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A Computational Optimization Framework for the Integration of FinTech into Supply Chain Management

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Abstract
This study develops an integrated optimization framework that links supply chain operations with FinTech-based financing mechanisms in order to jointly manage physical and financial flows. A linear programming model is proposed to combine inventory management decisions with two major supply chain finance instruments: dynamic discounting and reverse factoring. The objective is to minimize the total system cost, including purchasing, holding, shortage, and financing costs, under deterministic demand and liquidity constraints.
The model is implemented and solved using IBM ILOG CPLEX Optimization Studio. Computational experiments conducted on a set of representative benchmark instances demonstrate that the proposed framework ensures full demand satisfaction while maintaining zero inventory and backorders in the absence of fixed ordering costs. The results further highlight an optimal allocation between early payment and bank financing, where dynamic discounting is utilized up to the available liquidity budget and reverse factoring covers the remaining financing needs.
The findings confirm that liquidity constraints significantly influence financing strategies and working capital allocation. By integrating FinTech mechanisms into operational decision-making, the model improves financial efficiency without compromising operational performance. This research contributes to the literature at the intersection of Operations Research, supply chain management, and digital finance by providing a tractable and practically applicable decision-support framework.

Keywords : Supply Chain Management, Supply Chain Finance, FinTech Optimization, Working Capital Management.

1. Introduction

In recent years, supply chains have undergone profound transformations driven by digitalization, globalization, and increasing financial constraints [1] [2]. While traditional supply chain management (SCM) research has primarily focused on optimizing physical flows—such as procurement, production, and distribution—growing attention is now being directed toward the management of financial flows within supply networks [3]. The increasing importance of working capital efficiency, liquidity management, and risk mitigation has led to the emergence of Supply Chain Finance (SCF) as a strategic domain bridging operations and finance.
Concurrently, the rapid development of Financial Technology (FinTech) has introduced innovative digital solutions that reshape inter-organizational financial interactions. Mechanisms

such as dynamic discounting and reverse factoring enable firms to improve liquidity allocation, reduce financing costs, and enhance supplier stability through digital platforms. These instruments facilitate closer synchronization between operational transactions and financial settlements, contributing to greater transparency and efficiency across supply chains.

Despite the growing relevance of SCF and FinTech solutions, most existing studies treat operational and financial decisions separately. Classical inventory and lot-sizing models optimize order quantities and stock levels without explicitly incorporating financing mechanisms, while financial studies often analyze liquidity and credit decisions independently of operational constraints [4]. This separation limits the ability of firms to fully exploit digital financing opportunities within operational planning frameworks.

To address this gap, this study proposes an integrated optimization model that simultaneously considers inventory management and FinTech-based financing decisions [5]. The model incorporates dynamic discounting and reverse factoring within a linear programming framework under deterministic demand. By jointly optimizing ordering, inventory, and payment strategies, the approach enables a comprehensive evaluation of how digital financing instruments influence total system cost and working capital allocation [6].

The model is implemented and solved using IBM ILOG CPLEX Optimization Studio, and computational experiments are conducted on a set of representative benchmark instances inspired by classical inventory control literature. The results demonstrate that integrating FinTech mechanisms into operational planning enhances financial efficiency while preserving operational performance. In particular, the findings highlight the critical role of liquidity constraints in shaping financing strategies and confirm the complementarity between early payment and bank financing mechanisms.

This research contributes to the literature at the intersection of Operations Research, supply chain management, and digital finance. It provides a tractable analytical framework that bridges physical and financial decision-making and offers managerial insights into the optimal deployment of FinTech solutions in supply chains. The remainder of the paper is organized as follows: Section 2 presents the theoretical background, Section 3 introduces the mathematical model, Section 4 describes the computational experiments, Section 5 discusses the results, and Section 6 concludes with managerial implications and future research directions.

2. Theoretical Foundations

2.1 Integrated Flow Theory and Global Supply Chain Performance

Supply chain performance fundamentally depends on the coordinated alignment of physical, informational, and financial flows. According to [7] and [8], Supply Chain Management should not be viewed merely as a system of transportation and warehousing, but rather as an integrated network in which goods, data, and financial resources circulate simultaneously. Physical flows refer to the movement of raw materials, components, and finished products. Informational flows involve the transmission of data related to orders, forecasts, traceability, and compliance. Financial flows include payments, working capital financing, credit management, and risk coverage [1].

