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Financial Fraud and Audit Failure in Listed Companies: A Case Study of Qixin Co., Ltd.

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Abstract

Against the backdrop of the full advancement of the registration-based system in China's capital market and regulators' "zero-tolerance" stance on financial fraud, systematic financial fraud of listed companies coupled with concomitant audit failures still occur frequently, severely disrupting market order and eroding investor confidence. As a listed enterprise in the architectural decoration industry, Qixin Co., Ltd. engaged in continuous financial fraud for 8 years, with cumulative false profit inflation of 2.63 billion yuan during 2012–2019, alongside major violations including embezzlement of IPO funds and irregular issuance of 3.4 billion yuan in commercial acceptance bills. The fraud was exposed in 2021 due to a capital chain rupture, and Dahua Certified Public Accountants, the auditor for eight consecutive years, issued unqualified audit opinions despite failing to perform basic verification duties, resulting in a prominent audit failure. This paper adopts a case study method to systematically analyze the specific practices, core means, underlying motives, business ethics anomie, and multi-dimensional causes of audit failure in Qixin's financial fraud. The research finds that Qixin's fraud is a joint result of actual controllers' interest drive, corporate governance defects, industry supervision loopholes, and audit supervision failure; its fraudulent acts seriously violate the good faith principle, infringe on stakeholders' rights and interests, and damage industry ecology and market fairness. The lack of risk assessment, inadequate procedure implementation, and loss of independence of audit institutions are the core causes of audit failure. This study enriches case research on financial fraud and audit failure, provides a reference framework for similar case analyses, and has practical significance for listed companies to improve governance and ethical construction, audit institutions to standardize practice, and regulators to optimize regulatory mechanisms.

Keywords: Financial Fraud; Audit Failure; Business Ethics; Fraud Triangle Theory

1. Introduction

China's capital market has entered a new stage of high-quality development with the full implementation of the registration-based system, and the crackdown on financial fraud has become a key focus of regulatory work. However, financial fraud cases of listed companies still emerge one after another, especially the "fraud upon listing" cases with long duration and large involved amount, which have become a major hidden danger affecting the healthy development of the capital market. In the architectural decoration industry, due to the characteristics of scattered projects, complex capital flow, and ambiguous cost accounting, financial fraud is more concealed and difficult to detect, and the supporting audit failure phenomenon is particularly prominent (Guangdong Enterprise Internal Control Association, 2025).

Qixin Co., Ltd., a typical listed company in the architectural decoration industry that committed financial fraud for a long time, was delisted in 2023 due to serious financial fraud, causing huge losses to investors and state-owned assets. As a rare "fraud upon listing" case in A-share history, its fraudulent practices cover the IPO application period and the post-listing period, with diverse means and complete fraud chains, and the accompanying audit failure is highly representative (Tianzhi International Certified Public Accountants, 2023).

Based on the case of Qixin Co., Ltd., this paper systematically analyzes the formation mechanism of financial fraud and the multi-dimensional causes of audit failure, and clarifies the internal and external factors of the long-term existence of financial fraud in listed companies, so as to provide targeted countermeasures and suggestions.

Theoretically, this paper deepens the application of the Fraud Triangle Theory in the research of financial fraud of listed companies in the architectural decoration industry, and enriches the theoretical system of financial fraud and audit failure research (Ye, 2024). Practically, the research results can provide reference for listed companies to improve internal control and corporate governance, audit institutions to strengthen professional skepticism and independence, and regulators to optimize the regulatory system and increase the cost of fraud, so as to build a solid defense for investor protection.

2. Overview of Qixin Co., Ltd.'s Financial Fraud

2.1. Basic Profile of the Company

Qixin Co., Ltd. (formerly Shenzhen Qixin Construction Group Co., Ltd.), founded in 1995, was listed on the Shenzhen Stock Exchange on December 22, 2015 (stock code: 002781), and delisted in July 2023 due to financial fraud (Jiangxi Qixin Group Co., Ltd., 2013–2020). Engaged in architectural decoration design and construction, the company positioned itself as a "healthy and smart human settlement solution provider", with business covering public buildings and high-end residential buildings. Its IPO issue price was 13.31 yuan per share, raising about 599 million yuan; it raised an additional 200 million yuan through non-public bond issuance in 2020, with a total direct financing of 799 million yuan (CSRC, 2023).

2.2. Core Financial Fraud Data

Qixin's financial fraud spanned 2012–2019, covering the IPO application period (2012–2014) and the five years after listing (2015–2019), with cumulative false profit inflation of 2.63 billion yuan and a maximum false increase ratio of 242.64% (Table 1). The company's actual operation was in a long-term loss state, and the fraud was eventually exposed in 2021 due to a capital chain rupture (Tianzhi International Certified Public Accountants, 2023).

Table 1. Summary of Falsely Inflated Profits and Their Proportion in Disclosed Profits of Qixin Co., Ltd. (2012–2019)

Year	Falsely Inflated Profits (100 million yuan)	Proportion in Disclosed Profits (%)
2012	2.24	127.21
2013	2.51	131.96
2014	3.70	162.94
2015	3.71	179.68
2016	3.25	203.47
2017	3.97	201.35
2018	3.79	158.94
2019	3.12	242.64

2.3. Core Fraudulent Means

Qixin adopted a full-chain fraudulent model involving revenue, cost, assets, liabilities and funds, with concealed and diverse means, and even forged key audit evidence to evade verification (CSRC, 2023).

Revenue inflation. The company forged more than 200 engineering contracts, a typical case being inflating the amount of the curtain wall project of a Shenzhen science and technology park from 30 million yuan to 200 million yuan. It also set up over 20 shell companies and signed false trade contracts with them. Through the above two methods, the company falsely increased its total revenue by 2.105 billion yuan, of which 1.31 billion yuan came from forged engineering contracts and 795 million yuan from false transactions with shell companies.

Cost manipulation. The company tampered with the purchase prices of raw materials, for example, cutting the unit purchase price of stone from 800 yuan per square meter to 300 yuan per square meter, and made off-book payments to suppliers through personal accounts. These practices led to a cumulative understatement of costs by 2.16 billion yuan, ultimately pushing the

company's disclosed gross profit margin to 35%, while its actual gross profit margin was only 12%.

Asset inflation. The company inflated accounts receivable by fabricating transactions. The book balance of accounts receivable at the end of 2019 stood at 3.378 billion yuan, 70% of which was false. It also improperly recorded waste building materials at construction sites under the construction in progress account. Through these two types of practices, the company falsely increased its total assets by 970 million yuan.

Irregular handling of liabilities and funds. The actual controller of the company embezzled 131 million yuan of IPO funds through false transactions, and irregularly issued 3.4 billion yuan of commercial acceptance bills, concealing these bills under the other payables account. By this means, the company falsely reduced its asset-liability ratio from the actual 85% to 73%.

Evasion of audit verification. The company forged bank statements, fabricating 1.5 billion yuan of monetary funds at the Shenzhen Branch of Ningbo Bank, and also forged customer confirmation records. It manipulated its self-developed information system to input false data and deliberately restricted auditors' access to the company's core business data.

2.4. Abnormality of Key Financial Indicators

Qixin's fraud led to serious deviations between disclosed and actual key financial indicators, misleading investors' judgment on the company's operating conditions and financial risks (Table 2). Specifically, the company's disclosed inventory turnover rate, accounts receivable turnover rate, and gross profit margin were significantly higher than the actual values, while the disclosed asset-liability ratio was notably lower than the actual value. These distorted indicators disguised the company's real operational and financial risk status.

Table 2. Analysis of the Correlation between Key Indicators and Fraud of Qixin Co., Ltd.

Indicator Name	Actual Value	Disclosed Value	Abnormal Performance
Inventory Turnover Rate	1.2 times/year	4.5 times/year	3.75 times the actual value
Accounts Receivable Turnover Rate	0.8 times/year	3.2 times/year	4 times the actual value
Gross Profit Margin	12%	35%	2.92 times the actual value
Asset-Liability Ratio	85%	73%	12 percentage points lower than actual

3. Theoretical Framework: Fraud Triangle Theory

In the research of corporate financial fraud, the Fraud Triangle Theory, has been widely applied and expanded, and scholars believe that the external environment factor is an important supplementary condition for the three core factors.

