

Prioritizing Risk Factors in Supply Chain Finance for Logistics Company Using Analytic Hierarchy Process

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Abstract

This study aimed to identify and rank the risk factors associated with logistics companies engaged in supply chain finance (SCF) operations using the Analytic Hierarchy Process (AHP). The target population consists of three distinct groups: staff of logistics companies, professionals from financial institutions, and researchers affiliated with academic institutes. This study used questionnaire and convenient sampling to collect data. The results showed that logistics operations management, pledge management, and supply chain environment were significant dimensions of risk factors for logistics companies in SCF. The risk factors were divided into three groups: high-risk, medium-risk, and low-risk factors. The study recommends that logistics companies in SCF prioritize risk management strategies on the high-risk factors to minimize potential losses and reputational damage. Based on AHP, those high-risk factors are pledge disposal capability, pledge quality, pledge ownership, and legal & regulation. The study suggests that goods and companies can mitigate these risks by implementing advanced inventory management systems, partnering with third-party logistics providers or liquidators, seeking third-party assistance to identify the quality of the pledged goods, and conducting thorough investigations into the qualifications of applicants and the ownership of goods before conducting business. Furthermore, complying with relevant laws and regulations is crucial for logistics companies to avoid potential legal issues and safeguard the success of the SCF business. These findings can provide insights into developing effective risk management systems for logistics companies engaged in SCF operations, enhancing their ability to operate successfully in this industry.

Keywords: Analytic Hierarchy Process (AHP), Logistics Company, Supply Chain Finance (SCF)

บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อระบุและจัดลำดับปัจจัยเสี่ยงที่เกี่ยวข้องกับบริษัทโลจิสติกส์ที่มีส่วนร่วมในด้านสินเชื่อหมุนเวียนคู่ค้า (SCF) โดยใช้กระบวนการวิเคราะห์ตามลำดับชั้น (AHP) ประชากรเป้าหมายประกอบด้วยสามกลุ่มที่แตกต่างกัน ได้แก่ พนักงานของบริษัทโลจิสติกส์ ผู้เชี่ยวชาญจากสถาบันการเงิน และนักวิจัยในสังกัดสถาบันการศึกษา การเก็บข้อมูลใช้แบบสอบถามและการสุ่มตัวอย่างตามความสะดวก ผลการศึกษาพบว่าการจัดการการดำเนินงานด้าน โลจิสติกส์ การจัดการหลักประกัน และสภาพแวดล้อมของห่วงโซ่อุปทานเป็นปัจจัยเสี่ยงที่สำคัญสำหรับบริษัทด้านโลจิสติกส์ใน SCF ปัจจัยเสี่ยงถูกแบ่งเป็น 3 กลุ่มได้แก่ ความเสี่ยงสูง ความเสี่ยงปานกลาง และความเสี่ยงต่ำ งานวิจัยนี้แนะนำให้บริษัทโลจิสติกส์ใน SCF จัดลำดับความสำคัญของกลยุทธ์การจัดการความเสี่ยงบนปัจจัยที่มีความเสี่ยงสูงเพื่อลดความสูญเสียที่อาจเกิดขึ้นและความเสียหายต่อชื่อเสียงจากผลการวิเคราะห์ของ AHP ปัจจัยที่มีความเสี่ยงสูง ได้แก่ ความสามารถในการจำหน่ายหลักประกัน คุณภาพของหลักประกัน ความเป็นเจ้าของของหลักประกัน และกฎหมายและระเบียบข้อบังคับ การศึกษาชี้ให้เห็นว่าบริษัทโลจิสติกส์สามารถลดความเสี่ยงเหล่านี้ได้โดยการใช้ระบบการจัดการสินค้าคงคลังขั้นสูง การร่วมมือกับผู้ให้บริการโลจิสติกส์ที่เป็นบุคคลที่สามหรือผู้ชำระบัญชี การขอความช่วยเหลือจากบุคคลที่สามเพื่อระบุคุณภาพของสินค้าที่นำมาเป็นหลักประกัน และดำเนินการตรวจสอบอย่างละเอียดเกี่ยวกับคุณสมบัติของผู้ขอสินเชื่อ และกรรมสิทธิ์ในสินค้าก่อนอนุมัติสินเชื่อ นอกจากนี้ การปฏิบัติตามกฎหมายและข้อบังคับที่เกี่ยวข้องเป็นสิ่งสำคัญสำหรับบริษัทโลจิสติกส์เพื่อหลีกเลี่ยงปัญหาทางกฎหมายที่อาจเกิดขึ้นและปกป้องความสำเร็จของการให้สินเชื่อหมุนเวียนแก่คู่ค้า การค้นพบนี้สามารถให้ข้อมูลเชิงลึกในการพัฒนาระบบการจัดการความเสี่ยงที่มีประสิทธิภาพสำหรับบริษัทโลจิสติกส์ที่มีส่วนร่วมในด้านสินเชื่อหมุนเวียนคู่ค้า ซึ่งช่วยเพิ่มความสามารถในการดำเนินงานให้ประสบความสำเร็จในอุตสาหกรรมนี้

