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Research on the Risk Contagion and Governance Mechanism of Capital Chain Rupture in China's Construction Industry

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Abstract. (1) Currently, accounts receivable in China's construction industry have exceeded 26 trillion yuan. Influenced by the industry's unspoken rule of 'advancing funds and extended payment terms,' the problem of broken capital chains shows a trend of cash flow pressure being transmitted step by step along the industrial chain, with increasing delays in project payments. It is characterized by a concentration of fund-advancing by vulnerable intermediaries, the difficulty of recovering funds even after winning legal disputes, and the absence of industry capital protection mechanisms. This seriously undermines the wage rights of construction workers, hinders the development of the industry supply chain, and reduces the effectiveness of government regulatory policies.

(2)There is a substantial amount of research literature on this issue. Qualitative studies focus on the challenges of industry pre-financing, the empowerment provided by supply chain finance, and international risk mitigation systems, while quantitative studies concentrate on the quantification and assessment of risk factors. However, existing viewpoints fail to reflect the dynamic trend of multi-faceted and complex industry financial risks, resulting in conclusions with low applicability and a lack of consideration for full-process control enabled by technology.

(3)This article focuses on the governance of funding chain fracture risks caused by the advance payment of capital by disadvantaged intermediaries in the construction industry. The research targets intermediaries in weak positions, covering the identification, measurement, and prevention of financial risks in the domestic industry, as well as the design of preventive solutions and the construction of an intelligent risk control platform. From the perspective of supply chain finance, it integrates the innovation of engineering insurance products with intelligent risk management technology to build an AI-assisted risk analysis model, conducting research along the dual dimensions of 'product protection and technological empowerment.'

(4)Research has found that disadvantaged intermediaries face the risk of differentiated underfunding, with the risk transmitted along the hierarchy of "owner-general contractor-intermediate contractor-construction workers." The existing financial protection mechanisms in the industry have shortcomings: credit insurance coverage is low and mismatched with demand, while traditional legal and financial instruments have high thresholds and long cycles. Artificial intelligence technology can accurately identify and dynamically warn of financial risks, and innovations in construction insurance can effectively transfer and disperse risks across the industry chain.

(5)Recommendations: Develop innovative engineering insurance products, namely customized performance bonds insurance; leverage an online intelligent platform to build a full-process risk control system covering 'before, during, and after' project stages; establish escrow accounts to achieve closed-loop fund management, and utilize artificial intelligence models for precise risk prevention and control; construct a multi-party participation mechanism with clear responsibilities and obligations for macro and micro risk sharing, promoting deep integration of insurance technology with the construction industry; draw on international risk mitigation practices to optimize the domestic engineering fund risk control framework, and enhance the effectiveness of policy implementation.

(6)This study draws on the following: Methodologically, it refers to literature analysis, expert evaluation, and game theory analysis; conceptually, it draws on the core logic of the international

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engineering finance three-tier risk mitigation system, as well as the idea of integrating supply chain finance with financial technology and blockchain to optimize capital allocation; data is sourced from industry statistics, engineering cases, etc.; in terms of modeling, it incorporates artificial intelligence algorithm models such as gradient boosting decision trees and Transformers. By combining domestic practical optimization results, a dual protection mechanism and an online intelligent risk control platform were implemented. Through quantitative measurement of risk factors, simulation of game behaviors, and computational operations of AI algorithms, mathematical logic inference is accomplished, enabling precise assessment of intermediaries' default risk, validation of optimal insurance solutions, and scientific prediction of funding chain rupture risks.

Keywords: Supply Chain Finance, Construction Intermediary, Escrow Account, Performance Bond Insurance, Artificial Intelligence, Remuneration of construction workers