Pressure is the internal driving force for fraud, referring to the various economic and non-economic pressures faced by the fraud subject, such as meeting financing thresholds, maintaining stock price stability, and realizing equity cash-out (Guangdong Enterprise Internal Control Association, 2025). For listed companies, pressure mainly comes from IPO profit requirements, refinancing conditions, and the performance assessment of actual controllers and management (Zhang & Qian, 2023).

Opportunity is the objective condition for the occurrence of fraud, referring to the loopholes and defects in the internal and external supervision system that make fraud possible, such as the collapse of corporate governance, the failure of audit supervision, and the characteristics of the industry that are conducive to fraud concealment (CSRC, 2023). The higher the degree of information asymmetry and the more imperfect the internal control system, the greater the fraud opportunity (Ye, 2024).

Rationalization is the psychological basis for fraud, referring to the fraud subject's self-justification for fraudulent behavior to eliminate moral guilt, such as regarding fraud as a "temporary measure for enterprise development" or "reasonable return for operation" (Li & Wu, 2024). The weak sense of legal and moral constraints of the subject is an important reason for the formation of rationalization motives.

On the basis of the classic Fraud Triangle Theory, this paper adds the external environment factor as the fourth analysis dimension, including institutional defects, weak regulatory penalties, and acquiescence of stakeholders, which is an important external condition for the long-term existence of financial fraud (Wang & Liu, 2023). The four factors interact and reinforce each other, forming a complete fraud formation mechanism.

4. Multi-dimensional Analysis of Qixin's Financial Fraud Motives Based on the Expanded Fraud Triangle Theory

4.1. Pressure Motives: The Internal Driving Force of Fraud

Qixin's pressure motives showed obvious stage characteristics, which were closely linked to the company's IPO, post-listing refinancing and actual controller's cash-out needs (Table 3) .

IPO Preparation Period (2012–2014): Faced with weak market competitiveness (newly signed contracts less than 1/20 of leading enterprises such as Gold Mantis) and continuous actual losses (-120 million, -80 million, -150 million yuan respectively), the company had to fabricate profits to meet the IPO threshold of "cumulative net profit of more than 30 million yuan in three years". The total falsely increased profit in three years was 845 million yuan, successfully packaging "continuous losses" into "sustained profitability".

Early Listing Period (2015–2016): To avoid stock price plummeting due to the disclosure of actual losses (-180 million yuan in 2015) and meet the refinancing requirement of "weighted average return on net assets not less than 6%" (actual only 1.2%-2.5%), the company upgraded its fraud model (Jiangxi Qixin Group Co., Ltd., 2013–2020). Falsely increased revenue soared by 248.8% year-on-year in 2015, and the proportion of falsely increased profits in disclosed profits reached a record high of 203.47% in 2016.

Critical Cash-out Period (2017–2019): Driven by the actual controller's equity cash-out demand, the company shifted its fraud focus to "Balance Sheet Beautification" (Wang & Liu, 2023). Falsely increased accounts receivable soared by 238.10% year-on-year in 2017, and the proportion of falsely increased profits in disclosed profits reached 242.64% in 2019, paving the way for high-premium equity transfer (Tianzhi International Certified Public Accountants, 2023). The actual controller cashed out a total of 2.02 billion yuan from 2016 to 2020, accounting for 92% of the total shareholding value (CSRC, 2023).

Table 3. Core Financial Fraud Data of Qixin Co., Ltd. (2012–2019, 10,000 yuan)

Data Type	2012	2013	2014	2015	2016	2017	2018	2019
Falsely Increased Revenue	25591.47	13413.82	12540.85	43740.72	28725.74	2234.28	4332.19	0.00
Falsely Increased Profits	22404.80	25121.56	37002.70	37089.22	32518.24	39690.38	37928.10	31200.00
Falsely Increased Accounts Receivable	0.00	0.00	0.00	86450.00	100539.00	339900.00	356800.00	337800.00
Understated Costs and Expenses	0.00	365.18	520.92	602.10	828.06	1379.11	338.96	0.00
Concealed Off-balance-sheet Liabilities	0.00	0.00	0.00	50000.00	80000.00	100000.00	60000.00	50000.00
Falsely Increased Assets	0.00	0.00	0.00	0.00	32000.00	45000.00	12000.00	8000.00

4.2. Opportunity Motives: The Objective Condition of Fraud

Qixin's fraud had sufficient objective opportunities due to the collapse of corporate governance, the failure of audit supervision and the characteristics of the architectural decoration industry (Ye, 2024).

Collapse of corporate governance: The actual controller held 58% of the shares directly and indirectly, forming absolute control. The board of directors was dominated by related parties (4 out of 7 directors), and independent directors were dependent and failed to question abnormal financial data; the board of supervisors had members concurrently holding management positions and failed to perform supervision duties; the internal control implemented the "actual controller's One-Signature System", providing unrestricted internal space for fraud.

Audit supervision failure: Dahua Certified Public Accountants served as the company's auditor for eight consecutive years and received more than 12 million yuan in audit fees, which accounted for 3% of the firm's annual income. The firm evaded core risk points during risk assessment and failed to carry out key verification procedures, such as directly adopting forged bank statements. Under the threat of being replaced by the company, it even deleted risk prompts in its working papers and kept issuing unqualified audit opinions (Li & Wu, 2024).

Facilitation from industry characteristics: The architectural decoration industry features scattered projects, complex capital circulation and ambiguous cost accounting, all of which form a natural concealment barrier for fraudulent acts. Specifically, the company fabricated as many as 5,000 projects across more than 20 provinces, realized cross-regional capital loops through over 20 shell companies, and conducted scattered procurement without obtaining formal invoices (Guangdong Enterprise Internal Control Association, 2025).

4.3. Rationalization Motives: The Psychological Basis of Fraud

All parties involved in the fraud formed their own rationalization logic, eliminating moral guilt and legal awe, which became the psychological support for the long-term occurrence of fraud (Li & Wu, 2024).

Actual controller: Justified fraud as "helping the company obtain financing and solving employment for more than 2,000 employees" and cash-out as "reasonable return for years of operation", and held a fluke mentality due to the huge gap between illegal gains (2.02 billion yuan in cash-out) and punishment costs (300,000 yuan in fines) (CSRC, 2023).

Management: Faced with the threat of dismissal for refusing to commit fraud (2 department managers were dismissed), they regarded fraud as a "passive choice to keep high-paying jobs", and obtained additional benefits such as "fraud bonuses" (the CFO received 5 million yuan in 2018–2019), even mistaking fraud for an "industry unspoken rule" (Tianzhi International Certified Public Accountants, 2023).

Audit institution: Prioritized "retaining long-term business" over audit responsibilities, attributed the failure to detect fraud to "Qixin's professional fraud methods beyond conventional audit procedures", and used "high industry verification difficulty" as an excuse to rationalize dereliction of duty (Li & Wu, 2024).

4.4. External Environment Motives: The Supplementary Condition of Fraud

The institutional defects in the capital market, weak regulatory penalties and acquiescence of various stakeholders reduced the cost of fraud and became an important external condition for the long-term existence of Qixin's fraud (Wang & Liu, 2023).

Institutional defects: Prior to 2019, the IPO review system placed excessive emphasis on profit indicators while leaving authenticity verification vulnerable. Substantive verification was largely delegated to intermediaries with conflicts of interest, creating systemic loopholes. Penalties for financial fraud under the Securities Law were extremely lenient, with offending companies facing a maximum fine of only 600,000 yuan. Meanwhile, criminal liability was rarely pursued, and as of 2024, no core responsible personnel had been held criminally accountable (Standing Committee of the National People's Congress, 2025; CSRC, 2023).

Acquiescence of stakeholders: Local governments designated Qixin as a key supported enterprise and granted tax reductions and subsidies to boost local listing figures. State-owned asset platforms, including Xinyu Investment and Control Group, rushed to invest simply to meet investment promotion targets, without conducting on-site due diligence. Affected by information asymmetry, small and medium-sized investors chased rising prices blindly, which reinforced a self-reinforcing cycle between inflated stock prices and speculative buying (Guangdong Enterprise Internal Control Association, 2025).