คำสำคัญ: กระบวนการวิเคราะห์ตามลำดับชั้น บริษัทโลจิสติกส์ สินเชื่อหมุนเวียนคู่ค้า

Introduction

Supply chain finance (SCF) is a new concept that has been developed to address the funding issues faced by small and medium-sized firms (SMEs) when applying for loans from commercial banks or financial institutions. One of the main problems that limit the growth of SMEs is the lack of fixed assets, which makes it difficult for them to obtain funding. SCF offers an innovative solution to this challenge (Gelsomino et al., 2016). While numerous studies examine SCF risk from the perspective of banks and financial institutions (Liao, 2015; Deng & Lu, 2017; Marak & Pillai, 2018), there are not many studies on the role that logistics companies play in the SCF industry. Therefore, this study focuses on the logistics firms' role in the SCF business. In SCF, core firms act as the anchor, providing financial services to other node enterprises within the supply chain through trade ties (Mou et al., 2018). SCF can be categorized into three modes: the accounts receivable mode, the inventory pledge mode, and the prepayment mode (Chen et al., 2019). Logistics firms play an essential role in the inventory pledge and prepayment modes and are important supervisors in the SCF industry (Lu et al., 2020). This provides logistics firms with an opportunity to generate additional revenue from the operation process, such as warehousing fees, loading and unloading fees, and other service fees.

The current challenges of logistics companies in SCF encompass several critical areas. In logistics operations performance (Jia et al., 2020), issues such as inadequate risk management systems, internal control weaknesses, and human resource constraints have been identified. Evaluating client stability is imperative (Du et al., 2019), with concerns over financial stability, information asymmetry risks, and the assessment of client growth potential being crucial factors. Pledge management requires careful consideration of pledge quality, ownership verification, and accounting for price fluctuations in pledged assets (Liao, 2015). Additionally, in the supply chain environment (Tseng et al., 2018), adapting to rapid market changes, navigating legal and regulatory risks, and leveraging policy support and economic factors are all essential for successful SCF operations.

Despite the growing interest in SCF and its potential benefits for logistics companies, there is still a lack of research on how to prioritize risk factors in SCF. While previous studies have identified various risk factors associated with SCF (Liu et al., 2019; Abbasi et al., 2019), they have not provided a systematic method for prioritizing these factors based on their relative importance. Therefore, there is a research gap in understanding how to prioritize risk factors in SCF specifically for logistics companies. This study aims to address this gap by using the Analytic Hierarchy Process (AHP) to develop a systematic method for prioritizing risk factors in SCF for logistics companies. This method will enable logistics companies to better understand the relative importance of different risk factors in SCF and prioritize their risk management efforts accordingly. By doing so, this study will contribute to the development of more effective SCF programs for logistics companies, which can ultimately lead to improved financial performance and competitiveness in the market. Therefore, the objectives of this study are to identify the risk factors associated with SCF operations involving logistics companies, and to assess the severity of these risks, by ranking them using the Analytic Hierarchy Process (AHP). The findings will provide insights into the development of effective risk management systems for logistics companies engaged in SCF operations, which will enhance their ability to operate successfully in this industry. The scope of this study is to focus on the role of logistics firms in SCF, an emerging financial model designed to address funding challenges faced by Small and Medium Enterprises (SMEs).

Literature Review

Supply Chain Finance

Supply Chain Finance (SCF) is an emerging financial model that aims to improve the financial stability of Small and Medium Enterprises (SMEs) in the supply chain. According to Gelsomino et al. (2016), SCF refers to the financial services that are provided to the upstream and downstream enterprises of the supply chain based on core customers by methods such as trade financing, pledge registration of accounts receivable, third-party supervision, and other means to close capital flow or control property rights. This definition highlights the various methods used to control capital flow or property rights, which is crucial for financial institutes. However, from the perspective of logistics companies, there is a need to redefine SCF. Logistics companies play a critical role in the SCF business by acting as intermediaries between SMEs and financial institutes. They leverage their existing relationships and expertise in the supply chain to provide financial products tailored to the needs of SMEs (Lu et al., 2020). As logistics companies play an essential role in the SCF business, they need to have a clear understanding of the concept of SCF. Thus, SCF can be redefined as a capital cooperation model, a financial product that logistics companies use to connect SMEs that are clients and demanders of capital with their upstream and downstream enterprises and provide or introduce financing services to the SMEs. This definition emphasizes the role of logistics companies in providing financial services to SMEs in the supply chain.

The Risk Dimensions of Logistics companies in Supply Chain Finance

This study focuses on identifying the risk factors of SCF business from the perspective of logistics companies. According to the literature review and practical experiences, the identified risk factors can be categorized into four dimensions: logistics operations performance, client evaluation, pledge management, and supply chain environment. Each dimension has its own specific risk factors. The first dimension, logistics operations performance, includes risk factors such as inadequate risk management systems, lack of internal operational control, inadequate human resources, and weak pledge disposal capability (Jia et al., 2020). The second dimension, client evaluation, involves financial situation risk, information asymmetry risk, and development potential risk (Du et al., 2019). The third dimension, pledge management, encompasses the risk of pledged assets losing value (Liao, 2015), while the fourth dimension, supply chain environment, refers to external factors that are beyond the control of logistics companies (Tseng et al., 2018). Effective risk management requires a thorough understanding and management of these risk factors to prevent risk events from occurring.

