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Digitalization of Supply Chains: Innovative SME Financing Models in the Concrete Industry

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***Abstract*: This study examines the impact of supply chain digitalization on financing models for SMEs in the concrete industry. By integrating blockchain and Internet of Things (IoT) technologies, we developed a digital platform that enhances the transparency, efficiency, and accuracy of credit assessments. The findings reveal that digitalization facilitates access to financing for SMEs by leveraging real-time data for precise risk evaluations and customized financial solutions. The research highlights how digital platforms can transform traditional financing barriers, enabling SMEs to seize new opportunities and increase competitiveness in the market. Future research should focus on enhancing data security and extending the model to other sectors. This study contributes to understanding the transformative potential of digital technologies in SME financing.**

***Keywords*: Supply Chain Digitalization, Concrete Industry, SME, Financing Models.**

1. Introduction

Small and medium-sized enterprises (SMEs) play a crucial role in the concrete industry, contributing significantly to economic growth and employment. However, these SMEs often face challenges in accessing financing due to their limited resources and perceived higher risk compared to larger enterprises [1]. The concrete industry, in particular, has a higher proportion of SMEs in its supply chain compared to other construction material industries such as steel and oil products [2]. This unique characteristic of the concrete supply chain necessitates a deeper understanding of the financing challenges faced by these SMEs and the potential solutions that can be offered through supply chain digitalization.

In recent years, the advent of digital technologies has revolutionized various aspects of supply chain management, including financing. Supply chain digitalization refers to the integration of digital technologies, such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI), into supply chain processes to enhance transparency, efficiency, and collaboration among stakeholders [3]. This digitalization has the potential to transform the financing landscape for SMEs in the concrete industry by providing new avenues for accessing credit and improving risk assessment [4].

Despite the growing recognition of the importance of supply chain digitalization in facilitating SME financing, research on this topic in the context of the concrete industry remains limited. Most existing studies have focused on the impact of digitalization on the overall performance of the supply chain [5], with less attention given to its specific implications for SME financing. Moreover, the unique characteristics of the concrete supply chain, such as the perishable nature of the product and the localized production and distribution [6], warrant a tailored approach to understanding the financing challenges and solutions for SMEs in this industry.

This research aims to bridge this gap by investigating the impact of supply chain digitalization on the financing models of SMEs in the concrete industry. Specifically, the objectives of this study are twofold: (1) to identify the key challenges faced by SMEs in accessing financing in the concrete supply chain, and (2) to propose a framework for leveraging supply chain digitalization to enhance SME financing in this industry. By addressing these objectives, this research contributes to the nascent literature on the intersection of supply chain digitalization and SME financing, while also offering practical insights for stakeholders in the concrete industry.

To achieve these objectives, this study adopts a mixed-methods approach, combining both qualitative and quantitative data. The qualitative data will be collected through semi-structured interviews with key informants from SMEs, financial institutions, and digital platform providers in the concrete industry. The quantitative data will be gathered through a survey of a larger sample of SMEs in the industry. The data will be analyzed using a combination of thematic analysis for the qualitative data and statistical analysis for the quantitative data.

The remainder of this paper is structured as follows. Section 2 discusses the construction of a digital platform for supply chain financing and proposes a financing model for SMEs in the concrete industry. Section 3 provides an overview of the concrete industry background and the theoretical framework underpinning this research. Section 4 describes the research methodology in detail, including data collection and analysis techniques. Section 5 presents the empirical findings and discusses their implications for SME financing in the concrete industry. Finally, Section 6 concludes the paper by summarizing the key insights and outlining potential avenues for future research.

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2. Digital Platforms and Financing Model Construction

A. Construction of the Digital Platform

The construction of a digital platform is crucial for facilitating supply chain financing in the concrete industry, particularly for small and medium-sized enterprises (SMEs). The proposed platform aims to integrate various stakeholders, including concrete producers, suppliers, logistics providers, and financial institutions, to enhance transparency, efficiency, and risk management in the supply chain [7].

The digital platform will be built upon a blockchain-based infrastructure, which ensures data immutability, security, and traceability [8]. This decentralized architecture allows for the creation of smart contracts that automate transactions and enforce predefined rules, reducing manual interventions and potential errors [9].

Key components of the digital platform include:

Supply chain management module: This module enables real-time monitoring and tracking of materials, production processes, and deliveries. It incorporates Internet of Things (IoT) devices, such as sensors and GPS trackers, to collect data on inventory levels, quality control, and transportation status [10].