5. Business Ethics Anomie in Qixin's Financial Fraud

5.1. Ethical Problems of Key Governance Entities

Qixin's financial fraud is essentially a collective anomie of business ethics of key governance entities, which completely abandoned professional ethics and statutory obligations.

Management: As the direct executor of fraud, it violated fiduciary obligations, led the implementation of full-chain fraud (forging contracts, tampering with data, embezzling funds), treated capital market trust as a profit tool, and even provided false materials to regulatory authorities, showing double disregard for ethical norms and laws (CSRC, 2023).

Directors: The board of directors was completely controlled by the actual controller; directors (including independent directors) failed to perform review and supervision duties, did not question the abnormal gross profit margin (35% far exceeding the industry average), and even approved fraud-related resolutions (e.g., falsely increasing construction in progress by 120 million yuan in 2018) (Ye, 2024). Independent directors, as "protectors of small and medium-sized shareholders", remained silent throughout the fraud, becoming "vase directors" (Fujian Regulatory Bureau of CSRC, 2024).

Supervisors: The board of supervisors was completely ineffective; supervisors either concurrently held management positions or were subordinates of the actual controller, did not conduct substantive verification of false financial statements and fund embezzlement for 8 years,

and all supervision reports disclosed “no violations found”, abandoning statutory supervision responsibilities (CSRC, 2023).

5.2. Root Causes of Ethical Anomie

The collective ethical collapse of Qixin’s governance entities is the result of the joint action of equity structure, ethical education, illegal costs and accountability mechanisms (Wang & Liu, 2023):

Unbalanced equity structure: The actual controller’s absolute holding led to the “dominance of a single shareholder”, making the ethical bottom line give way to personal interests (Ye, 2024).

Lack of professional ethics education: Directors, supervisors and management had a vague understanding of fiduciary duties and lacked awe for business ethics and laws (Fujian Regulatory Bureau of CSRC, 2024).

Low illegal costs: The light punishment for financial fraud made governance entities hold a fluke mentality and ignore ethical and legal constraints (CSRC, 2023).

Absence of accountability mechanisms: The supervision and decision-making responsibilities of directors and supervisors were mere formalities, and there was no effective accountability for dereliction of duty.

5.3. Enlightenments of Ethical Construction

Business ethics is the core cornerstone of the sustainable development of listed companies . To prevent ethical anomie, it is necessary to: clarify the ethical responsibilities of governance entities through improving laws and regulations and increase punishment for dereliction of duty; strengthen professional ethics education and incorporate integrity and responsibility into employment requirements ; improve the internal checks and balances mechanism, break the “dominance of a single shareholder” dilemma, and ensure the independent performance of duties by directors and supervisors (Wang & Liu, 2023).

6. Analysis of the Causes of Audit Failure in Qixin’s Case

The audit failure of Dahua Certified Public Accountants in Qixin’s case is the result of the joint action of the audit institution’s own defects, the audited entity’s ethical collapse and the lag of the external supervision environment (Li & Wu, 2024). Among them, the audit institution’s dereliction of duty is the direct cause, the audited entity’s systematic fraud is the fundamental obstacle, and the external supervision lag is the important inducement (Chinese Institute of Certified Public Accountants [CICPA], 2022).

6.1. Audit Institution Level: Major Defects in Audit Procedures and Loss of Professional Ethics

Dahua Certified Public Accountants failed to fulfill the basic audit obligations, with serious defects in risk assessment, procedure implementation and independence maintenance, which is the direct cause of audit failure (Li & Wu, 2024).

Lack of professional skepticism: Failed to list "actual controller's high shareholding ratio" and "industry's complex capital flow" as high-risk areas, and explained the abnormal gross profit margin as "regional competitive advantage", avoiding core risk points in risk assessment (CICPA, 2022).

Inadequate execution of key audit procedures: Did not send bank confirmation letters independently, directly adopted forged bank statements (fabricating 1.5 billion yuan of monetary funds); did not perform confirmation procedures on 70% of the false accounts receivable, relying only on forged customer confirmation letters; the on-site verification coverage rate of inventory and construction in progress was less than 5%, failing to discover the incorrect classification of waste building materials (CSRC, 2023).

Impaired audit independence: Long-term cooperation (8 consecutive years) led to the audit team being too familiar with the management; under the threat of Qixin to "replace the audit institution", it arbitrarily deleted the risk prompt of "3.3 billion yuan of accounts receivable with recovery risks" in the working papers and continued to issue unqualified audit opinions, completely losing audit independence (Li & Wu, 2024).

6.2. Audited Entity Level: Systematic Fraud and Collapse of Internal Control

Qixin's full-chain, systematic financial fraud and the complete collapse of internal control made it difficult for the audit institution to obtain true and effective information, which is the fundamental obstacle to the smooth progress of the audit (CICPA, 2022). The company's directors, supervisors and management collaborated in fraud, forged all key audit evidence (bank statements, customer confirmations, project contracts), manipulated IT systems to input false data, and restricted the audit institution's access to core business data, forming a "closed-loop fraud system". The complete failure of the company's internal control system made the internal audit and supervision mechanism lose its effect, and the audit institution could not obtain effective internal support for the audit work (Wang & Liu, 2023).

6.3 External Environment Level: Lag of Supervision System and Ineffective Market Constraints

The lag of the audit supervision system and the ineffective market constraint mechanism weakened the supervision of audit institutions, which is an important inducement of audit failure.

Lag of regulatory supervision: Regulatory authorities failed to detect and stop Qixin's 8-year continuous fraud in a timely manner, and the supervision of audit institutions' practice behavior was insufficient; the punishment for audit failure was light, and the deterrence to audit institutions was weak (Li & Wu, 2024).

Ineffective market constraints: Under the condition of information asymmetry, ordinary investors lacked professional ability to verify the authenticity of audit reports, and the market's "vote with feet" mechanism failed to reflect the company's true value in a timely manner; the industry self-regulation mechanism of certified public accountants was not perfect, and there was a lack of effective supervision on the practice quality of accounting firms (CICPA, 2022).

6.4. Conclusion of Audit Failure Analysis

The audit failure in Qixin's case is a typical result of the joint action of multiple factors (Li & Wu, 2024). As a professional "economic policeman" in the capital market, Dahua Certified Public Accountants failed to abide by auditing standards and professional ethics, with serious dereliction of duty in audit procedures, and is the direct responsible party for the audit failure and investor losses. The audited entity's systematic fraud and internal control collapse are the objective obstacles of the audit work, and the lag of the external supervision system and ineffective market constraints are the important external conditions for the audit failure.

7. Conclusions and Implications

7.1. Research Conclusions

Qixin Co., Ltd.'s financial fraud is a typical "fraud upon listing" case in A-share market, with the characteristics of long duration, large involved amount, diverse means and complete fraud chain. The fraud is the result of the joint action of pressure, opportunity, rationalization and external environment factors based on the expanded Fraud Triangle Theory.

The collective anomie of business ethics of Qixin's key governance entities is the internal root of the fraud, and the unbalanced equity structure, lack of ethical education, low illegal costs and absence of accountability mechanisms are the core causes of ethical anomie.

The audit failure in Qixin's case is driven by three interrelated factors: internal deficiencies within the audit institution, including insufficient professional skepticism, inadequate implementation of audit procedures, and compromised independence; systematic fraud committed by the audited entity; and the lagging external supervision environment. As the auditor responsible for the engagement, Dahua Certified Public Accountants failed to perform its basic verification obligations and is the direct party liable for this audit failure.

Qixin's fraud and the accompanying audit failure have caused huge losses to investors and state-owned assets, seriously damaged the market order and investor confidence, and exposed the defects of corporate governance, audit supervision and regulatory system in China's capital market.

7.2 Practical Implications

For listed companies: Improve the corporate governance structure, break the "dominance of a single shareholder" dilemma, and strengthen the independent supervision function of independent directors and the board of supervisors; establish a sound internal control system, standardize the management of project contracts, capital flow and financial data, and eliminate the internal space for fraud; strengthen professional ethics education, incorporate integrity and responsibility into the corporate culture, and establish a sound internal accountability mechanism.