The Risk Factors in Each Dimension of Logistics companies in Supply Chain Finance

The first risk dimension of logistics company in SCF is logistics operations performance. Several studies have investigated the risk factors that affect the logistics operations performance in SCF from different perspectives. Mu (2022) found that logistics companies in China face risks related to customer selection, financial risks, logistics risks, and operational risks. Jia et al. (2020) found that environmental risks and social risks are the critical factors affecting logistics operations performance in the context of green logistics. Ali et al. (2018) highlighted information technology risks, operational risks, and financial risks as the primary risk factors affecting logistics operations performance of SCF in Malaysia. The following discussion pertains to the risk factors of this dimension associated with operation management, employee quality, and pledge disposal capability affecting logistics companies in SCF.

Operation Management

Operations management refers to the systematic process of creating and delivering goods and services (Amin & Shahwan, 2020). In the context of SCF, the operation of a logistics company is vital in ensuring the success of the SCF business. This involves managing inventory, supervising the movement of goods, monitoring price changes, and implementing efficient controls to ensure that contractual requirements are met (Pan et al., 2020). Failure to effectively manage operations can result in losses and increased business risks.

Employee Quality

Employee quality refers to the characteristics and skills possessed by an employee that enable them to perform their job effectively and efficiently (Liang et al., 2018). Research studies have shown that employees who are trained and skilled in logistics operations are better able to manage the complexities of the supply chain (Meng & Wang, 2022; Schleper et al., 2021). Thus, lack of personal integrity or fraudulent behavior by employees can lead to financial losses for the logistics company in SCF.

Pledge Disposal Capability

Pledge disposal capacity is the ability to convert pledge assets into cash or other liquid assets quickly at a fair price (Mou et al., 2018). According to Lin et al. (2021), they suggest that companies should invest in improving their pledge disposal capacity to enhance their logistics performance. In addition, logistics companies in the SCF business may act as regulators and providers of funds simultaneously. Therefore, logistics companies must have the necessary knowledge and expertise to ensure that the disposal of collateral is carried out efficiently and without any losses.

The second risk dimension for a logistics company in SCF is client evaluation. SCF involves various stakeholders, and one of the critical stakeholders is the client. Evaluating the client's creditworthiness and risk profile is essential to ensure the success of supply chain finance programs. Several studies have examined the risk factors associated with client evaluation in SCF from different perspectives, such as financial stability, industry sector, customer concentration, and operational efficiency (Du et al., 2019); creditworthiness, collateral, industry sector, and customer concentration (Li et al., 2020); trust between buyers and suppliers, information sharing, credibility of the financing platform, and institutional support (Jia et al., 2020) as critical factors affecting the credit risk of suppliers. The following discussion pertains to the risk factors of this dimension associated with financial situation, information asymmetry, and potential development of clients affecting logistics companies in SCF.

Financial Situation

The financial situation of clients, such as profitability and net asset growth rate, is a significant risk factor in client evaluation for SCF programs. It serves as a basic guarantee for the repayment capacity of a company and also shows its potential for growth (Mou et al., 2018). Evaluating the financial situation of clients is essential for determining their creditworthiness and repayment capacity in SCF (Zhu et al., 2019). Ali et al. (2019) also highlight the importance of considering the financial situation of clients before extending credit to them. Li et al. (2020) emphasize that assessing the financial stability of clients is critical in mitigating risk in SCF programs.

Information Asymmetry

Information asymmetry refers to a situation in which one party in a transaction has more or better information than the other party (Liu et al., 2021). It is another important risk factor in client evaluation as companies may have fraudulent behaviors in the SCF business, such as conceal transaction information, and collude with upstream and downstream cooperation to obtain loans from commercial banks (Huang et al., 2021). Data analytics and other technologies can also be used to improve information symmetry in SCF (Liu et al., 2019). Moreover, Song et al. (2016) suggest that logistics companies should establish effective communication channels with their clients to ensure transparency and reduce information asymmetry.

Client Development Potential

Client development potential in logistics company in SCF refers to the client's potential to develop its business and increase its demand for financing solutions in the future (Zhu et al., 2019). The evaluation of client development potential is crucial in ensuring the sustainable growth of logistics companies in SCF. Several studies have investigated the risk factors related to client development potential in SCF, for such as, financial status, industry sector, business model, size, reputation, management efficiency, and creditworthiness (Liang et al., 2018; Li et al., 2020). In addition, a study by Zhao and Wang (2021) examined e-commerce SCF and found that transaction frequency, amount, cycle, and customer ratings were crucial factors.

The third risk dimension for a logistics company in SCF is pledge management. In SCF, pledge management is an essential factor for logistics companies to mitigate the financial risks. Studies have shown that the quality, ownership, and price fluctuations of pledged assets are significant risk factors in pledge management that can impact the loan-to-value ratio and legal validity of transactions (Liao, 2015; Yu et al., 2021). Failure to verify ownership can lead to legal disputes and financial losses (Li et al., 2022). The following discussion regards the risk factors of this dimension associated with pledge quality, pledge ownership, and pledge price fluctuation affecting logistics companies in SCF.

Pledge Quality

Pledge quality is a significant risk factor in pledge management. Pledge quality refers to the value of the assets that are pledged as collateral by a borrower to obtain financing (Deng & Lu, 2017). It is a crucial risk factor in determining pledge assets' value and the ability of logistics companies to recover their investment, according to Bai et al. (2022). They recommend that logistics companies evaluate the quality of pledged assets before accepting them as collateral and provide timely supervision to prevent deterioration during the financing period (Wang et al., 2019).