In this framework, overall supply chain performance can be expressed as a joint function of these three interdependent flows:

$$Performance_{SC} = f(Physical\ Flows, Information\ Flows, Financial\ Flows)$$

This relationship highlights that any misalignment or disruption in one flow can destabilize the entire system. For instance, when financial flows are not synchronized with physical deliveries, such as in the case of delayed payments, suppliers may experience liquidity constraints that limit their capacity to invest, produce, and deliver efficiently. These imbalances increase the cash conversion cycle and weaken operational continuity. [9] emphasize that extended payment periods and inefficient cash management are major sources of financial vulnerability in supply chains.

Intelligent digitalization enables real-time synchronization between operational and financial processes. Technologies such as integrated platforms, application programming interfaces (APIs), Internet of Things devices, and blockchain systems allow financial transactions to be automatically triggered by verified logistical events, such as delivery confirmation or quality approval. [10] argue that such real-time integration enhances supply chain resilience by enabling rapid adaptation to disruptions and improving decision-making accuracy. Consequently, integrated flow theory provides a fundamental conceptual basis for understanding how FinTech solutions strengthen coordination, transparency, and efficiency in modern supply chains.

2.2 Transaction Cost Theory and the Role of Blockchain

Transaction Cost Theory, developed by [11], explains that economic organizations aim to structure their relationships in ways that minimize the costs associated with negotiating, monitoring, and enforcing contracts. In traditional supply chains, these transaction costs are often substantial due to geographical dispersion, organizational complexity, and information asymmetry among partners. Activities such as manual document verification, repeated audits, dispute resolution, and payment follow-ups significantly increase administrative and operational expenses [12].

These costs are further amplified by environmental uncertainty, contractual incompleteness, and opportunistic behavior. Firms may strategically delay payments, manipulate information, or renegotiate contractual terms to improve their short-term position, thereby increasing monitoring and enforcement requirements. As a result, supply chain relationships often rely on costly control mechanisms and intermediaries.

Blockchain technology and smart contracts provide structural solutions to these inefficiencies [13]. [14] argue that blockchain significantly reduces verification and networking costs by establishing a shared, immutable, and transparent ledger accessible to all authorized participants. This eliminates the need for repeated reconciliations and external audits.

Smart contracts automate contractual execution by enforcing predefined conditions without human intervention. For example, once a delivery is digitally validated, payment can be automatically released. This automation reduces administrative burdens, limits human error, and constrains opportunistic behavior. Recent empirical studies by [15] and [16] demonstrate that blockchain adoption in supply chain finance enhances transaction transparency and lowers financing costs by strengthening inter-organizational trust. From a transaction cost perspective, FinTech technologies therefore function as institutional mechanisms that improve governance efficiency and stabilize long-term supply chain relationships.

2.3 Information Asymmetry Theory and Alternative Credit Scoring

Information asymmetry theory, introduced by [17] in his seminal work on “The Market for Lemons,” highlights the negative consequences that arise when one party possesses superior information in market transactions. Such asymmetries lead to adverse selection, credit rationing, and market inefficiencies, disproportionately affecting high-quality but poorly documented participants.

Within supply chains, this problem is particularly acute for small and medium-sized supplier firms. These enterprises often lack formal financial histories, credit ratings, and access to capital markets. Consequently, financial institutions perceive them as high-risk borrowers and impose unfavorable lending conditions or deny credit altogether. [18] emphasize that this financial exclusion weakens supply chain stability by increasing the likelihood of supplier failures and delivery disruptions.

FinTech solutions based on artificial intelligence and alternative data analytics help mitigate information asymmetry by leveraging non-traditional data sources. These include logistics performance indicators, transaction histories, ERP records, delivery reliability metrics, and operational stability measures. By integrating these data into predictive models, lenders can

assess creditworthiness based on actual operational behavior rather than solely on financial statements.

[19] show that machine learning-based scoring models significantly improve risk prediction accuracy in uncertain and data-scarce environments. Credit scores thus become multidimensional, reflecting delivery punctuality, volume stability, quality compliance, and transactional consistency. This approach reduces adverse selection and promotes financial inclusion among SMEs.

At a systemic level, reducing information asymmetry strengthens supply chain resilience by preventing liquidity shortages, limiting risk propagation, and fostering sustainable inter-firm cooperation. Consequently, alternative scoring mechanisms represent a central pillar in the financial digitalization of supply chains.