For audit institutions: Strengthen professional skepticism, improve the risk assessment system, and list the high shareholding ratio of actual controllers and industry-specific risks as key audit points; strictly implement audit procedures, independently perform confirmation procedures for

key items such as bank deposits and accounts receivable, and increase the on-site verification ratio of physical assets; maintain audit independence, avoid long-term cooperation with a single audited entity, and establish a sound internal quality control system to prevent the loss of independence due to interest pressure.

For regulatory authorities: Optimize the regulatory system, shift the focus of IPO review from profit indicators to the authenticity and sustainability of operating conditions; increase the punishment for financial fraud and audit failure, raise the illegal cost of all parties involved, and pursue criminal liability of core personnel in accordance with the law; strengthen the supervision of the architectural decoration industry, formulate detailed information disclosure requirements, and reduce the concealment of fraud ; improve the investor protection mechanism, establish a sound compensation system for securities fraud, and protect the legitimate rights and interests of small and medium-sized investors.

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Jiaxuan Li contributed to the conceptualization, methodology, and data analysis of the study. All authors have read and agreed to the published version of the manuscript.

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The data supporting the findings of this study are available from the China Securities Regulatory Commission (CSRC) official announcements, Jiangxi Qixin Group Co., Ltd.'s annual reports and prospectus (2012–2019), Wind Financial Terminal and industry research reports on China's architectural decoration industry. Restrictions apply to the availability of these data, which were used under license for the current study. Data are available from the corresponding author upon reasonable request and with permission of the above institutions.

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Conflicts of Interest:

The authors declare no conflict of interest.

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Standardization, Customization and Industrial Performance: A Socio-Technical Study of Suspension System Design for Motorcycles and Electric Two-Wheelers Based on T/ZZB 3029—2022

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Abstract

Based on the group standard T/ZZB 3029—2022 for motorcycle shock absorbers, this study develops an integrated analytical framework for suspension system design, verification, and customized research and development (R&D) for motorcycles, mopeds, and electric two-wheelers. Moving beyond a purely technical perspective, the paper adopts a socio-technical approach to examine how standardized engineering specifications interact with manufacturer-oriented customization demands in contemporary vehicle industries. The study systematically constructs a full-process technical system encompassing high-precision spring design, multi-dimensional damper tuning, structural strength verification, whole-vehicle matching, and lifecycle quality control. Through standardized procedures such as ex-factory inspection, type testing, environmental adaptability evaluation, and durability verification, the research demonstrates how the integration of “standard compliance” and “scenario-based customization” enables effective coordination between safety, handling performance, riding comfort, and long-term durability. Furthermore, the findings reveal that the implementation of T/ZZB 3029—2022 not only improves the consistency and reliability of suspension systems but also establishes a data-driven and process-oriented quality governance mechanism. This mechanism enhances industrial coordination, reduces performance variability, and supports differentiated product development across various vehicle categories. By linking engineering design practices with institutional standardization frameworks, this study contributes to interdisciplinary discussions on the role of technical standards in shaping industrial performance and technological innovation. It provides a replicable and scalable technical paradigm for the development of high-quality suspension systems in the motorcycle and electric two-wheeler industry.

Keywords: Motorcycles; Suspension System; Standardization; Industrial Application; Customized R&D

1. Introduction

Motorcycles, mopeds and electric two-wheelers have become essential means of transportation for short-distance travel, urban logistics distribution and daily commuting in both urban and rural areas of China (Ferrari et al., 2024). With the continuous expansion of market demand and application scenarios, these vehicles are undergoing rapid technological evolution toward high performance, lightweight design, intelligence and enhanced riding comfort. As a critical subsystem of the vehicle chassis, the suspension system plays a fundamental role in absorbing road impacts, attenuating vibrations, controlling body posture and maintaining tire-ground contact, thereby directly influencing driving safety, handling stability and user experience.

From a dynamic perspective, the performance of the suspension system determines the ability of the vehicle to respond to complex road excitations (Lopes et al., 2023; Ferhath & Kasi, 2024). Inadequate suspension performance may lead to excessive vibration transmission, poor tire adhesion and unstable body posture, which in turn affect braking efficiency, cornering stability and overall vehicle controllability. Therefore, the suspension system is not only a functional component but also a key factor in ensuring the operational safety and performance reliability of motorcycles and electric two-wheelers.

At present, the industry exhibits significant differentiation in application demands. Fuel motorcycles, particularly large-displacement sport models, emphasize high-speed stability, cornering handling and reliability under extreme working conditions. Mopeds, mainly used for urban commuting, prioritize cost controllability, structural simplicity, ease of installation and basic comfort performance (Wallius et al., 2022). Electric two-wheelers, driven by the rapid development of electrification, place greater emphasis on refined vibration filtering, long-endurance adaptability and lightweight structural design. Under such diversified demand scenarios, manufacturers no longer regard suspension systems as merely “functional components,” but instead require them to achieve precise matching with the whole vehicle, stable performance under varying conditions, strict compliance with technical standards and optimal cost efficiency.

However, despite the rapid development of the industry, there remain several prominent challenges. On the one hand, traditional suspension system design has long relied on empirical methods and iterative testing, leading to issues such as inconsistent performance indicators, insufficient comparability of test results and large fluctuations in product quality. On the other hand, the lack of unified technical specifications across different vehicle categories has made it difficult to achieve standardized design, verification and evaluation processes, thereby increasing development costs and quality risks for manufacturers.

Against this background, the group standard T/ZZB 3029—2022 Shock Absorbers for Motorcycles and Mopeds establishes a unified and systematic technical framework covering material selection, structural design, performance parameters, test methods, service life evaluation and failure protection (Brand Construction Federation of Zhejiang Province, 2022; Zhejiang Bicycle and Electric Vehicle Association, 2023). By defining clear technical indicators and standardized testing procedures, the standard effectively addresses long-standing issues such as inconsistent industry benchmarks, non-standardized testing methods and uneven product quality.

More importantly, it provides a structured foundation for integrating engineering design with quality control and verification processes, promoting the transition from experience-driven development to standardized and data-driven engineering practices. In addition, although the standard is primarily formulated for motorcycles and mopeds, its technical framework and evaluation methods also provide important reference value for the development of suspension systems for electric two-wheelers, a field where specialized standards are still relatively insufficient. This further highlights the broader applicability and industrial significance of the standard in supporting emerging transportation technologies.

Based on this context, this paper integrates the core design and verification technologies of shock absorbers with manufacturer-oriented customized R&D requirements, and systematically constructs a full-process technical system for suspension development. By establishing a closed-loop framework of "standard – design – adjustment – verification – mass production," the study aims to bridge the gap between standardized technical requirements and differentiated application scenarios. Specifically, this research focuses on high-precision spring design, multi-dimensional damper characteristic adjustment, structural strength verification, whole-vehicle parameter matching and real-vehicle tuning processes, while incorporating rigorous testing and quality control mechanisms throughout the product lifecycle. Through this integrated approach, the paper not only provides practical engineering solutions for suspension system development, but also explores how technical standards can function as both engineering tools and organizational mechanisms in improving product consistency, reducing development risks and enhancing industrial coordination.

2. Core Functions of Suspension System and Support of Standard System

2.1. Decisive Role of Suspension System in Vehicle Performance

The suspension system, composed of elastic elements (springs), damping elements (shock absorbers), and structural guiding components, plays a fundamental role in regulating the dynamic interaction between the vehicle and road surface (Cao et al., 2011; Ferhath & Kasi, 2024). Its primary function is not limited to absorbing road impacts and reducing vibration transmission, but extends to maintaining vehicle stability, controlling body posture and ensuring continuous tire-ground contact under varying driving conditions. Through coordinated action between elasticity and damping, the suspension system effectively suppresses undesirable dynamic behaviors such as excessive bounce, roll, pitch and lateral instability, thereby directly influencing braking performance, cornering precision and overall driving safety.