Pledge Ownership

Pledge ownership is another important risk factor in pledge management. Pledge ownership refers to the legal ownership of assets pledged as collateral by a borrower in order to obtain financing (Chen et al., 2019). According to Wang et al. (2020), pledge ownership is a risk factor in determining the legal rights of logistics companies to recover their investment in case of default. Therefore, logistics companies should ensure that pledge ownership is clearly defined and legally enforceable before accepting them as collateral when extending credit to clients.



Pledge Price Fluctuation

Pledge price fluctuation is also another important risk factor in pledge management. Pledge price fluctuation refers to the variability in the value of assets pledged as collateral for financing (Hu et al., 2020). Deng and Sen (2017) advise logistics companies to assess the price volatility of pledged assets before accepting them as collateral, while Huo et al. (2022) suggest that logistics companies should also consider the price volatility of pledged assets before providing financial services.

The fourth risk dimension for a logistics company in SCF is the supply chain environment. The supply chain environment refers to the conditions and factors that impact the performance, efficiency, and sustainability of supply chain operations (Soni et al., 2022). It plays a critical role in the success of SCF businesses operating in a globalized world. Sustainable supply chain management involves managing environmental, social, and economic factors across the supply chain (Seuring & Müller, 2008). In the logistics industry, market changes, legal and regulation risks, and policy support are significant risks associated with the external environment which can impact the operations of logistics companies in SCF (Ioannou & Demirel, 2022; Tseng et al., 2018). The following discussion regards the risk factors of this dimension associated with market change, legal & regulation, and policy support affecting logistics companies in SCF.

Market Changes

Market change is another important risk factor in the supply chain environment. Market changes refer to shifts in the economic and financial conditions that impact the availability, cost, and risk of financing options for supply chain participants, such as shifts in consumer demand, competitive landscapes, or economic conditions (Bai et al., 2022). While Lyu et al. (2021) recommend logistics companies to monitor market changes and adjust financial services to manage risks, Lam et al. (2019) suggest developing contingency plans to manage market risks. Moreover, Yu et al. (2019) propose a framework for assessing and responding to changes in SCF caused by shifts in consumer demand or supply chain disruptions.

Legal and Regulation

Legal and regulation is another important risk factor in the supply chain environment. Legal and regulation refer to the possibility of changes to laws, regulations, or compliance requirements that can impact the operations of a business, such as product safety standards, environmental regulations, or data privacy laws (Seuring & Müller, 2008). Legal and regulation risks can arise from factors such as compliance requirements for government policies (Ioannou & Demirel, 2022), contract disputes (Wang et al., 2020), and intellectual property infringement (Li et al., 2022), which can impact the creditworthiness of supply chain participants and the ability of logistics companies to recover their investment in the event of default.

Policy Support

Policy support is also another important risk factor in the supply chain environment. Policy support refers to government initiatives and programs aimed at promoting the development and adoption of supply chain finance solutions (Tseng et al., 2018). These policies can take various forms, such as tax incentives (Huang et al., 2021), loan guarantees, regulatory reforms (Lyu & Zhao, 2019), and financial assistance to support research and development (Liu et al., 2022). By providing policy support, governments can help to improve the availability and affordability of supply chain finance, increase the efficiency of supply chain operations, and promote economic growth and development. The above literature was summarized in Table 1.

Table 1: Risk Dimension and Its Risk Factors Affecting Logistics Company in SCF

Dimensions	Risk Factors
Logistics operations performance	Operations management Employee quality Pledge disposal capability
Client evaluation	Financial situation Information asymmetry Development potential
Pledge management	Pledge ownership Pledge quality Pledge price fluctuation
Supply chain environment	Market changes Legal & regulation Policy support

Methodology

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty in the 1970s as a measurement theory to aid in decision-making. It is a valuable tool for breaking down complex problems into a multi-level hierarchy of objectives, criteria, sub-criteria, and alternatives (Saaty, 1990). AHP uses paired comparisons to derive a ratio scale of relative priority units, which are integrated to determine the overall priority of each alternative. By employing a structured and hierarchical approach, AHP allows decision-makers to evaluate and weigh different factors. This method has been widely applied in various fields, such as engineering, business, and public policy.

Target population and data collection

The target population for this study comprises three distinct groups: staff of logistics companies, professionals from commercial banks and financial institutions, and researchers affiliated with academic institutes and universities. The rationale in choosing each group is given as follows: the first group can provide insights into the operational aspects and challenges faced by logistics companies in the context of SCF; the second group can offer perspectives from the financial service providers, allowing for an understanding of their role, challenges, and risk assessment in SCF; and the last group can bring academic insights, research findings, and theoretical perspectives to the study, providing a broader understanding of SCF. By including these groups, the study aims for a comprehensive understanding, practical relevance, and a balance between theory and practice in addressing risk factors in supply chain finance. Our study employed a convenience sampling method due to practical constraints and the nature of the population under investigation. As such, we did not have access to an exhaustive list of the entire target population. Instead, we gathered data from seven representatives within each group, which allowed us to gain valuable insights into the perspectives of logistics company staff, financial professionals, and academic researchers.

The appropriate sample size for an Analytic Hierarchy Process (AHP) study depends on factors like decision complexity, the number of criteria and alternatives, and desired precision. Although no strict rule exists, stability and consistency in pairwise comparisons guide sample size determination. Studies suggest 10-30 participants for reliable AHP results (Saaty, 1980; Saaty & Vargas, 2006). It is important to note that in AHP, the focus is more on the quality of participants' judgments rather than the quantity. Therefore, this study ensures that 21 participants are well-informed, have relevant expertise, and understand the decision problem. Overall, the demographics of the participants reflected a diverse range of ages, educational backgrounds, and work experiences, which helped to ensure the validity of the study results as shown in Table 2.