3. FinTech Technologies Integrated into Supply Chain Management

3.1 Digital Supply Chain Finance (SCF 4.0)

Digital Supply Chain Finance represents an advanced evolution of traditional working capital management practices by leveraging digital platforms, real-time data integration, and automated decision systems. Unlike conventional supply chain finance models, which rely heavily on manual verification and bilateral agreements, SCF 4.0 is characterized by platform-based ecosystems that connect buyers, suppliers, financial institutions, and logistics providers within a unified digital infrastructure. According to [9], such digitalization enhances financial transparency and facilitates more efficient risk-sharing mechanisms across supply chain partners.

One of the most prominent instruments within digital SCF is automated reverse factoring. In this mechanism, the buying firm validates the supplier's invoice through an integrated enterprise system. This validation triggers the FinTech platform to initiate early payment through a partner financial institution, which transfers funds directly to the supplier. The buying firm subsequently reimburses the bank at the contractual maturity date. This process significantly reduces administrative delays and information asymmetries while strengthening trust among stakeholders. Empirical evidence suggests that automated reverse factoring shortens the cash conversion cycle, stabilizes supplier liquidity, and mitigates the risk of supply disruptions [18].

In parallel, algorithmic dynamic discounting has emerged as a sophisticated pricing mechanism for early payment incentives. Instead of applying fixed discount rates, FinTech platforms employ optimization algorithms that determine optimal discount levels based on time to maturity, capital costs, and perceived risk. This mechanism can be represented as:

$$Discount = f(t, Cost_{capital}, Risk)$$

By continuously adjusting discount rates, firms can balance profitability objectives with liquidity provision. Buyers benefit from higher returns on excess cash, while suppliers gain flexible access to short-term financing. According to [20] and [21], dynamic discounting improves working capital efficiency and fosters long-term cooperative relationships within supply networks. Consequently, SCF 4.0 contributes not only to financial optimization but also to strategic supply chain stability.

3.2 Blockchain Technology and Smart Contracts

Blockchain technology constitutes a foundational infrastructure for enhancing transparency, security, and trust in supply chain financial transactions. By providing a decentralized and immutable ledger, blockchain enables stakeholders to record, verify, and share transaction data without relying on centralized intermediaries. This feature is particularly valuable in complex global supply chains characterized by multiple contractual layers and heterogeneous regulatory environments [22].

A core application of blockchain in supply chain finance is the implementation of smart contracts, which are self-executing digital protocols that automatically enforce contractual

terms when predefined conditions are met. For instance, when Internet of Things sensors confirm the arrival of goods at a destination and verify compliance with quality standards, the smart contract validates the transaction and releases payment automatically. This integration between physical monitoring and digital finance reduces settlement delays, minimizes human intervention, and eliminates redundant verification processes.

Recent empirical studies demonstrate that blockchain adoption improves inter-organizational trust by enhancing data integrity and auditability. [15] show that improved transaction transparency lowers corporate financing costs by reducing information risk. Similarly, [16] identifies blockchain-enabled documentation systems as key drivers for mitigating fraud and operational disputes in supply chain finance. These findings indicate that blockchain acts as an institutional trust mechanism that reduces dependency on costly governance structures and enhances contractual efficiency.

3.3 Artificial Intelligence and Alternative Credit Scoring

Artificial intelligence and machine learning technologies play a central role in transforming credit assessment processes within digital supply chains. Traditional credit evaluation models primarily rely on financial statements, collateral availability, and historical repayment records, which often disadvantage small and medium-sized enterprises. In contrast, FinTech-driven scoring systems integrate operational and behavioral data derived from logistics and transactional systems.

These models analyze variables such as delivery reliability, compliance rates, shipment delays, transportation performance, and transaction stability. By processing large-scale heterogeneous datasets, machine learning algorithms identify complex nonlinear relationships between operational behavior and financial risk. Creditworthiness can thus be expressed as a multidimensional function:

$$Score = \alpha(Logistical\ Performance) + \beta(Payment\ History) + \gamma(Volatility)$$

[19] and [23] demonstrate that AI-based scoring models significantly enhance risk prediction accuracy, particularly in environments characterized by data scarcity and uncertainty. This improved precision enables financial institutions to offer tailored financing solutions to previously underserved suppliers, thereby promoting financial inclusion.

Furthermore, predictive analytics allow buyers and financiers to detect early warning signals of supplier distress, enabling proactive risk mitigation strategies. This shift from reactive to preventive risk management enhances supply chain resilience and reduces the likelihood of cascading disruptions.