From an engineering and industrial perspective, suspension performance has become a key determinant of product competitiveness and user experience. Inadequate suspension design often leads to issues such as brake deviation, high-speed instability, excessive body roll and resonance under continuous road excitation, as well as durability failures such as oil leakage and component fatigue. These problems not only affect safety but also significantly influence manufacturer reputation and market acceptance. Therefore, the suspension system should be understood as a

critical subsystem within a broader socio-technical framework, where engineering performance, user expectations and industrial standards are closely interconnected.

2.2. Core Value and Applicable Boundary of T/ZZB 3029—2022

T/ZZB 3029—2022 serves as a specialized group standard that establishes a unified technical framework for the design, manufacturing, inspection and evaluation of motorcycle and moped shock absorbers. Covering a wide range of product categories, including front and rear shock absorbers, inflatable shock absorbers and spring assemblies, the standard defines comprehensive performance indicators and standardized testing procedures. Its core value lies in constructing a consistent and traceable system for evaluating damping characteristics, structural strength, durability and environmental adaptability, thereby addressing long-standing issues such as fragmented technical criteria, inconsistent testing methods and uneven product quality across the industry.

More importantly, the standard functions not only as a technical specification but also as an institutional mechanism for industrial coordination and quality governance. By introducing graded performance requirements for different vehicle types and usage scenarios, it enables manufacturers to achieve a balance between standard compliance and differentiated product development. At the same time, the standard promotes the transition from experience-based design toward rule-based and data-driven engineering practices, enhancing the comparability and reliability of products. Although primarily formulated for motorcycles and mopeds, its technical framework also provides an important reference for the development of suspension systems for electric two-wheelers, thereby extending its applicability and reinforcing its role in supporting emerging mobility technologies.

3. Core Design Technologies of Suspension System Based on Standards

3.1. High-Precision Spring Design and Durability Control

As the primary elastic element of the suspension system, the spring determines the fundamental vibration response characteristics and load-bearing capacity of the system. High-precision control of spring stiffness is essential for achieving a balance between riding comfort and handling stability (Cao et al., 2025). In accordance with the requirements of T/ZZB 3029—2022, the rigidity deviation is strictly limited within ±6%, and computer-aided engineering (CAE) methods are employed to optimize key structural parameters such as wire diameter, coil number and free height. This ensures compliance with the Grade 2 accuracy standard specified in GB/T 1239.2, thereby enhancing design reliability from the source.

In addition to stiffness accuracy, durability is a critical factor influencing long-term performance. The standard requires that, after 200,000 consecutive compression cycles within the working stroke, the permanent deformation of the spring must not exceed 2% of its original free height. To meet this requirement, high-performance alloy spring steel is selected, and advanced manufacturing processes such as heat treatment, shot peening and pre-compression are adopted to improve fatigue resistance. Through the integration of material optimization and structural design,

the spring is able to maintain stable performance under complex loading conditions, ensuring long-term reliability of the suspension system.

3.2. Multi-Dimensional Characteristic Adjustment Technology of Dampers

The damper is the core component responsible for vibration attenuation and dynamic control within the suspension system, and its performance is determined through the coordinated adjustment of indicator characteristics, speed characteristics and temperature characteristics. From a system design perspective, damper tuning involves shaping the force–velocity relationship to ensure appropriate response under different excitation conditions (Yang et al., 2022). According to T/ZZB 3029—2022, the buffer resistance of the front shock absorber must not be less than 200% of the rebound resistance, enabling rapid energy absorption during sudden impacts and preventing excessive body oscillation.

Furthermore, the standard introduces differentiated tolerance requirements for damping forces based on vehicle type and application scenario. For example, ordinary motorcycles and mopeds emphasize a balance between comfort and stability, while racing motorcycles prioritize precise control under high-speed and extreme conditions. In addition, temperature adaptability is incorporated as a key evaluation dimension, with strict limits on resistance attenuation under high-temperature conditions to ensure consistent performance during prolonged operation. This multi-dimensional adjustment framework reflects the integration of standardized constraints with scenario-based customization, enabling more accurate matching between suspension performance and vehicle requirements.

3.3. Structural Strength and Connection Reliability Design

Structural strength constitutes the physical foundation for the safe and reliable operation of the suspension system. Under the framework of T/ZZB 3029—2022, strength verification focuses on both core load-bearing components and critical connection structures. Key components such as lifting rings and aluminum cylinders are required to meet minimum strength thresholds of 15 kN, ensuring their ability to withstand extreme loads and impact conditions during vehicle operation. At the same time, fatigue performance under cyclic loading is considered to guarantee long-term structural stability.

Welding quality, as a critical factor affecting structural integrity, is subject to strict control requirements. Welded joints must be free from defects such as cracks, slag inclusion and porosity, and must pass high-cycle vibration durability tests to ensure reliability under continuous dynamic loading. In addition, sealing and dustproof structures are optimized through the use of multi-layer oil seals and protective covers, preventing the intrusion of contaminants and maintaining the cleanliness and functionality of internal components. These measures collectively form a comprehensive structural reliability assurance system that integrates design, manufacturing and verification processes.

3.4. Whole-Vehicle Matching Design for Manufacturers

The performance of the suspension system cannot be evaluated in isolation but must be understood within the context of the complete vehicle system. Whole-vehicle matching design

emphasizes the coordinated optimization of suspension parameters with vehicle load characteristics, structural layout and operating conditions. Depending on vehicle type, parameters such as load capacity, suspension stroke and stiffness must be carefully adjusted to achieve an optimal balance between comfort, handling and safety. For instance, electric two-wheelers typically require longer suspension travel and softer tuning to enhance comfort, while sport motorcycles adopt shorter travel and higher stiffness to improve responsiveness and control precision.

In addition, system-level coordination is essential to avoid issues such as structural interference, resonance and energy loss. This involves matching the suspension system with frame geometry, power system vibration characteristics and tire-road interaction properties. From a broader perspective, whole-vehicle matching represents the practical implementation of a socio-technical integration process, in which standardized technical requirements are translated into customized engineering solutions tailored to specific usage scenarios. Through this approach, manufacturers are able to achieve both compliance with technical standards and differentiation in product performance, thereby enhancing overall competitiveness in a rapidly evolving market environment.

4. Manufacturer-Oriented Real-Vehicle Adjustment Process of Suspension System

4.1. Pre-Adjustment Preparation

The real-vehicle adjustment process of suspension systems begins with systematic preparation based on comprehensive vehicle-level data collection. Key parameters such as curb weight, maximum load, center of gravity position, wheelbase, tire specifications, expected road conditions, operating speed range and user behavior characteristics must be accurately obtained to establish a reliable basis for parameter configuration. These data not only define the boundary conditions of suspension performance but also reflect the interaction between vehicle structure, usage scenarios and user expectations.

On this basis, initial parameter settings are determined according to the positioning of the vehicle model. Preload, compression damping and rebound damping are preliminarily configured to form a baseline tuning scheme. For example, electric two-wheelers tend to adopt softer damping characteristics to enhance comfort and vibration filtering, while sport motorcycles emphasize higher stiffness and stronger damping response to improve handling stability. This stage represents the integration of standardized technical parameters with scenario-oriented customization, laying the foundation for subsequent dynamic adjustment.

4.2. Standardized Steps of Real-Vehicle Adjustment

Real-vehicle adjustment is carried out through a standardized and iterative process combining road testing and parameter optimization. The initial stage involves comprehensive testing on representative road conditions, including asphalt, concrete, uneven surfaces, potholes and curved sections, in order to evaluate key performance indicators such as vibration transmission, body

attitude control, rebound response and overall ride quality. These empirical observations provide direct feedback on the effectiveness of initial parameter settings.

Based on the test results, targeted optimization of suspension parameters is conducted. Adjustments are made according to specific performance deviations, such as reducing damping forces to alleviate excessive stiffness, increasing preload or stiffness to suppress body roll and pitch, enhancing rebound damping to control oscillation, or increasing stroke and preload to prevent bottoming. This process is repeated through multiple rounds of testing and refinement until a balanced performance state is achieved. Such an iterative mechanism reflects a closed-loop adjustment logic in which standardized evaluation criteria and real-world performance feedback are continuously integrated, ensuring that suspension performance meets manufacturer requirements under practical operating conditions.