Table 2: Demographics of Participants

Group	Gender	Age	Education	Working Years	Position
Logistics Company	Male: 6	40-49:1	Master: 1	20-29: 1	Management Level: 2
	Female: 1	30-39: 6	Bachelor: 5 Other: 1	10-19: 4 Less than10: 2	Supervisor Level: 5
Financial Institution	Male: 4	Over 50: 2	Master: 1	Over 30: 2	Management Level: 2 Supervisor Level: 5
	Female: 3	40-49: 3 30-39: 2	Bachelor: 6	20-29: 2 10-19: 2 Less 10: 1	
Academic Institution	Male: 3	40-49: 7	Master: 7	20-29: 5	Associate Professor: 5 Lecturer: 2
	Female: 4			10-19: 2	

Questionnaire Design

To analyze the risk factors involved in the SCF business for logistics companies, the 16 risk factors were selected based on relevant literature. They were classified into four main dimensions: logistics operations performance, client evaluation, pledge management, and supply chain environment, based on their respective characteristics. A questionnaire was designed for participants to rate the importance of each factor on a scale of 1 to 9, with 1 being the equal importance and 9 being the absolute importance. Detailed information regarding the ratio scales is presented in Table 3. The use of a 1 to 9 scale in AHP for assessing risk factors in SCF for logistics companies is appropriate for several reasons (Saaty, 1990). This scale allows for fine-grained distinctions and clear differentiation between factors, ensuring participants make explicit decisions about their relative importance. It prevents neutral ratings, promotes consistency, and aligns well with the AHP methodology. To verify the questionnaire for our study employing AHP, we followed a systematic process. Initially, we sought content validity through expert reviews, involving professionals who are highly knowledgeable in the field. Feedback was crucial, as participants' input helped refine clarity and relevance. We ensured questions were non-redundant and that the response scale was appropriate. Incorporating this feedback, we revised the questionnaire and sought further expert review for final validation. This process ensured that our questionnaire effectively captured the required data for our AHP-based study. Using the AHP model, the authors aggregated the responses to calculate the relative importance of each risk factor and dimension, identifying the most significant risk factors in each dimension. This systematic approach can help logistics companies develop appropriate risk management strategies for their SCF business.

Table 3: Ratio Scale and Explanation of Analytic Hierarchy Process

Ratio Scale	Name	Definition
1	Equal Importance	Equally Comparing two elements, their contributions and significances are equal importance.
3	Weak Importance	Moderately Based on the judgement and experience, the participants compare two elements, and the participants <i>slightly incline</i> to one element.
5	Essential Importance	Strongly Based on the judgement and experience, the participants compare two elements, and the participants <i>strongly incline</i> to one element.
7	Very Strong Importance	Very Strong Based on the judgement and experience, the participants compare two elements, and the participants <i>very strongly incline</i> to one element.
9	Absolute Importance	Extremely Based on the judgement and experience, the participants compare two elements, and the participants <i>absolutely incline</i> to one element.
2,4,6,8	Intermediate Values	There are intermediate values between five main ratio scales.

Data Analysis

To determine the priority risk factors, the weight of each risk factor is calculated based on the collected data. To ensure reliability and accuracy, consistencies in the data must be checked using a consistency ratio, which is a tool used to evaluate the consistency of the pairwise comparisons made by the participants. If the consistency ratio is less than or equal to 0.1, the data is consistent and can be used to calculate the total weight rank of the risk factors. The weight of each factor is calculated by multiplying the value of its dimension's weight by the value of its weight in the hierarchy. These priority risk factors can help logistics companies identify and mitigate the most significant risks in their SCF business.

Calculation Process

To clarify the process of calculation, this study has chosen one of the participants, an academic staff member (A3), as an example, and the evaluation results are shown in Table 4.

Table 4: The Result of Participant (A3) of Dimension Level

Dimension Level																		
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Logistics operations performance							3											Client evaluation
Logistics operations performance							3											Pledge management
Logistics operations performance											3							Supply chain environment
Client evaluation								2										Pledge management
Client evaluation											3							Supply chain environment
Pledge management											3							Supply chain environment

Step 1: Construct the Normalized Pair-wise Comparison Matrix

This involves setting n as the number of components in the matrix, A as the pair-wise comparison matrix in AHP, and a_{ij} as the comparison weight, where i represents the component number (1, 2, 3, ..., n) and j represents the comparison number (1, 2, 3, ...).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} \\ \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} \end{bmatrix}$$

Step 2: Calculating the Weight of each Dimension

Once the normalized pair-wise comparison matrix has been constructed as shown in Table 5, the next step in the AHP process is to calculate the weight of each dimension. To do this, the researchers first need to calculate the geometric mean of each row. The geometric mean of each row is obtained by multiplying all the elements of the row and taking the n^{th} root, where n is the number of elements in the row.