1. Realistic Background

The global construction industries have long been troubled by the common issue of "advance payment–delayed settlement," where small and medium-sized intermediaries face high accounts receivable volumes, and cash flow pressure is transmitted along the industry chain, triggering risks of delayed project payments and broken capital chains[1]. In China, companies pursuing litigation for rights protection often encounter the predicament of "easy to win the case, hard to collect payment," with low coverage of credit insurance and mismatches with actual needs[2]. Traditional legal remedies and financial instruments have high thresholds and long cycles[3]. Although supply chain finance, combined with fintech and blockchain technology, has optimized capital allocation and risk management, there are still shortcomings in the funding protection mechanisms for vulnerable intermediaries, and policy implementation is uneven. In the international market, government projects are prone to political and fund diversion risks, while intermediaries in multi-tier subcontracting chains face complex challenges such as profit repatriation and guarantee transfer[4]. In response, the international market has established a three-layer risk mitigation system of "front-end closed-loop financing—mid-end risk transfer—back-end liquidity realization," empowering the process through third-party custody, non-recourse factoring, and insurance tools, forming a full-chain, multi-entity governance framework. The core logic of closed-loop fund management, precise risk segmentation, and advance liquidity realization provides an important theoretical reference and practical pathway for improving domestic project fund risk prevention mechanisms[5].

2. Artificial Intelligence-Assisted Risk Analysis Model

This project, centered on artificial intelligence, aims to build a comprehensive end-to-end financial security risk control system covering 'pre-access assessment—dynamic monitoring during the process—Post-event claim settlement.' Through the collaboration of five core models, it achieves proactive identification, precise early warning, and effective prevention of financial risks for intermediaries in the construction industry. The control model is shifted from 'passive response' to 'active prevention,' providing decision-making support for government supervision, insurance, and financial institutions, and establishing a digital infrastructure for the financial security of industry intermediaries.

Table 1. Artificial Intelligence-Assisted Risk Analysis Model

Model	Main Tasks	Risk control process
A. Credit Scoring Model(Credit Scoring)	Assess the comprehensive risk of the enterprise/project entity	Pre-approval and underwriting pricing
B. Risk Clause Identification Model(Transformer)	Automatically parse contract texts, extract key clauses, and provide risk alerts	Preliminary risk assessment and contract evaluation

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C. Prediction of Capital Chain Break(LSTM/TS Forecast)	Forecasting Future Cash Shortfalls and Rupture Probabilities	In-Process Dynamic Monitoring
D. Anomaly Detection Model(Isolation Forest/AutoEncoder)	Detection of abnormalities in funds, operations, and project management	In-Process Anomaly Detection
E. Visual Progress Verification Model(YOLO/Segmentation)	Automatically identify the actual progress of on-site engineering	On-site Project Verification and Claim Decision-making

Model A (Dynamic Credit Scoring Model): It conducts a comprehensive credit assessment of the insured entities (intermediaries, general contractors, and owners) and provides a dynamic credit score. Using a gradient boosting decision tree algorithm, the input features include the entity's operational qualifications, financial status, performance behavior, project compliance, environmental and industry policies, market conditions, and historical default records; it monitors the entity's credit and performance capabilities to prevent financial losses due to default, and is applied in pre-approval and pricing processes to ensure transparent and traceable assessments.

The learning objective of the GBDT model is to minimize the loss function L:

$$F(x) = \sum_{m=1}^{M} f_m(x)$$

where f_m denotes the m-th regression tree. Taking binary classification as an example, the logistic loss is used:

$$L = -\sum_{i=1}^{n} [y_i \log p_i + (1 - y_i) \log (1 - p_i)] , p_i = \sigma\big(F(x_i)\big)$$

Each tree is boosted according to the gradient:

$$f_m = argmin_f \sum_i L\left(y_i, F_{m-1}(x_i) + f(x_i)\right)$$

The model has high interpretability, and the source of scores can be traced at any time through SHAP values.

Model B (Risk Clause Identification Model): The core function is the intelligent risk analysis of contracts and judicial texts. It utilizes a pre-trained Transformer algorithm, with data encompassing event-related contract clauses, judicial cases, environmental laws and regulations, industry standards, as well as the rights and obligations of entities and fulfillment history. Through text preprocessing, it identifies potential clause risks and prevents payment disputes, serving insurance institutions and related enterprises. It is applied in pre-event risk assessment to enhance the efficiency and reliability of risk identification.

Transformer Attention Formula:

$$Attention(Q, K, V) = softmax\left(\frac{Qk^T}{\sqrt{d_k}}\right)V$$

Assist manual review by highlighting the original text of contracts.