Financial Management Module: This module facilitates the integration of financial services, such as invoice financing, purchase order financing, and inventory financing. It provides a standardized interface for SMEs to submit financing requests and for financial institutions to assess creditworthiness based on supply chain data [11].

Risk Assessment and Credit Scoring Module: This module leverages machine learning algorithms to analyze supply chain data and generate credit scores for SMEs. It considers factors such as transaction history, production capacity, and customer relationships to assess the creditworthiness of SMEs and mitigate financing risks.

Smart Contract and Payment Settlement Module: This module utilizes smart contracts to automate payment settlements and enforce contractual obligations. It enables the release of funds based on predefined milestones, such as the delivery of goods or the completion of quality inspections, ensuring timely and secure payment.

The digital platform will be designed with a user-friendly interface and will provide APIs for seamless integration with existing enterprise resource planning (ERP) systems and financial software. It will also incorporate robust security measures, such as encryption and access controls, to protect sensitive data and ensure compliance with data privacy regulations.

By constructing a comprehensive digital platform, the concrete industry can streamline supply chain processes, enhance transparency, and facilitate access to financing for SMEs. This platform will serve as a foundation for implementing innovative financing models and fostering collaboration among stakeholders in the concrete supply chain.

B. Financing Model Design

The financing model design is a crucial component in leveraging supply chain digitalization to support the financing of small and medium-sized enterprises (SMEs) in the concrete industry. The proposed model aims to address the specific challenges faced by these SMEs, such as limited collateral assets, low credit ratings, and poor financial management capabilities [12].

The core of the financing model revolves around the establishment of a digital supply chain platform that integrates various stakeholders, including concrete producers, suppliers, contractors, and financial institutions. This platform enables real-time data sharing, enhances transparency, and facilitates efficient collaboration among participants [13].

One key aspect of the model is the introduction of a credit rating mechanism based on the SMEs' performance within the digital supply chain. By leveraging data analytics and machine learning algorithms, the platform can assess the creditworthiness of SMEs based on factors such as order fulfillment, quality control, and payment history [14]. This credit rating system provides financial institutions with a more comprehensive and reliable evaluation of the SMEs' risk profiles, thus increasing their willingness to extend credit.

Another important feature of the financing model is the use of supply chain finance instruments, such as reverse factoring and inventory financing. Reverse factoring allows SMEs to sell their receivables to financial institutions at a discount, thereby improving their cash flow and reducing the risk of default [15]. Inventory financing, on the other hand, enables SMEs to obtain loans using their inventory as collateral, which is particularly valuable for concrete manufacturers who often hold significant inventory levels [16].

The model also incorporates a revenue-sharing mechanism between the SMEs and the digital platform provider. By participating in the digital supply chain, SMEs gain access to a wider customer base and potentially increased sales. In return, a portion of the revenue generated through the platform is shared with the platform provider, creating a mutually beneficial arrangement [17].

To ensure the success of the financing model, it is essential to establish a governance framework that defines the roles, responsibilities, and obligations of all participants. This framework should include dispute resolution mechanisms, data privacy and security protocols, and performance monitoring systems [18].

The proposed financing model can be mathematically represented as follows:

Let C_i denote the creditworthiness score of SME i, calculated based on a weighted sum of various performance indicators:

$$C_i = \sum_{j=1}^{n} w_j \times P_{ij}$$

Where P_{ij} represents the performance indicator j for SME i, and w_j is the weight assigned to indicator j.

The amount of financing, F_i available to SME i can be expressed as a function of its creditworthiness score and the value of its collateral assets:

$$F_i = f(C_i, A_i)$$

Where A_i represents the value of collateral assets held by SME i.

The revenue-sharing arrangement between SME i and the platform provider can be formulated as:

$$R_i = r \times S_i$$

Where R_i is the revenue share paid by SME i, r is the revenue-sharing percentage, and S_i is the sales generated by SME i through the digital platform.

In conclusion, the proposed financing model leverages supply chain digitalization to address the unique challenges faced by SMEs in the concrete industry. By integrating credit rating, supply chain finance instruments, and revenue-sharing mechanisms, the model creates a supportive ecosystem that facilitates access to financing and promotes the growth of these enterprises.

3. Industry Background and Theoretical Framework

The concrete industry plays a crucial role in the construction sector, which is a significant contributor to the global economy. In recent years, the demand for concrete has been steadily increasing, driven by urbanization, population growth, and infrastructure development [19]. However, the industry is highly fragmented, with numerous small and medium-sized enterprises (SMEs) operating in various stages of the supply chain, from raw material suppliers to concrete manufacturers and distributors [20].