Table 5: The Matrix: Dimension Level

	Logistics operations performance	Client evaluation	Pledge management	Supply chain environment
Logistics operations performance	1	3	3	1/3
Client evaluation	1/3	1	2	1/3
Pledge management	1/3	1/2	1	1/3
Supply chain environment	3	3	3	1

The formula for calculating the geometric mean of each row (W_i) is:

$$W_i = \frac{\left(\prod_{j=1}^n a_{ij}\right)^{\frac{1}{n}}}{\sum_{j=1}^n \left(\prod_{j=1}^n a_{ij}\right)^{\frac{1}{n}}} \quad i, j = 1, 2 \dots n$$

The calculation process is as followed:

$$M_1 = 1 \times 3 \times 3 \times \frac{3}{3} = 3$$

$$M_2 = \frac{1}{3} \times 1 \times 2 \times \frac{1}{3} = \frac{2}{9}$$

$$M_3 = \frac{1}{3} \times \frac{1}{2} \times 1 \times \frac{1}{3} = \frac{1}{18}$$

$$M_4 = 3 \times 3 \times 3 \times 3 = 27$$

$$\bar{W}_1 = \sqrt[4]{M_1} = \sqrt[4]{3} = 1.316$$

$$\bar{W}_2 = \sqrt[4]{M_2} = \sqrt[4]{\frac{2}{9}} = 0.6866$$

$$\bar{W}_3 = \sqrt[4]{M_3} = \sqrt[4]{\frac{1}{18}} = 0.4855$$

$$\bar{W}_4 = \sqrt[4]{M_4} = \sqrt[4]{27} = 2.2795$$

$$\bar{W} = [\bar{W}_1 + \bar{W}_2 + \bar{W}_3 + \bar{W}_4]^j = [1.316, 0.6866, 0.4855, 2.2795]^j$$

$$\sum_{j=1}^n \bar{W}_j = 1.316 + 0.6866 + 0.4855 + 2.2795 = 4.7676$$

$$W_{logistics\ operations\ performance} = \frac{\bar{W}_1}{\sum_{j=1}^n \bar{W}_j} = \frac{1.316}{4.7676} = 0.276$$

$$W_{Client\ evaluation} = \frac{\bar{W}_2}{\sum_{j=1}^n \bar{W}_j} = \frac{0.6866}{4.7676} = 0.144$$

$$W_{Pledge\ management} = \frac{\bar{W}_3}{\sum_{j=1}^n \bar{W}_j} = \frac{0.4855}{4.7676} = 0.1018$$

$$W_{Supply\ chain\ environment} = \frac{\bar{W}_4}{\sum_{j=1}^n \bar{W}_j} = \frac{2.2795}{4.7676} = 0.4781$$

Step 3: Consistency Ratio (C.R.) Checking

In the AHP calculation, the step of consistency ratio (C.R.) checking is crucial to ensure the validity of the data. The C.R. is a measure that indicates how consistent the pairwise comparisons are. Inconsistency in the data can lead to inaccurate results and undermine the reliability of the decision-making process. Therefore, it is essential to check the C.R. to ensure that the calculated weights are reliable and valid. To calculate the C.R., the consistency index (C.I.) is first calculated using the formula:

First, calculating the value of λ_{max} , the formula is as follows:

$$\lambda_{max} = \sum_{i=1}^n \frac{(AW)_i}{nW_i} \quad i = 1, 2, \dots, n$$

where λ_{max} is the maximum eigenvalue of the pair-wise comparison matrix, and n is the number of components (or dimensions) in the matrix. To calculate λ_{max} , the authors need to find the eigenvector corresponding to the maximum eigenvalue. This can be done using matrix algebra or software such as excel. The maximum eigenvalue of the weighted matrix is $\lambda_{max} = 2.000$. The calculation process is as followed:

$$AW = \begin{bmatrix} 1 & 3 & 3 & \frac{1}{3} \\ \frac{1}{3} & 1 & 2 & \frac{1}{3} \\ \frac{1}{3} & \frac{1}{2} & 1 & \frac{1}{3} \\ 3 & 3 & 3 & 1 \end{bmatrix} \begin{bmatrix} 0.276 \\ 0.144 \\ 0.1018 \\ 0.4781 \end{bmatrix}$$

$$= \begin{bmatrix} 1 \times 0.276 + 3 \times 0.144 + 3 \times 0.1018 + \frac{1}{3} \times 0.4781 \\ \frac{1}{3} \times 0.276 + 1 \times 0.144 + 2 \times 0.1018 + \frac{1}{3} \times 0.4781 \\ \frac{1}{3} \times 0.276 + \frac{1}{2} \times 0.144 + 1 \times 0.1018 + \frac{1}{3} \times 0.4781 \\ 3 \times 0.276 + 3 \times 0.144 + 3 \times 0.1018 + 1 \times 0.4781 \end{bmatrix}$$

$$\begin{aligned}
&= \begin{bmatrix} 1.172766667 \\ 0.598966667 \\ 0.425166667 \\ 2.0435 \end{bmatrix} \\
\lambda_{max} &= \sum_{i=0}^n \frac{(AW)_i}{nW_i} = \frac{(AW)_1}{4W_1} + \frac{(AW)_2}{4W_2} + \frac{(AW)_3}{4W_3} + \frac{(AW)_4}{4W_4} \\
&= \frac{1.172766667}{4 \times 0.276} + \frac{0.598966667}{4 \times 0.144} + \frac{0.425166667}{4 \times 0.1018} + \frac{2.0435}{4 \times 0.4781} \\
&= 4.214836399
\end{aligned}$$