3.4 Internet of Things and Parametric Insurance

The Internet of Things constitutes a critical enabler of real-time monitoring and risk management in digital supply chains. IoT devices embedded in containers, vehicles, and storage facilities continuously collect data on temperature, humidity, vibration, shock, and geographical position. These data streams provide unprecedented visibility into transportation and storage conditions, particularly for sensitive products such as pharmaceuticals, food, and high-value electronics [24].

When integrated with FinTech platforms, IoT data supports the development of parametric insurance schemes, in which compensation is automatically triggered when predefined thresholds are breached. For example, if temperature sensors detect a cold-chain violation beyond acceptable limits, the insurance system immediately initiates indemnification without requiring manual claims processing. This automation reduces administrative costs, accelerates compensation, and minimizes disputes between insurers, carriers, and shippers.

According to [25], IoT-enabled insurance models significantly reduce moral hazard and information manipulation by providing objective, tamper-resistant data. Moreover, predictive analytics based on sensor data allows insurers and logistics operators to anticipate risks and

implement preventive measures. As a result, IoT-driven parametric insurance contributes to a more transparent, responsive, and resilient supply chain risk management framework.

4. Model Hypotheses

H1: Deterministic Demand Hypothesis
Customer demand is assumed to be known with certainty and constant within each planning period, allowing the firm to optimize ordering and financing decisions under deterministic conditions.

H2 : Integrated Financing Hypothesis
The buyer finances each invoice using a combination of dynamic discounting and reverse factoring, subject to liquidity constraints, in order to minimize total operational and financial costs.

H3 : Rational Cost-Minimization Hypothesis
All decision-makers are assumed to behave rationally and aim to minimize the total system cost by optimally balancing inventory, shortage, and financing expenses.

5. Mathematical Model: Joint Optimization of Ordering and FinTech-Based Financing

4.1 Sets

T={1,…,H}: set of planning periods.

4.2 Parameters

$D_t \geq 0$: demand to be satisfied in period (t ∈ T).
c>0: unit purchasing cost.
h ≥ 0: unit holding cost per period.
p ≥0: unit backorder (shortage) penalty per period.
$I_0 \geq 0$: initial inventory level.
r ≥ 0: financing interest rate (reverse factoring) per period.
$\delta \in [0,1]$: discount rate for early payment (dynamic discounting).
$\overline{Y_t} \geq 0$: maximum early payment budget in period (t) (optional).

4.3 Decision Variables

Operational Decisions (SCM)
$x_t \geq 0$: order quantity in period (t).
$I_t \geq 0$: ending inventory in period (t).
$B_t \geq 0$: backorder level in period (t).
Financial Decisions (FinTech)
$y_t \geq 0$: amount paid in advance through dynamic discounting in period (t).
$z_t \geq 0$: amount financed through reverse factoring in period (t).

4.4 Constraints

4.1.1 Inventory Balance

$$I_t - B_t = I_{t-1} - B_{t-1} + x_t - D_t \qquad \forall t \in T$$

with I_0 given and (B_0=0).

4.1.2 Invoice Coverage Constraint

The invoice generated by order x_t is equal to cx_t. This invoice must be fully covered by the two FinTech-based payment mechanisms:

$$y_t + z_t = cx_t \qquad \forall t \in T$$

4.1.3 Early Payment Budget Constraint (Optional)

$$y_t \leq \overline{Y_t} \qquad \forall t \in T$$

4.5 Objective Function

Minimize the total system cost, including purchasing, inventory holding, shortage, financing cost, and early payment discount:

$$\min \sum_{t \in T} (cx_t + hI_t + pB_t + rz_t - \delta y_t)$$

4.6 Domain

$$x_t, I_t, B_t, y_t, z_t \geq 0 \qquad \forall t \in T$$

This model aims to integrate operational and financial decision-making within a unified Supply Chain Management–FinTech framework. It considers a single-supplier, multi-period system in which a firm must satisfy known demand while optimizing both its ordering and payment strategies.

At each period, the firm determines the order quantity and manages inventory and backorders to ensure service continuity. Simultaneously, it decides how to finance its purchases using two FinTech-based mechanisms: early payment with dynamic discounting and reverse factoring. The invoice generated by each order is fully covered by these two payment options, which directly links operational decisions to financial choices.

The objective of the model is to minimize the total system cost, including purchasing, holding, shortage, and financing costs, while accounting for the financial benefits of early payment discounts. By jointly optimizing logistics and financing decisions, the model highlights the interdependence between supply chain operations and digital financial solutions.

Overall, this formulation provides a simple yet effective analytical tool to evaluate how FinTech-based financing mechanisms influence supply chain performance and working capital efficiency.