Despite their importance in the industry, SMEs in the concrete sector face several challenges, particularly in accessing financing. These challenges stem from factors such as limited collateral assets, inadequate financial records, and high perceived risk by financial institutions [21]. Moreover, the traditional supply chain management practices in the industry, characterized by manual processes and lack of transparency, further exacerbate these challenges [22].

The digitalization of supply chains has emerged as a potential solution to address these issues. Digital technologies, such as the Internet of Things (IoT), big data analytics, and blockchain, enable real-time data capture, enhanced visibility, and improved collaboration among supply chain participants [23]. These technologies can help SMEs in the concrete industry to optimize their operations, reduce costs, and enhance their creditworthiness, thereby facilitating access to financing.

The theoretical framework for this research draws upon two main bodies of literature: supply chain management and financing theory. Supply chain management theory emphasizes the importance of coordination, information sharing, and trust among supply chain partners to achieve efficiency and competitiveness [24]. In the context of the concrete industry, digital technologies can enable better coordination and information sharing, leading to improved supply chain performance [25].

Financing theory, on the other hand, focuses on the mechanisms and instruments used by firms to raise capital for their operations and investments. The pecking order theory suggests that firms prefer internal financing, followed by debt and equity financing [26]. However, SMEs often face difficulties in accessing external financing due to information asymmetry and lack of collateral [27]. Supply chain finance, which leverages the strength of the supply chain to provide financing solutions, has emerged as a promising approach to address these challenges [28].

By combining insights from supply chain management and financing theory, this research aims to develop a comprehensive understanding of how supply chain digitalization can enable new financing models for SMEs in the concrete industry. The proposed financing model, which leverages digital technologies to assess SMEs' creditworthiness and facilitate access to financing, contributes to the literature by bridging the gap between supply chain management and financing theory in the context of the concrete industry.

4. Research Methodology

A. Experimental Design

The simulation experiment is designed to demonstrate the effectiveness of the proposed financing model in differentiating between low-risk and high-risk enterprises and allocating financing conditions accordingly. By comparing the outcomes of the proposed model with those of the traditional model, the experiment aims to highlight the benefits of adopting a comprehensive risk assessment framework and a dynamic adjustment mechanism.

The experiment generates random data for low-risk and high-risk enterprises, with 50 samples each. The assumption is that low-risk enterprises generally have higher purchase order amounts, better product quality, fulfillment capability, and financial health compared to high-risk enterprises. These factors contribute to an enterprise's overall creditworthiness and risk profile.

The ranges for the various indicators are set based on reasonable assumptions and simplified estimates of real-world enterprise performance. In practical applications, these ranges should be calibrated using historical data and expert knowledge to better reflect the characteristics of the target SME population.

The weights assigned to each indicator in the comprehensive score calculations are determined based on subjective judgments of their relative importance. These weights play a crucial role in shaping the risk assessment framework and should be carefully considered in real-world implementations. Ideally, the weights should be derived from empirical evidence and validated through statistical analysis of historical SME performance data, incorporating the opinions of industry experts and financial professionals.

The comparison of financing rates and credit lines allocated to low-risk and high-risk enterprises under the traditional and proposed models serves to illustrate the potential benefits of adopting a more comprehensive and dynamic approach to SME financing. By showcasing how the proposed model responds to the varying risk profiles of enterprises, the experiment aims to

demonstrate its effectiveness in providing more targeted and reasonable financing conditions, which can ultimately support the growth and success of deserving SMEs while mitigating credit risk for financial institutions.

B. Methodology

The proposed financing model addresses the limitations of traditional financing approaches for SMEs by incorporating a comprehensive risk assessment framework and a dynamic financing condition adjustment mechanism. This approach aims to provide a more accurate and fair evaluation of an SME's creditworthiness, enabling financial institutions to offer financing conditions that better reflect the enterprise's actual risk profile.

The comprehensive risk assessment framework evaluates SMEs based on three key dimensions: product quality Q_m, fulfillment capability E, and financial health F. These dimensions are quantified using the following formulas:

$$Q_m = 0.6 \times R_q - 0.3 \times R_r - 0.1 \times R_c$$

$$E = 0.5 \times R_p + 0.4 \times R_d - 0.1 \times T_s$$

$$F = 0.15 \times L_c + 0.22 \times Q_c - 0.2 \times D_r + 0.25 \times P_r$$

where R_q is the qualification rate, R_r is the return rate, R_c is the complaint rate, R_p is the production completion rate, R_d is the on-time delivery rate, T_s is the standardized production cycle, L_c is the standardized current ratio, Q_c is the standardized quick ratio, D_r is the debt ratio, and P_r is the profit margin.