Second, calculating the consistency index (C.I.), the formula is as follows:

$$C.I. = \frac{\lambda_{max} - n}{n - 1}$$

The calculation process is as followed:

$$C.I. = \frac{\lambda_{max} - n}{n - 1} = \frac{4.214836399 - 4}{4 - 1} = 0.071612133$$

Next, the random index (R.I.) is determined based on the value of n, shown in Table 6. The R.I. is a measure of the expected C.I. for a random pairwise comparison matrix of the same size as the original matrix. Once the C.I. and R.I. are determined, the C.R. is calculated by dividing the C.I. by the R.I. A C.R. value of less than or equal to 0.1 is generally considered acceptable, indicating a reasonable level of consistency in the data. If the C.R. is greater than 0.1, the pairwise comparisons need to be reviewed and revised to improve their consistency. To calculate the consistency ratio, the formula of consistency ratio is as follows:

$$C.R. = \frac{C.I.}{R.I.}$$

Table 6: The Consistency Index in Different n

n	R.I.	n	R.I.	n	R.I.
1	0	6	1.26	11	1.52
2	0	7	1.36	12	1.54
3	0.52	8	1.41	13	1.56
4	0.89	9	1.46	14	1.58
5	1.12	10	1.49	15	1.59

Source: Saaty (1980)

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.071612133}{0.89} = 0.080463071 \approx 0.0805$$

Therefore, when $C.R. < 0.1$, the matrix has high consistency. According to the above data, the participant's λ_{max} = 4.2148, C.I. = 0.0716, and C.R. = 0.0805 in the dimension level. The $C.R. = 0.0805 < 0.1$, which means the matrix has high consistency and the data is valid.

Table 7: The Calculation Result of the AHP

The Total Calculation Results of Analytic Hierarchy Process			
The Weight of Dimension Level			
Dimensions	Weight in Hierarchy	Weight in Dimension	
Logistics operations performance	0.2542	0.2542	
Client evaluation	0.1269	0.1269	
Pledge management	0.3496	0.3496	
Supply chain environment	0.2694	0.2694	
The Weight of Total Factors			
Factors	Weight in Total		
Operations Management	0.093	0.3659	Logistics operations performance
Employee Quality	0.0316	0.1244	
Pledge Disposal Capability	0.1296	0.5098	
Financial Situation	0.0741	0.5841	Client evaluation
Information Asymmetry	0.0221	0.174	
Development Potential	0.0307	0.2419	
Pledge’s Quality	0.1264	0.3617	Pledge management
Price Fluctuations	0.0975	0.2788	
Pledge’s Ownership	0.1257	0.3595	
Market Changes	0.0697	0.2587	Supply chain environment
Legal & Regulation	0.1016	0.3773	
Policy Support	0.0981	0.364	

The weights calculation results are presented in Table 7. Based on the ranking of risk factor weights, the next section will propose suggestions for the logistics company to develop SCF business by considering these factors.

Discussion

This section discusses the risk factors that impact logistics companies in SCF business and provides recommendations for developing the business. The study identified logistics operations management, pledge management, and supply chain environment as the most significant risk factors, with client evaluation being less impactful. Table 8 presents the risk factors ranked by weight and grouped into high-risk, medium-risk, and low-risk categories based on AHP analysis.

Table 8: The Results of Prioritizing Risk Factors

Risk Factors	Weight in Total	Rank
High: Pledge Disposal Capability	0.1296	1
High: Pledge Quality	0.1264	2
High: Pledge Ownership	0.1257	3
High: Legal & Regulation	0.1016	4
Medium: Policy Support	0.0981	5
Medium: Price Fluctuations	0.0975	6
Medium: Operation Management	0.093	7
Medium: Financial Situation	0.0741	8
Low: Market Changes	0.0697	9
Low: Employee Quality	0.0316	10
Low: Development Potential	0.0307	11
Low: Information Asymmetry	0.0221	12

The *high-risk* factors, listed from 1st to 4th in table 8, are pledge disposal capability, pledge quality, pledge ownership, and legal and regulation. These factors threaten the logistics company's SCF business by influencing the pledge's value and security, requiring risk management strategies. Non-compliance with law and regulation can result in financial penalties, legal liabilities, and reputational harm, making legal and regulatory compliance critical.

The *medium-risk* factors, listed from 5th to 8th in table 8, are policy support, price fluctuations, operations management, and financial situation. Although they are not as severe as the high-risk factors, they require the logistics company's attention to prevent negative effects on the SCF business. While policy support affects financing availability and cost, pledge price fluctuations, operations management, and financial situation affect pledge value and security. Thus, effective operations improve SCF processes, reduce costs, and enhance satisfaction.

The *low-risk* factors, listed from 9th to 12th in table 8, are market changes, employee quality, development potential, and information asymmetry. Although these factors pose a lower risk, they still require proper consideration and management for SCF business success. Logistics companies should monitor and adjust strategies for market changes to avoid potential default or non-payment. Skilled employees can improve service, efficiency, and reduce fraud. Transparency and clarity in communication and documentation are necessary to avoid information asymmetry risks. The following section will discuss only the high-risk factors relating to the three dimensions.