Model C (Funding Chain Break Prediction Model): Core function is to predict the probability of funding chain breaks and cash shortfalls. It employs LSTM or temporal Transformer algorithms, using data that includes client advance payments, accounts receivable flow data, economic and financial indicators, project progress, industry trends, policy guidance, and historical event cases; monitors fund liquidity, issues alerts for break risks, serves intermediaries, financial institutions, and regulatory bodies, enabling dynamic monitoring during events and supporting decision-making.

Input features such as special account balance, payable wages, etc., Given a time step t, the input x_t, hidden state h_{t-1}, and cell state c_{t-1} are used as inputs to the model:

$$f_t = \sigma\big(W_f[h_{t-1}, x_t] + b_f\big)$$
$$i_t = \sigma(W_i[h_{t-1}, x_t] + b_i)$$
$$c_t = f_t \cdot c_{t-1} + i_t \cdot tanh(W_c[h_{t-1}, x_t] + b_c)$$
$$h_t = o_t \cdot tanh(c_t)$$

Output future cash shortfall:

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$$\hat{y}_{t+1\ldots t+T}$$

Specify confidence intervals and integrate with the risk warning system.

Model D (Anomaly Detection Model): primarily identifies anomalies in fund flows and corporate behavior (such as misappropriation of funds and unauthorized transfers). It uses unsupervised algorithms like Autoencoder and Isolation Forest. The data includes detailed fund transactions, factor transaction features, operational behavior, records of anomalous events, and regulatory requirements; aims to prevent fund misappropriation incidents, stop losses promptly, serve financial institutions, insurance, and intermediaries, trigger real-time warnings, reduce false alarm rates, and, when necessary, freeze funds for verification.

Fund anomaly scoring formula:

$$s(x,n) = 2^{-\frac{E(h(x))}{c(n)}}$$

Construct isolation trees based on random partitioning, where anomalous samples have shorter average path lengths. A short path length indicates an anomaly; a long path length indicates normality.

Autoencoder reconstruction anomalies:

$$L = \|x - \hat{x}\|^2$$

The larger the reconstruction error, the more anomalous it is.

Model E (Visual Progress Verification Model): The core function is to verify the authenticity of construction progress through site images and prevent fraudulent fund claims. It employs algorithms such as object detection and scene segmentation, with data including construction project declarations and image materials, factors such as construction personnel and equipment data, cases of false declarations, and environmental regulatory standards. It monitors progress discrepancies to ensure that fund disbursements match progress, serving insurance companies, general contractors, and regulatory authorities, and ensuring that verification is efficient and accurate.

3. Scheme Design

3.1 Design Concept

Operating Logic.

Claim-free situation. After the guarantee contract takes effect, the insurance company shall pay interest to the project owner regularly according to the contractually agreed interest rate, thereby realizing the scheme’s "financial management function." At the start of each project stage, the project owner deposits the advance payment into a escrow account proportionally, and the insurance company returns a rebate B to the project owner (B = reserved amount in the escrow account P0 * rebate rate r > retained financing income P). The insurance company provides premium discounts to intermediaries (contractors, subcontractors) and collects their project funding data, which is displayed in real time on the online platform. Upon completion of each stage, the contractor uploads a certificate of overall project progress, and upon joint approval by the insurance company and the project owner, the stage payment is made from the escrow account. The insurance company actively invests any remaining funds in the account at each stage to increase returns. Provided that no default occurs, the contract expires at maturity.

Claim Situation. After the guarantee contract takes effect, the insurance company will pay interest to the project owner at the contractually agreed rate on a regular basis to realize the plan's "financial management function." At the start of each project phase, the owner deposits the prepayment into a escrow account in proportion, the insurance company rebates amount B to the owner, offers premium discounts to intermediaries (contractors, subcontractors), collects their project funding data, and displays it in real-time on the online platform. If, after a certain phase, the contractor receives the project payment and defaults, the online platform automatically processes the relevant claim data for damage assessment, triggers the claim conditions, resulting in accounts

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payable A (payable to subcontractor A1 and to contractor A2) losses, the insurance company pays compensation amount A, which is divided into A1 and A2 parts returned respectively to the subcontractor and the owner, and the remaining funds in the escrow account are returned to the owner, marking the conclusion of the contract.