4.7 Verification of Model Linearity

The proposed model belongs to the class of linear programming problems, as both the objective function and all constraints are formulated exclusively as linear combinations of the decision variables. According to the fundamental principles of linear programming established by [26] and [27], a model is considered linear when all mathematical relationships involve constant coefficients multiplying the variables, without introducing products between variables or nonlinear functions. In the present formulation, purchasing, holding, shortage, and financing costs are expressed as proportional terms of the corresponding decision variables, which ensures their linear structure.

Similarly, the inventory balance and invoice coverage constraints are written as linear equalities directly linking ordering, inventory, and payment variables. No quadratic, exponential, or logarithmic expressions are introduced, and all parameters are assumed to be constant and independent of the decision variables. This formulation satisfies the linearity conditions described by [28], confirming that the problem belongs to the class of continuous linear programs.

Due to this property, the model can be efficiently solved using exact algorithms such as the simplex method or interior-point methods, which guarantee the attainment of a global optimal solution for realistically sized instances [27]. Linearity therefore constitutes a major strength of the proposed formulation, as it ensures computational tractability, reproducibility, and practical applicability in real-world supply chain environments.

5. Methodology

This study adopts a quantitative and analytical approach based on linear optimization to investigate the interaction between supply chain operations and FinTech-based financing mechanisms. An integrated mathematical model combining inventory management with dynamic discounting and reverse factoring is developed under deterministic demand assumptions. The model captures both physical and financial flows by jointly optimizing ordering, inventory, and payment decisions. It is implemented and solved using IBM ILOG CPLEX Optimization Studio through its Python interface (DOcplex), which applies exact linear programming algorithms to obtain globally optimal solutions.

Due to the absence of publicly available benchmark datasets specifically designed for FinTech-enabled supply chain finance, a set of small-size synthetic instances is constructed based on classical inventory control and lot-sizing models reported in the literature [29] [30]. The demand patterns and cost parameters are generated within realistic ranges inspired by empirical

and analytical studies on supply chain finance and working capital management [9]. FinTech-related parameters, including discount rates and financing interest rates, are calibrated according to existing studies on dynamic discounting and reverse factoring mechanisms [18].
To evaluate the impact of digital financing instruments, several comparative scenarios are analyzed, including a baseline configuration without FinTech mechanisms and alternative settings incorporating early payment, bank financing, or a combination of both. Model validity is ensured through feasibility and consistency checks, such as inventory balance verification and full invoice coverage. Performance is assessed using multiple indicators, including total system cost, order quantities, inventory and backorder levels, and working capital utilization. This experimental framework enables a systematic assessment of how FinTech-based financing affects operational efficiency and financial performance in supply chains.

❖ **Source of Benchmark Instances**

Due to the absence of publicly available benchmark datasets specifically designed for FinTech-enabled supply chain finance, this study relies on a synthetic small-size benchmark inspired by classical inventory control and lot-sizing instances reported in the literature. The demand patterns and cost structures are generated based on well-established models in inventory management and production planning, such as the Wagner–Whitin framework [29] and its subsequent extensions [30]. In addition, parameter ranges for holding costs, shortage penalties, and purchasing costs are aligned with empirical and analytical studies on supply chain finance and working capital management [9]. FinTech-related parameters, including discount rates and financing interest rates, are calibrated according to recent studies on dynamic discounting and reverse factoring mechanisms [18]. This benchmark therefore reflects realistic operational and financial conditions while ensuring computational tractability for numerical experiments.

6. Analysis of Results

The results in table 1 indicate that, for all instances, the optimal order quantities exactly match period demand, leading to zero inventory and zero backorders. This behavior is consistent with deterministic lot-sizing models without fixed ordering costs, in which holding inventory generates unnecessary expenses and firms adopt a just-in-time replenishment policy. According to [29], when demand is known in advance and replenishment is instantaneous, the optimal strategy consists of synchronizing production and demand to avoid inventory accumulation. Similar conclusions are reported by [30], who emphasize that deterministic inventory systems tend to operate with minimal stock levels when holding costs are positive. Therefore, the operational structure observed in this study is theoretically sound and aligned with classical inventory management principles.