The first high-risk factor identified for logistics companies in SCF is *pledge disposal capability*. This is because logistics companies need to have the ability to dispose of pledges efficiently in case of default by their clients. The lack of proper disposal channels or a weak network of buyers can lead to longer pledge liquidation periods and higher costs. Studies have shown that logistics companies with effective pledge disposal management practices are more likely to reduce credit risk and improve financial performance (Faisal & Sagar, 2021; Ronchini et al., 2021; Yang et al., 2021). To enhance their pledge disposal capability, logistics companies can implement advanced inventory management systems, establish partnerships with third-party logistics providers or liquidators, and conduct regular assessments of their collateral management processes. They can also partner with auction houses, establish direct relationships with buyers specializing in the type of goods being pledged, and leverage technology solutions such as online marketplaces or platforms. Ensuring that collateral can be sold quickly and at a fair market price is critical to minimizing credit risk and ensuring the success of SCF programs.

The second high-risk factor identified for logistics companies in SCF is *pledge quality*. Poor pledge quality can lead to credit risk and financial losses (Zhang et al., 2015). Logistics companies may lack the expertise to accurately assess the quality of the diverse pledges involved in the SCF business, leading to potential blind spots. To mitigate this risk, logistics companies can seek the assistance of third-party organizations to provide an objective evaluation of the quality of the pledged goods. Research has shown that the use of third-party organizations significantly improves the accuracy and reliability of quality evaluation in SCF transactions (Li & Chen, 2019). Additionally, logistics companies can leverage technology such as blockchain to enhance transparency and traceability in the supply chain, making it easier to track the quality of goods. A study found that blockchain-based SCF platforms can improve the transparency and efficiency of the supply chain, reducing the risk of accepting low-quality pledges (Bai et al., 2022).

The third high-risk factor identified for logistics companies in SCF is *pledge ownership*. This is due to the potential for ownership disputes or uncertainty, leading to legal issues and credit risk for logistics companies. Research by Mou et al. (2018) highlights the importance of effective pledge ownership management in reducing credit risk and improving financial performance. In inventory pledge mode, pledge ownership is critical for logistics companies, as it can impact the validity of the pledge business (Chen et al., 2019). When ownership of pledged goods is unclear, it can result in repeated pledges or transfer of goods to downstream enterprises, leading to potential risks and losses (Marak & Pillai, 2018). To mitigate this risk, logistics companies should conduct thorough investigations into applicant qualifications and ownership of goods before conducting business, ensuring the authenticity and reliability of the transaction. It is essential for logistics companies to operate only when the ownership of the cargo is clear and controllable to avoid disputes and maintain the value of the pledge.

The fourth high-risk factor identified for logistics companies in SCF is legal and regulation. This risk arises from the complex and often uncertain legal and regulation frameworks governing SCF transactions, leading to financial penalties, legal liabilities, and reputational damage if logistics companies fail to comply with them (Guo et al., 2022). Legal risks should not be underestimated, and logistics companies must comply with all relevant laws and regulations. Legal considerations are crucial for logistics companies in SCF as they enter into various contracts and agreements with suppliers, buyers, and financial institutions, which can involve complex legal issues such as jurisdiction, governing law, dispute resolution, and security interests (Zhou et al., 2022). Compliance with tax regulations and environmental, health, and safety regulations is also essential. To mitigate legal and regulation risks, logistics companies must have effective risk management strategies in place. In sum, all four high-risk factors identified in this study are interrelated and critical for the success of logistics companies in SCF.

Conclusion

The study's objectives were met through a comprehensive analysis of risk factors in SCF operations involving logistics companies. Firstly, the study successfully identified high-risk factors specific to logistics companies in SCF. These include pledge disposal capability, pledge quality, pledge ownership, and legal and regulatory compliance. Secondly, the severity of these risk factors was thoroughly evaluated, providing valuable insights into their potential impact on logistics companies engaged in SCF. For instance, pledge disposal capability emerged as a critical risk factor due to its direct association with efficient collateral management. Inadequate disposal channels or weak buyer networks can lead to prolonged liquidation periods and increased costs. This result emphasizes the imperative for logistics companies to implement advanced inventory management systems and establish strategic partnerships with third-party providers. Moreover, the study employed the Analytical Hierarchy Process (AHP) to rank the identified risk factors, enabling a structured and systematic assessment. This approach offers a clear prioritization of risk factors based on their relative importance, aiding logistics companies in allocating resources and efforts towards effective risk management strategies. Lastly, the study provided practical insights to enhance risk management practices for logistics companies in the SCF industry. Recommendations included leveraging technology solutions like blockchain for improved transparency in quality evaluation and ensuring clear ownership of pledged goods to avoid potential legal disputes. These findings contribute significantly to the development of more effective SCF programs, ultimately leading to improved financial performance and competitiveness in the market.

Limitation and Future Research

While identifying and prioritizing risk factors for logistics companies in SCF is crucial for effective risk management, there are some limitations to consider. One limitation is the lack of consistency in identifying and measuring risk factors across studies. Different researchers may use different criteria to identify and measure risk factors, making it challenging to compare results across studies. Additionally, some risk factors may be more relevant to certain industries or countries, which may limit the generalizability of findings. Future research could focus on developing standardized criteria for identifying and measuring risk factors in SCF, exploring the impact of different risk mitigation strategies, and investigating the impact of technological advancements on risk factors.

One limitation relating to AHP is the potential subjectivity in the weighting of criteria and sub-criteria. Different experts or decision-makers may assign different weights to the same criteria, which could affect the prioritization of risk factors. Future research could develop more objective and standardized methods for weighting criteria and sub-criteria in AHP analysis, explore the effectiveness of using AHP analysis in practice, and examine how decision-makers perceive and use the results of AHP analysis to inform their risk management strategies.

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