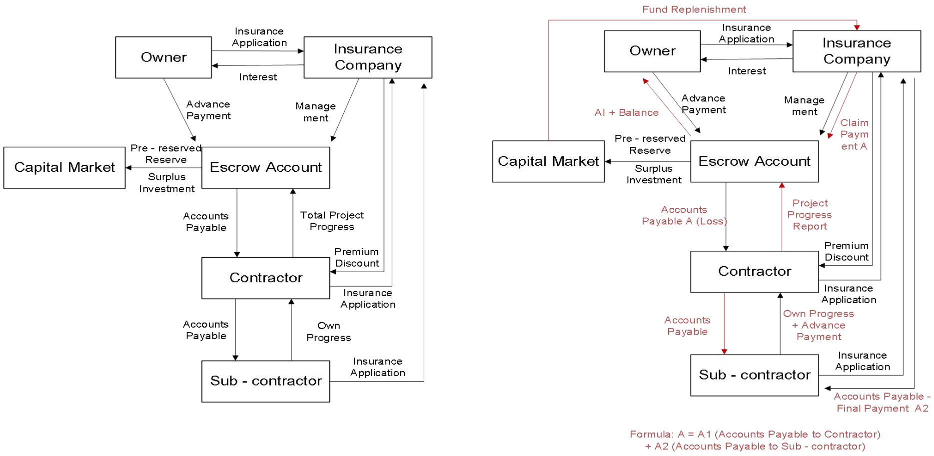

Fig. 1 Claim-free situation of plan

Game Theory Derivation.

Key Parameter Definitions: a. Owner's Financial Loss (L): The project funds withheld or the invalid construction costs already paid to the contractor when the contractor falsifies progress; b. Subcontractor's Financial Loss (M): The advance payment withheld from the subcontractor when the contractor falsifies progress; c. Contractor's Profit (G): "G = L + M" (Contractor's profit = Owner's financial loss + Subcontractor's financial loss);d. Premium (C): A small cost paid when all three parties are insured, where C is much smaller than L, M, L', M' (the cost of risk avoidance is far less than the potential loss).

However, the above represents only the ideal state of the losses and profits for each party. It is also necessary to consider: a. Owner's Non-financial Loss (L'): The penalty for schedule delays and lost market opportunities caused by project stagnation when the contractor falsifies progress; b. Subcontractor's Non-financial Loss (M'): The bankruptcy risk cost incurred by the subcontractor when loans cannot be repaid due to unrecovered advances. In the table: '0' indicates not insured, and '1' indicates insured.

Table 2. Game Theory Analysis of Plan A

Policy Combination (Owner, Contractor, Subcontractor)	Owner's payment (Y)	Contractor 's payment (C)	Subcontractor Payment (S)	Total payment of three parties	Key conclusion
(0,0,0)	-L	+G	-M	G-L-M	owners and subcontractors suffered heavy losses
(0,0,1)	-L	+G	-C	G-L-C	owner's loss not avoided
(0,1,0)	-L	-C	-M	-L-M-C	Contractor's improper profit, mutual loss
(0,1,1)	-C	-C	-C	-L-2C	The owner remains liable for core losses
(1,0,0)	-C	+G	-M	G-C-M	Subcontractor's loss not avoided
(1,0,1)	-C	+G	-C	G-2C	contractor's unjust enrichment
(1,1,0)	-C	-C	-M	-2C-M	subcontractor remains liable for losses
(1,1,1)	-C	-C	-C	-3C	optimum solution