Table 1: Optimal Results for Test Instances

Instance	Objective Value	$\bar{Y}$ (Budget)	$\bar{x}$ (Average Order)	$\bar{y}$ (Early Payment)	$\bar{z}$ (Reverse Factoring)	Inventory (I)	Backorders (B)
Small_1	1942.38	235.44	43.6	235.44	156.56	0	0
Small_2	2937.33	356.40	59.4	356.40	237.60	0	0
Small_3	3488.63	423.72	64.2	423.72	282.48	0	0
Small_4	4394.12	534.24	74.2	534.24	356.96	0	0
Small_5	2411.70	292.80	48.8	292.80	195.20	0	0
Small_6	2395.82	290.52	53.8	290.52	193.28	0	0
Small_7	3769.67	458.04	69.4	458.04	305.16	0	0

Notes:
$\bar{x}$, $\bar{y}$, $\bar{z}$ represent average values over five periods.
I and B denote final inventory and backorders.

❖ **Financial Allocation and FinTech Mechanisms**

From a financial perspective, the results show a systematic prioritization of early payment through dynamic discounting up to the available budget limit. In all instances, the variable (y_t) reaches its maximum admissible value, indicating that firms exploit early payment discounts

whenever internal liquidity is available. This finding is consistent with the analysis of [21], who shows that early payment mechanisms are preferred when discount rates exceed short-term financing costs. Furthermore, the remaining portion of each invoice is financed through reverse factoring (z_t), which reflects a hybrid financing strategy combining internal and external resources. [18] argue that such hybrid structures are central to modern supply chain finance systems, as they allow firms to balance liquidity constraints and financing costs efficiently.

❖ **Role of Liquidity Constraints**

The early payment budget plays a central role in shaping financial decisions. Instances with higher budgets rely more heavily on dynamic discounting, while those with limited liquidity resort more intensively to reverse factoring. This behavior supports the conclusions of [31], who demonstrate that liquidity availability is a key determinant in the adoption of supply chain finance solutions. Similarly, [9] highlight that financial constraints strongly influence the selection of FinTech instruments in inter-organizational networks. The results therefore confirm that budget constraints act as a structural driver of financial decision-making in supply chains.

❖ **Economic Performance**

The objective function values increase with demand volume and purchasing costs, reflecting the combined impact of procurement and financing expenses. This monotonic relationship is economically intuitive and has been widely documented in integrated operational–financial models [9]. Moreover, the rapid convergence of CPLEX after presolve indicates that the proposed formulation is computationally efficient and well-structured. According to [28], linear programming models with limited dimensionality typically exhibit strong tractability, which explains the fast resolution observed in this study. This confirms the practical applicability of the proposed framework in decision-support contexts.

❖ **Validation with Existing Literature**

Overall, the observed results are consistent with established findings in inventory management and supply chain finance research. The absence of inventory and backorders aligns with deterministic planning models [29] [30], while the prioritization of early payment followed by reverse factoring corresponds to the financial optimization logic described by [18] and [21]. In addition, the balanced use of internal and external financing supports the theoretical arguments of [31] regarding optimal financing portfolios in supply chains. Consequently, the empirical outcomes of this study provide strong validation for the proposed integrated optimization model.

7. Conclusion

This study proposed an integrated optimization framework combining supply chain operations and FinTech-based financing mechanisms in order to jointly manage physical and financial flows. By developing a linear programming model that incorporates inventory management, dynamic discounting, and reverse factoring, the research addressed the growing need for coordinated operational and financial decision-making in digitalized supply chains.

The computational results obtained on a set of representative benchmark instances demonstrate that the proposed model ensures full demand satisfaction while maintaining zero inventory and backorders under deterministic conditions. This confirms the operational efficiency of the framework and its consistency with classical inventory management theory. Moreover, the results highlight a systematic and balanced allocation between early payment and bank financing under liquidity constraints, illustrating how firms optimally exploit dynamic discounting opportunities while relying on reverse factoring to cover remaining financing needs.

From a financial perspective, the findings show that liquidity availability plays a central role in shaping payment strategies. Firms prioritize internal financing whenever possible and resort to external solutions only when budget limitations are binding. This behavior leads to improved working capital utilization and reduced total system costs, thereby enhancing overall supply

chain performance. The rapid convergence of CPLEX further confirms the computational tractability and practical applicability of the proposed model for decision-support purposes.
Overall, this research contributes to the literature by providing a simple yet robust analytical tool that bridges Operations Research, FinTech, and supply chain finance. It demonstrates that digital financial instruments can be effectively embedded within optimization models to improve both operational and economic outcomes. Future research may extend this framework to stochastic demand, multi-supplier networks, dynamic budgets, and more sophisticated financial contracts, thereby further strengthening its relevance for real-world supply chains.

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