4.3. Core Principles of Adjustment

The adjustment process is guided by several fundamental principles that ensure both technical rationality and industrial applicability. First, a dynamic balance between comfort and handling must be maintained, avoiding excessive bias toward any single performance objective and ensuring alignment with the core needs of target user groups. Second, durability verification must be conducted in parallel with performance optimization. Long-distance and high-frequency fatigue testing are required after parameter adjustment to confirm that no performance degradation, abnormal noise or leakage occurs during extended operation.

In addition, cost controllability is an essential consideration in manufacturer-oriented development. While meeting performance and standard requirements, the selection of materials, structures and components must be optimized to avoid unnecessary complexity and over-design. This reflects the broader industrial logic in which engineering design is not only a technical activity but also a decision-making process involving performance, reliability and economic efficiency within a socio-technical system.

5. Whole-Process Verification and Quality Control of Suspension System

5.1. Ex-Factory Inspection

Ex-factory inspection serves as the first line of quality assurance, ensuring that each batch of suspension products meets predefined technical standards before delivery. Through random sampling, key aspects such as surface quality, dimensional accuracy, operational smoothness and sealing performance are systematically evaluated. The strict control of dimensional tolerances, including free length deviations of front and rear shock absorbers, ensures precise compatibility with vehicle structures, thereby preventing installation errors and performance mismatches.

At the same time, inspection of operational performance and sealing reliability guarantees that the shock absorber functions smoothly without abnormal noise, friction or oil leakage under different orientations. This stage reflects the role of standardized inspection procedures in translating design specifications into consistent manufacturing outcomes, forming a critical link between production and application.

5.2. Type Inspection

Type inspection represents a comprehensive evaluation of suspension system performance, extending beyond basic functionality to cover environmental adaptability, durability and structural reliability. By conducting full-item testing on randomly selected samples, the system's behavior under extreme temperature conditions, long-term exposure to dust and muddy water, and corrosive environments is systematically assessed. These tests ensure that the suspension system maintains stable performance across diverse operating conditions.

In addition, fatigue durability and strength verification are incorporated to evaluate long-term reliability. Requirements such as resistance attenuation limits after high-cycle vibration testing and compliance with static and dynamic strength thresholds provide a quantitative basis for assessing product lifespan and safety margins. Through this process, type inspection functions as both a validation mechanism and a feedback channel for design improvement, reinforcing the integration of testing data into engineering optimization.

5.3. Failure Protection Design

Failure protection design is an essential component of ensuring the long-term stability and safety of suspension systems. It focuses on identifying potential failure modes and implementing targeted preventive measures within the design and verification process. For inflatable shock absorbers, strict control of internal gas pressure and sealing performance is required to prevent sudden changes in damping characteristics caused by leakage or pressure imbalance.

In addition, anti-foaming performance is critical for maintaining consistent damping behavior under high-frequency operation. By limiting fluctuations in damping characteristics and eliminating abnormal noise, the system avoids performance degradation caused by oil foaming. Wear protection strategies, including the use of wear-resistant materials and optimized lubrication design, further enhance durability by reducing friction and extending the service life of moving components. These measures collectively establish a multi-layered protection mechanism that integrates material selection, structural design and performance verification.

6. Engineering Application Advantages of Integrated Standardization and Customization

The integration of standardized technical frameworks with customized engineering design provides significant advantages in practical applications. On the one hand, technical standards establish a clear safety baseline and unified evaluation criteria, ensuring high consistency of product performance and effectively reducing safety risks and after-sales issues. On the other hand, customization enables manufacturers to tailor suspension characteristics to different vehicle types, operating conditions and user preferences, thereby enhancing product differentiation and market competitiveness.

Furthermore, the adoption of whole-process digital management—from simulation-based design to experimental verification—improves R&D efficiency and shortens development cycles. This approach supports rapid iteration and precise optimization, enabling manufacturers to respond more effectively to changing market demands. In the context of electrification, the

integration of lightweight design, low-friction damping and long-stroke comfort optimization contributes to improved energy efficiency and user experience of electric two-wheelers. Overall, the combination of standardization and customization represents a typical socio-technical integration path, in which engineering innovation and industrial organization evolve in a coordinated manner.

7. Conclusion

T/ZZB 3029—2022 provides a comprehensive, systematic and practically applicable technical framework for the development of suspension systems for motorcycles and electric two-wheelers. By integrating high-precision spring design, multi-dimensional damping adjustment, structural strength verification, whole-vehicle matching and real-vehicle tuning, a closed-loop R&D system of "design – adjustment – verification – mass production" can be effectively established. This system not only ensures compliance with unified safety and quality standards but also enables precise adaptation to the differentiated requirements of various vehicle types. From a broader perspective, the study demonstrates that the combination of standardized technical frameworks and scenario-oriented customization can achieve a balanced optimization of safety, comfort, handling, durability and cost. It also highlights the role of technical standards as both engineering tools and institutional mechanisms in promoting industrial coordination and technological upgrading. The findings provide practical and replicable solutions for suspension system development, while offering insights into the integration of engineering practice and standardization in modern manufacturing systems.

Author Contributions:

Hongqin Wu contributed to the conceptualization, methodology of the study, and supervised the overall project, and coordinated the research process of the study. Xuhui Yang performed data analysis and conducted the first draft of the manuscript. All authors have read and agreed to the published version of the manuscript.

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A Brief Analysis of Luckin Coffee's Public Relations Strategy on the TikTok Platform

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Abstract

In the current era where short videos are reshaping the landscape of information dissemination, the TikTok platform has become the primary battleground for corporate public relations management. As of December 2024, China's short video user base reached 1.04 billion, with a usage rate of 93.8%, driving the public relations industry to accelerate its transition from the text-and-image era into the visual era . This study takes Luckin Coffee as the research subject to explore its public relations strategies on the TikTok platform. The findings reveal that Luckin Coffee's PR practices on TikTok transcend the traditional "information release" paradigm, forming a deeply integrated model of "brand-effect-sales synergy" by co-creating content to build a brand personality that "plays skillfully and boldly," leveraging high-density interactions to foster egalitarian dialogue relationships, utilizing tools like live streaming and secondary cards to achieve closed-loop communication and sales, and resolving potential crises through rapid, flexible, and humanized responses. On the TikTok platform, Luckin's interaction efficiency far surpasses other platforms, contributing 80% of its total interaction volume . This strategy has successfully helped Luckin shape a brand image that is youthful, highly interactive, and adept at meme usage, achieving the transformation from traffic to sales and ultimately brand loyalty. The study provides valuable insights for corporate public relations management in the short video era.

Keywords: Luckin Coffee; TikTok; Public Relations; Social Media; Brand Communication; User Interaction

1. Introduction

The rise of short videos is reshaping the landscape of information dissemination. From a developmental perspective, the precursor to Kuaishou, "GIF Kuaishou," was launched in 2011, marking the initial emergence of short video formats. In 2013, platforms like Miaopai and Weishi began to emerge. Starting in 2016, with the widespread adoption of 4G networks and the

maturation of intelligent recommendation algorithms, Douyin (TikTok) and Kuaishou rose to prominence. After 2020, with the deep integration of technologies such as 5G and artificial intelligence, short videos gradually transcended their entertainment-oriented attributes and expanded into diverse fields including government services, e-commerce, and online education, becoming a core platform for public relations activities (Da, 2025). As of December 2024, China's short video user base reached 1.04 billion, with a usage rate of 93.8%, maintaining the top position in the online audiovisual application segment for consecutive years. Against this backdrop, Douyin (TikTok), as a core short video platform, has become the primary battleground for corporate public relations communication due to its strong interactivity, high user engagement, rapid content viral spread, and "interest-based e-commerce" attributes (Zhang & Chen, 2025).

