	-	-	3,200	-	-	-	-	-	-
Year 2	-	-	-	-	-	-	-	3,200	-	-	-	-	-	-
Year 3	-	-	-	-	-	-	-	500	-	-	-	-	-	-
Year 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Year 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-

B. Comparison between the Profit and EVA Maximization

TABLE XVIII
THE COMPARATION
BETWEEN EVA AND THE PROFIT MAXIMIZATION ($)

Objective	PROFIT	EVA
	$45,868,200	$19,556,832
Comparison	EVA	PROFIT
	$16,717,138	$45,468,200
Other Costs:		
Revenue (*Rev*)	$220,880,000	$220,000,000
Production Cost (*PC*)	$39,758,400	$39,600,000
Raw Material Cost (*RMC*)	$33,171,600	$33,000,000
Transportation Cost (*TRC*)	$31,017,800	$30,533,800
Installation Cost (*FDC*)	$4,800,000	$3,000,000
Inventory Holding Cost (*HC*)	$66,264,000	$67,518,000
Penalty Shortage (*TLS*)	$0	$880,000
Invested Capital (*IC*)	$145,755,310*	$129,556,840
Depreciation Cost (*DPR*)	$14,575,531*	$12,955,684

*Not applicable for the profit calculation (only for illustration)

The interpretation underscores the distinction between the profit and EVA maximization in decision-making processes concerning various variables, including suppliers and distribution centers selection, production level and machine capacity at the plant, shortages at retailers, sizes of the plant, distribution centers, and retailers. The comparison aims to highlight that EVA maximization offers more advantages than solely focusing on profit maximization. While profit maximization primarily concentrates on optimizing revenue while minimizing costs to boost profitability, EVA maximization in addition considers invested capital and depreciation, as shown in Table XVIII. This underscores the importance of considering factors beyond revenue and total costs alone, as they directly influence the objective. Ignoring these aspects may appear advantageous in the short term but could lead to erroneous decisions and increased financial losses over the long term.

These highlights underscore the advantages of employing Economic Value Added (EVA) maximization over profit maximization.

1. EVA prioritizes not just minimizing total costs, but also factoring in facility and machinery investment costs. This approach suggests opening only DC3 and operating it at full capacity at the distribution center. This is to avoid unnecessary expansion during the demand surges that would not be sustainable in the long term if the future demand drops. For example, as seen in Table XII, the profit maximization model suggests opening another Distribution Center (DC2) when the demand exceeds the maximum size of DC3. Nevertheless, the customer demand shows a gradual decline starting from year 3, resulting in DC2 not being fully utilized after year 3.

2. At the plant, the EVA maximization model recommends setting production levels that could match or exceed the customer demands to maintain some inventory buffers, as shown in Table XVII. This approach enables efficient production management during the peak demand period by utilizing inventory reserves from earlier periods. As a result, it leads to minimize the need for increased the number of machines as well as plant expansion during the high demand period, which could be not fully utilized once the future customer demands at the retailers drop.

3. It illustrates the substantial benefits of EVA maximization in the capital utilization compared to profit maximization, as shown in Table XVIII. Particularly, the EVA maximization model facilitates the lower investment capital in the fixed assets. Instead of allocating $145,755,310 under profit maximization, the EVA maximization model suggests an allocation of only $129,556,840, with a seemingly minimal difference in the achieved profitability. This highlights an importance of considering all economic values, not only operational costs in the supply chain, as overlooking them can lead to inefficient allocation of the fixed assets.

In conclusion, in terms of considering the investment and utilization of facilities within the supply chain network, EVA optimization offers valuable insights by integrating various factors and fostering connections across the chain. It recognizes the interdependence of different elements within the supply chain such as inventory, invested capital, shortage, and other costs. By doing so, EVA optimization ensures that decisions, regarding size allocation and resource utilization, are aligned with broader supply chain objectives in the long term. This holistic approach reinforces the interconnectedness of the supply chain network, preventing it from solely focusing on the immediate profit.

VII. Conclusion

In this study, we employed Mixed-Integer Linear Programming (MILP) for the optimal design of activities within a food supply chain network design. This approach has been applied to a real case study where agricultural regions of South Vietnam have been considered. The case study was based on the production of food from the raw materials available. The primary objective was to highlight the benefits of employing Economic Value Added (EVA) to determine the optimal operating conditions of the analyzed supply chain, aiming for maximizing long-term economic income, as opposed to the conventional approach of maximizing profit commonly utilized in most studies. The optimal results derived from the profit maximization model might lead to underutilized capacities of facilities, resulting in a waste of resources and missed opportunities. This could potentially cause incorrect operational assessments and have adverse effects on long-term strategic planning. Consequently, the proposed EVA emerges as a valuable decision-making tool in practice. EVA maximization impresses crucial importance on the company's wealth assessment, particularly about the allocation of invested capital. This allocation directly impacts on the production levels and capacity at the plant, the selection of suppliers and distribution centers, as well as the sizes at distribution centers and retailers, all while considering shortages.

The primary limitation of our case study lies in the assumption of deterministic data, which may lead to imprecise results when applied to real-world scenarios. Decision-makers should prioritize the acquisition and utilization of data based on true judgment regarding past resources. Furthermore, future researchers are encouraged to incorporate uncertain data into the models to better align with practical applications and improve the robustness of the analyzes.

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