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4. Online Platform Display

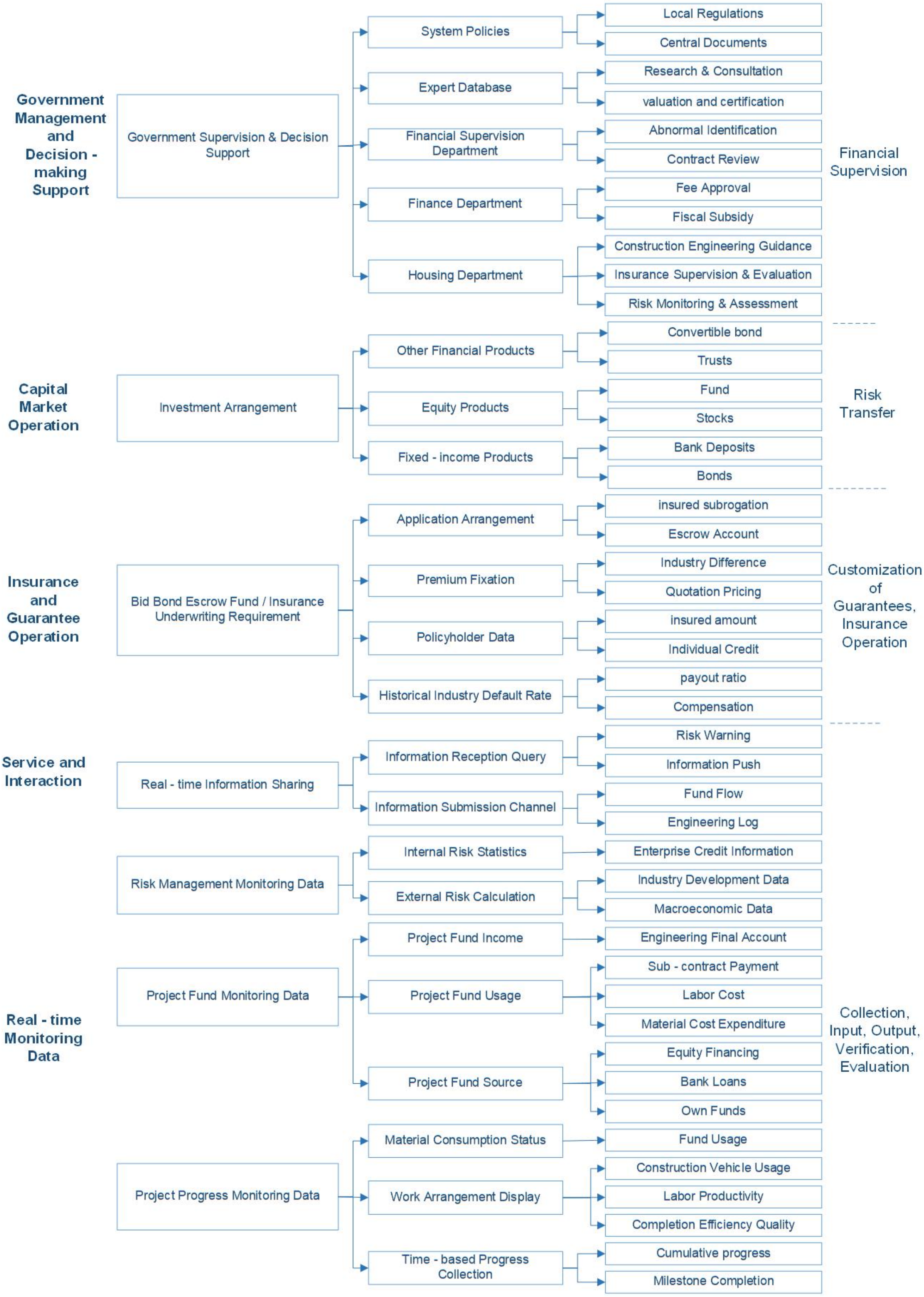

Fig. 2 Illustration of the Online Platform

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5. Simulated Scenarios

Based on the insurance plan designed in the previous section, this article constructs practical application scenarios and systematically analyzes the specific protections the plan provides for different entities from four dimensions: risk units, insured units, risk subjects, and insured subjects, as shown in the figure below.