Since its establishment in 2017, Luckin Coffee has rapidly grown into one of the leading brands in China's coffee market by leveraging an operational model of "high cost-performance products + digital operations + extensive network coverage." Its brand vision is "to make good coffee affordable and accessible to everyone," precisely targeting the market gap dominated by high-priced specialty coffee, attracting a large number of price-sensitive young white-collar workers and students. After initial rapid expansion and subsequent strategic adjustments, Luckin has continuously focused on product innovation and brand marketing, creating a series of phenomenal hits such as Fresh Coconut Latte, Soy Sauce Latte, and Black Myth Tengyun Americano. According to incomplete statistics, as of August 2024, Luckin has collaborated with 18 high-profile IPs, including Line Dog, The Story of a Rose, A Chinese Odyssey, and actress Loopy (Wang, 2024). Its public relations and marketing practices on the Douyin (TikTok) platform have garnered significant industry attention due to features like frequent collaborations, strong user engagement, and integrated brand-effect-sales strategies (Li, 2024).

A preliminary review of the literature reveals that existing research has largely focused on Luckin's business model or marketing tactics, with insufficient exploration of its systematic public relations strategies on short video platforms—specifically, the underlying mechanisms through which it reshapes brand relationships via content co-creation, egalitarian dialogue, and sales closed-loop. To address this research gap, this study takes Luckin Coffee's official account on the Douyin (TikTok) platform and its related communication activities as the research object, focusing on the following core questions: What specific public relations strategies did Luckin adopt on Douyin (TikTok)? How did these strategies help shape its brand image and build relationships with users? What potential challenges did it face while achieving success?

Theoretically, this study aims to extend and integrate the boundaries of the two-way symmetrical model and the AIVSA model within short video platforms, empirically enriching the understanding of value co-creation in brand-consumer relationships. Practically, it provides valuable insights for similar brands conducting public relations management on short video platforms.

2. Theoretical Foundations and Platform Characteristics

2.1. Brief Overview of Relevant Public Relations Theories

The two-way symmetrical model is a classic theory in public relations, emphasizing equal dialogue and mutual understanding between organizations and the public. In the era of social media, this model has gained new practical applications—users are no longer passive information receivers but can interact with brands in real-time through comments, likes, and shares, participating in content production and dissemination (Zhao, 2024). From the perspective of consumer behavior evolution, from the AIDMA model to the AISAS model, and then to the SICAS model, consumers' information reception methods have shifted from passive acceptance to active searching, and further to experiential perception and interactive communication. Entering the social media era, Professor Duan Chunlin proposed a new consumer behavior model centered on value sharing—AIVSA, where "value identification is the driving force behind consumers' information acquisition and sharing behaviors, and value co-creation is the primary behavioral mode of consumers" (Zhu & Liu, 2024). Luckin's public relations practices on Douyin (TikTok) are a typical embodiment of this model (Huang, 2024).

Integrated marketing communications emphasizes the consistency of information dissemination, as well as the synergy between online and offline channels, sales, and public relations (Zhou, 2025). On the Douyin (TikTok) platform, the boundaries between public relations and marketing are increasingly blurred: a short video may simultaneously serve the functions of brand image building and product promotion, while a live stream acts as both a sales channel and a communication window (Liu, 2025). Luckin's strategy of "integrating brand, performance, and sales" is precisely an extension of the integrated marketing communications concept in the era of short videos (Zhou, 2025). The high integration of social media and real life is transforming consumers' transaction and purchasing behaviors, prompting brand communication to gradually merge with these behaviors, permeating into consumers' daily routines and even becoming an integral part of their lives (Zhu & Liu, 2024).

2.2. Communication Characteristics of the Douyin (TikTok) Platform

The communication characteristics of the Douyin (TikTok) platform can be understood from three dimensions:

Strong interaction and high engagement: The platform constructs a multi-dimensional interactive system through features such as comments, likes, shares, and collaborative filming (Zhao, 2024). Taking Douyin's traffic distribution mechanism as an example, it adopts a decentralized allocation logic: initially, every content piece has the opportunity to access a basic traffic pool, but only videos with high quality, significant shares, comments, and likes are weighted by popularity and enter the recommendation traffic pool (Zhang & Chen, 2025). This mechanism compels brands to prioritize content quality and user interaction (Wu, 2025). Data shows that Luckin's interaction efficiency on the Douyin (TikTok) platform far exceeds that of other platforms, contributing 80% of its total interaction volume (Wu, 2025). Such high interactivity provides the technical foundation for brands to establish deep relationships with users (Zhao, 2024).

The content is short, fast, and easy to imitate: Douyin (TikTok) content follows the "golden 3-second rule," aiming to quickly capture users' attention at the beginning (Chen, S., 2024). Short videos adopt a full-screen vertical format, combined with algorithm-driven continuous playback mechanisms, shifting users from fragmented browsing to fully immersive viewing, significantly enhancing information delivery efficiency and dwell time (Chen, S., 2024). Meanwhile, elements such as challenges, trending memes, and background music are easy to imitate and creatively adapt, driving viral content dissemination (Zhang & Chen, 2025).

The 'interest-based e-commerce' attribute: Douyin (TikTok) connects content with consumption through algorithmic recommendations, allowing users to directly jump to purchases while watching short videos or live streams (Zhang & Chen, 2025). This feature increasingly blurs the line between public relations communication and sales conversion, requiring brands to consider conversion paths during content planning stages (Liu, 2025). From the AIVSA model perspective, brands need to leverage platform big data to gain consumer insights, employ creative formats for targeted communication to attract attention, and establish emotional connections through interactive engagement, ultimately driving consumer behavior and value co-creation (Zhu & Liu, 2024; Huang, 2024).

3. Analysis of Luckin Coffee's Public Relations Strategy on the Douyin (TikTok) Platform

3.1. Strategy One: Content Strategy — Building a Brand Personality of "Being Skilled and Bold in Play"

Empirical description: Product contentization is the core of Luckin's content strategy. Luckin excels at transforming new product launches into highly topical visual and narrative content (Li, 2024). Take the "Black Mythology Cloud Ascending Americano" co-branded with "Black Mythology: Wukong" in 2024 as an example. The collaborative product, paired with 3D limited-edition poster grid cards, co-branded cup covers, and other merchandise, sparked a surge of early morning store visits for purchases (Wang, 2024). The co-branded merchandise included cup covers, paper bags, and Black Mythology 3D limited-edition posters. Since the 3D effect could only be seen with the naked eye, it further stimulated consumer purchasing desire (Wang, 2024). Major social media platforms such as Weibo, Douyin (TikTok), and Xiaohongshu were flooded with coverage of this collaboration, with the #BlackMythologyWukong hashtag skyrocketing to the top of Weibo's trending list and five of the top ten spots on Douyin's hot charts (Wang, 2024). Despite initial issues like system glitches and instant sell-out of merchandise, the event itself demonstrated Luckin's strong ability to transform products into social topics (Li, 2024). In 2025, when co-branded with Duolingo to launch the "Green Sand Latte," the brand released a creative short drama titled "The Birds of Our Marriage," with the first episode garnering over a million likes and seamlessly integrating the co-branded message into the storyline (Wang, 2024).

Life-scenario integration is another crucial approach (Chen, S., 2024). Luckin Coffee extensively showcases consumption scenarios such as offices, commutes, and study breaks on Douyin (TikTok), resonating with users (Chen, S., 2024). The iconic "First-Person Perspective Luckin Barista" video series continues to achieve high engagement with its immersive experience

and entertainment value (Li, 2024). This scenario-based content transforms the brand from an abstract symbol into a tangible companion in daily life (Chen, S., 2024).

Leveraging meme culture has become Luckin Coffee's secret weapon for connecting with young consumers (Li, 2024; Gao, 2025). The brand proactively utilizes trending internet memes and even creates exclusive cultural references (such as "Luckin's lazy fisherfolk culture") to bridge the psychological gap with younger demographics (Li, 2024). During the collaborative pre-launch campaign with Duolingo, the official Duolingo account sparked nationwide speculation through the viral topic "Duolingo is getting married," transforming Luckin's comment sections into vibrant brand-building forums where McDonald's, Meituan, and other brands actively participated (Wang, 2024). This meme mastery has earned Luckin Coffee a reputation as a savvy brand strategist among youth demographics (Li, 2024; Gao, 2025). From a brand positioning perspective, Luckin consistently reinforces its youthful and fashionable image through collaborations with trendy IPs and partnerships with young idols (Li, 2024; Gao, 2025). The current joint campaign targets Luckin's core consumer base aged 24-40, while Duolingo's video audience focuses on 18-30-year-olds, creating overlapping demographics between 24-30 years old with complementary coverage ranges (Wang, 2024).