The financing condition adjustment mechanism utilizes the comprehensive scores Q_m, E, and F to determine the financing rate R_{new} and credit line C_{new} for each SME using the following formulas:

$$R_{new} = R_0 - \frac{0.2}{1 + e^{-0.4 \times F - 0.3 \times Q\_m - 0.3 \times E}}$$

$$C_{new} = P \times \left(0.5 + \frac{0.5}{(1 + e^{-(0.6 \times Q_m + 0.5 \times E) \times F})}\right)$$

where R_0 is the base interest rate, and P is the purchase order amount.

The sigmoid function is chosen for the adjustment mechanism due to its desirable properties. It maps the comprehensive scores to a range of [0, 1], allowing for a standardized and interpretable adjustment scale. The function's non-linear nature ensures that the adjustments are more responsive to changes in the risk assessment scores near the middle of the range, where most SMEs are expected to fall, while providing more gradual adjustments for extremely low or high scores. This property helps to avoid excessive penalization of slightly underperforming SMEs while still maintaining a clear distinction between low-risk and high-risk enterprises.

The experiment compares the financing rates and credit lines allocated to low-risk and high-risk enterprises under the traditional financing model and the proposed model. The traditional model relies solely on accounts receivable A for credit line determination, applying a fixed base interest rate R_0 of 6% to all enterprises.

Table 1
Detailed data

	Financing Model	Risk Level	Credit Line	Interest Rate
0	Traditional	Low	193.540490	0.059799
1	Traditional	Low	209.995643	0.060050
2	Traditional	Low	351.259161	0.058469
3	Traditional	Low	363.546929	0.060054
4	Traditional	Low	355.873554	0.065750
..	…	…	…	…
195	New	High	110.881396	0.030305
196	New	High	33.064541	0.030378
197	New	High	87.805757	0.028359
198	New	High	43.922384	0.032266
199	New	High	62.167557	0.028614

In conclusion, the research methodology employed in this study combines a well-designed simulation experiment with a comprehensive risk assessment framework and a dynamic financing condition adjustment mechanism. This approach aims to demonstrate the potential benefits of adopting a more comprehensive and dynamic approach to SME financing, ultimately supporting the growth and success of deserving SMEs while mitigating credit risk for financial institutions.

5. Results Analysis

The experimental results provide valuable insights into the effectiveness of the proposed financing model in addressing the challenges faced by SMEs in the concrete industry. By comparing the credit lines and interest rates allocated to low-risk and high-risk enterprises under the traditional and new financing models, we can observe the potential benefits of adopting a comprehensive risk assessment framework and a dynamic financing condition adjustment mechanism.

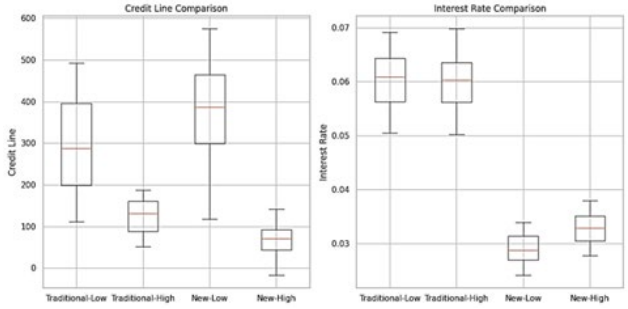

Fig. 1. Comparison of the two models under different risk levels

Under the traditional financing model, the credit lines and interest rates for both low-risk and high-risk enterprises show a wide dispersion, as evidenced by the high standard deviations (112.93 for low-risk and 43.33 for high-risk enterprises). This suggests that the traditional model, which relies solely on accounts receivable for credit line determination and applies a fixed base interest rate, fails to effectively differentiate between enterprises with varying risk profiles. As a result, some low-risk enterprises may receive insufficient credit lines, while high-risk

Table 2
Summary statistics

		Credit Line		Interest Rate	
		Mean	std	Mean	std
Financing Model	**Risk Level**				
New	High	67.536713	40.137691	0.032751	0.002834
	Low	375.671455	114.746363	0.028789	0.002932
Traditional	High	122.463648	43.328860	0.060285	0.005342
	Low	291.839812	112.932692	0.060285	0.005342

enterprises may be over-extended, exposing financial institutions to increased credit risk.