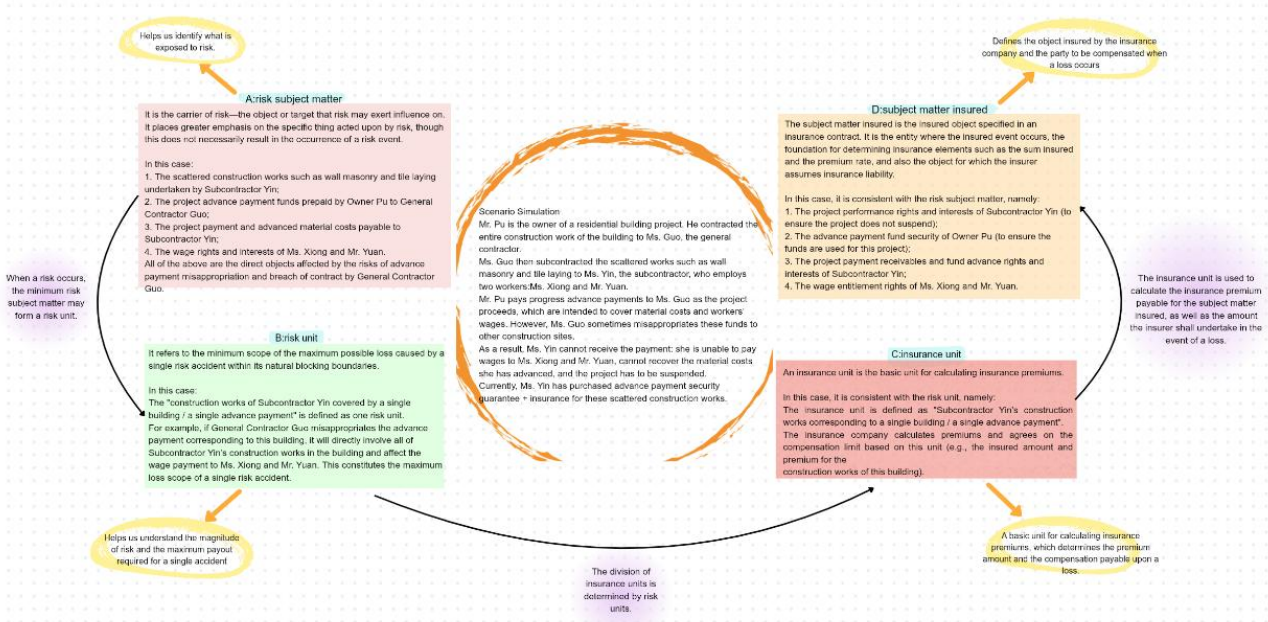

Fig. 3 Simulated Scenario Diagram

6. Feasibility Analysis

This plan stands out for its feasibility in addressing the risk of capital chain disruption in the construction industry, with its core aspects reflected in four areas: First, the model design addresses industry pain points, integrating a fund-management account closed loop, innovative financial performance guarantees, and a staged payment mechanism. This both resolves issues of advance payment misappropriation and project payment arrears, and enhances participation willingness through interest rebates and insurance premium discounts, aligning with the industry's current practice of "advance funding and extended payment terms." Second, the technical support is solid and implementable. The five AI risk control models developed cover the entire process before, during, and after projects, enabling core functions such as credit assessment, progress verification, and risk early warning. Existing algorithms and engineering digitalization technologies can support model implementation, and the online platform can achieve multi-party data interoperability and real-time supervision. Third, interest alignment forms an optimal solution. Game theory simulations validate that tri-party insurance participation is the optimal strategy, with participation costs far lower than potential losses, effectively avoiding the localized risks of single or dual-party insurance and creating shared interests and risk-sharing among owners, contractors, and subcontractors. Fourth, the plan combines experience learning with local adaptation, drawing on the core logic of international engineering capital’s three-layer risk mitigation system, integrating mature experiences such as third-party escrow and coordinated insurance tools with domestic construction industry regulatory requirements and participant characteristics, while aligning with the policy direction of integrating supply chain finance and insurtech, ensuring strong implementability. Additionally, insurance companies can achieve profitability through premium income and returns on invested escrow funds, with a self-consistent business logic and a sustainable assurance model.

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7. Conclusion

Capital chain disruption risks in the construction industry spread along the industrial chain, with advance payments and delayed project payments hindering development, harming workers' rights, and undermining supply chain stability and policy effectiveness. This paper targets vulnerable intermediaries, integrates engineering insurance and AI risk management from a supply chain finance perspective to build an AI-assisted risk model, designs an "escrow account + wealth-management performance guarantee" scheme verified by game theory, and realizes whole-process capital risk control via an intelligent online platform. It fills the research gap on multi-dimensional dynamic capital risks, transforming management from passive response to proactive prevention with a "product protection + technological empowerment" pathway. The findings incorporate international experience with local optimization, offering references for regulators, insurers and industrial participants. Future research will improve scenario adaptation, data connectivity, algorithm iteration, risk-sharing mechanisms, and the integration of insurtech and construction, so as to strengthen China's construction capital protection system, mitigate capital chain risks, protect workers' rights, and support the industry's high-quality development.

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