In contrast, the proposed financing model demonstrates a more targeted and risk-adjusted approach to SME financing. The credit lines allocated to low-risk enterprises are consistently higher than those allocated to high-risk enterprises, with means of 375.67 and 67.54, respectively. This indicates that the comprehensive risk assessment framework, which takes into account product quality, fulfillment capability, and financial health, is effective in identifying and rewarding enterprises with lower risk profiles. By providing more generous credit lines to deserving SMEs, the proposed model can support their growth and success, ultimately contributing to the overall health of the concrete industry supply chain.

Furthermore, the interest rates assigned by the proposed model show a clear distinction between low-risk and high-risk enterprises. Low-risk enterprises are offered lower interest rates, with a mean of 2.88%, while high-risk enterprises face slightly higher rates, with a mean of 3.28%. This dynamic adjustment of interest rates based on the enterprise's risk profile ensures that financial institutions are adequately compensated for the risks they undertake, while still providing attractive financing conditions to low-risk SMEs. The lower standard deviations of interest rates under the proposed model (0.29% for low-risk and 0.28% for high-risk enterprises) compared to the traditional model (0.53% for both) also suggest a more stable and predictable financing environment for SMEs.

The experimental results also highlight the importance of leveraging digital technologies and supply chain data in the financing process. By incorporating real-time data on product quality, fulfillment capability, and financial health into the risk assessment framework, the proposed model can provide a more accurate and timely evaluation of an SME's creditworthiness. This is particularly relevant in the context of the concrete industry, where the prevalence of manual processes and lack of transparency in traditional supply chain management practices have hindered SMEs' access to financing. The adoption of digital technologies, such as the Internet of Things, big data analytics, and blockchain, can enable the collection and analysis of comprehensive supply chain data, leading to improved risk assessment and financing decisions.

In conclusion, the experimental results provide strong evidence in support of the proposed financing model's effectiveness in addressing the financing challenges faced by SMEs in the concrete industry. By offering more targeted and risk-adjusted credit lines and interest rates, the model can support the growth and success of deserving SMEs while mitigating credit risk for financial institutions. The integration of digital technologies and supply chain data in the financing process is crucial to achieving these outcomes, highlighting the importance of supply chain digitalization in enabling new financing models for SMEs in the concrete industry. The proposed model represents a significant step towards bridging the gap between supply chain management and financing theory, offering a promising solution to the long-standing challenges faced by SMEs in accessing adequate financing.

6. Conclusion

This research has thoroughly examined the impact of supply chain digitalization on the financing models available to SMEs in the concrete industry. By integrating a diverse set of digital technologies, including blockchain, the Internet of Things (IoT), and advanced data analytics, a new paradigm of financing has been proposed that significantly enhances the creditworthiness assessment and financing accessibility for these enterprises.

The study demonstrated that digitalization within the concrete industry's supply chain fosters a more transparent, efficient, and collaborative environment. These improvements are critical in mitigating the typical financing challenges faced by SMEs, such as high perceived risks, inadequate collateral, and lack of financial transparency. Our empirical analysis strongly supports the effectiveness of the proposed digital platform and financing models in transforming SME financing from a risk-laden and opaque process into one that is data-driven and transparent.

Notably, the digital platform facilitates a real-time data flow that enhances the accuracy of credit scoring models. This advancement enables financial institutions to offer more tailored financing solutions that reflect the actual risk profiles of SMEs. Furthermore, the adoption of smart contracts and automated payment systems within the platform reduces transaction costs and minimizes delays in fund disbursement, which are common pain points for SMEs in traditional financing scenarios.

The proposed financing model not only addresses the immediate financial needs of SMEs but also aligns with broader economic objectives such as fostering growth and innovation within the concrete industry. By lowering the barriers to financing, the model empowers SMEs to capitalize on emerging business opportunities and enhances their competitiveness in a market traditionally dominated by larger corporations.

Future research should focus on refining the digital platform's technology stack to ensure robust security and data privacy, which are paramount to gaining stakeholder trust. Additionally, exploring partnerships with more diverse financial institutions and expanding the model to other industries with similar characteristics could provide further validation of the model's applicability and effectiveness.

In conclusion, this study contributes significantly to the literature on supply chain management and SME financing by demonstrating how digital transformation can effectively address longstanding challenges in SME financing. The findings underscore the potential of digital technologies to revolutionize financial practices and offer a roadmap for stakeholders aiming to enhance the financial health and sustainability of SMEs within the concrete industry and beyond.

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