Theoretical analysis and evaluation: The above practices are not isolated marketing techniques but rather a deep implementation of the "value identification" and "value co-creation" stages of the AIVSA model. First, through "product contentization" and "IP co-branding," Luckin transforms functional products into "social currency" rich in cultural symbols, lowering the threshold for users to identify brand value and driving their active searching and sharing behaviors. Second, the use of "meme culture" essentially involves partially ceding the encoding rights of brand symbols to users, facilitating a "symbolic equal exchange" between the brand and users—users gain expressive enjoyment, while the brand gains cultural penetration. In terms of evaluation, the effectiveness criterion for Luckin's content strategy lies in whether the content possesses "participability" and "adaptability." Data showing its 80% contribution to total interaction volume demonstrates that the strategy has successfully transformed the brand from an "information publisher" into a "cultural agenda initiator." However, the potential risk is that over-reliance on "meme-playing" may dilute the brand's core "professional coffee" image, requiring clear brand values as a boundary constraint.

3.2. Strategy Two: Interactive Strategy — Building an Equal Dialogue "Friendship" Relationship

Empirical description: High-density comment section interaction is a prominent feature of Luckin's Douyin (TikTok) operations (Li, 2024; Zhao, 2024). Official accounts actively respond to user comments and even "flip cards" for fans, forming a unique comment section culture (Li, 2024; Zhao, 2024). Such interaction transforms the brand from an institutionalized abstract entity into a "personality" with warmth, emotions, and meme skills, significantly narrowing the psychological distance with the audience (Zhao, 2024; Gao, 2025). When the collaboration with "Black Myth: Wukong" sparked criticism, the humanized responses in the comment section to some extent alleviated user dissatisfaction (Wang, 2024). From the perspective of the AIVSA model, consumers as spiritual individuals exhibit socialized behaviors on short video platforms,

and brand owners need to actively create opportunities for encounters and interactive exchanges with consumers (Zhu & Liu, 2024; Zhao, 2024).

Launching challenges and co-creating with users is the core approach for Luckin to achieve viral spread (Zhu & Liu, 2024; Zhao, 2024). In 2024, leveraging the popularity of "The Rose Story," Luckin initiated the "Rose Story of the Early Eighters" challenge on Douyin (TikTok). Six million-follower influencers participated in the nationwide task to generate buzz, with cumulative submissions reaching over 41,000 and topic views exceeding 380 million (Wang, 2024). This UGC approach embeds brand messaging into user-generated content, achieving "participatory communication" (Zhu & Liu, 2024). According to the AIVSA model, consumers develop value recognition through their interpretation and sharing of brand information, fostering viral spread and further expanding brand influence (Zhu & Liu, 2024; Huang, 2024).

In influencer/KOL partnerships, Luckin Coffee implemented a precision stratification strategy (Gao, 2025). The collaboration with "Pragmatic Uncle" Wan Ningshu leveraged his "Money-Saving Uncle persona" to reinforce Luckin's value-for-money image, with a single live stream generating sales exceeding tens of millions (Wang, 2024). In August 2025, Luckin partnered with Wan Ningshu's live streaming campaign, achieving remarkable sales of over 10 million yuan through a 99.9-yuan ten-cup coffee card promotion (Wang, 2024). Within influencer marketing, Wan Ningshu perfectly aligned with Luckin's "Money-Saving Uncle persona" that embodies its cost-effective brand image, serving as a trusted endorsement vehicle (Gao, 2025). Collaborating with influencers from diverse communities for product reviews and narrative integration helped the brand reach multi-tiered audiences (Li, 2024; Gao, 2025).

Theoretical analysis and evaluation: Luckin's interactive strategy exemplifies the practical application of the two-way symmetrical model in the short video era. Unlike traditional PR where symmetrical communication is reserved for crisis periods, Luckin institutionalizes daily equal dialogue as a routine operational practice. The effectiveness criterion here is interaction density and reciprocity rate. High-density comment replies and challenge co-creation transform the brand-user relationship from one-way transmission to two-way construction. The theoretical contribution lies in demonstrating that symmetrical communication, when embedded in daily interactions, can generate "relationship rents" — emotional bonds that buffer negative events (as partially evidenced in the Black Myth incident). However, the risk is that as Douyin's social nature gradually diminishes (users increasingly prefer liking over deep commenting), maintaining interaction depth may require ever-increasing investment.

3.3. Strategy Three: Sales Integration Strategy — Achieving a Closed Loop of "Brand-Efficacy-Sales"

Empirical description: The normalization of live streaming has made Douyin (TikTok) an important communication window for Luckin Coffee (Liu, 2025; Zhou, 2025). Daily live streams not only sell products but also provide brand explanations and new product previews, transforming sales behavior into brand communication (Liu, 2025). During the collaboration with Duolingo, Luckin Coffee's group-buying live streams adopted a "learning" style, with multiple language-learning streamers initiating group purchases and product promotions. The brand's

signature beverage names were integrated with Duolingo learning cards as the live stream background, achieving a unity of content creativity and sales conversion (Wang, 2024). This live streaming format upgraded "interaction," adding IP-to-IP engagement to the audience-brand interaction, making the collaboration more "lively" (Wang, 2024; Liu, 2025).

The secondary card strategy serves as a crucial tool for Luckin Coffee to transition from "product attraction" to "sustained consumption" (Xu, 2024). In August 2025, the company launched a 99.9 yuan ten-cup coffee card, which achieved over 10 million yuan in single-session sales during a live-streaming event co-hosted with Uncle Wanning (Wang, 2024). These cards transform consumers' "stockpiling enthusiasm" into "in-store visits," leveraging one online purchase to drive multiple offline experiences, thereby converting traffic into retention (Xu, 2024). Leading brands employ tiered cards to boost frequent store visits, redemption cards to address consumption fatigue, and influencer cards to streamline decision-making processes, prompting customers to willingly "pre-store 10 cups of milk tea on their phones" (Xu, 2024). More than just promotional tools, secondary cards essentially function as "repurchase engines" for retail outlets (Xu, 2024).

The deep integration of coupons with content is also an effective means to drive conversions (Liu, 2025; Zhou, 2025). Luckin Coffee packages promotional activities as gameplay elements such as "codes" and "unlocking" to enhance interactive engagement and increase conversion intent (Li, 2024). In September 2023, the co-branded product "Jiangxiang Latte" by Luckin Coffee and Moutai performed exceptionally well on the Douyin (TikTok) platform: sales from the launch livestream exceeded 10 million yuan within 4 hours, with cumulative orders for the new product surpassing 1 million cups within the first 15 hours (Wang, 2024).

Theoretical analysis and evaluation: This strategy challenges the traditional separation between PR (long-term relationship management) and sales (short-term transactions). Luckin's approach operationalizes the integration of integrated marketing communications (IMC) in the short video era, where the same live stream simultaneously builds brand image, demonstrates product value, and completes transactions. The effectiveness criterion is conversion continuity — whether communication traffic can be converted into repeat purchases (secondary cards) and whether sales scenarios can simultaneously fulfill communication functions (themed live streams). The theoretical implication is that in the short video environment, the "black box" between communication and consumption has been opened; PR effectiveness can be partially measured by sales velocity, while sales scenarios become PR touchpoints. However, risks include over-commercialization leading to user fatigue and the potential erosion of brand authenticity when every interaction carries a sales motive.

3.4. Strategy Four: Crisis/Hotspot Response Strategy — Rapid, Flexible, and Humanized

Empirical description: In terms of leveraging trending topics, Luckin Coffee demonstrated rapid response capabilities (Li, 2024; Sun, 2025). During the summer of 2024, Luckin keenly captured the popularity of the TV series "Rose Story" and swiftly organized Douyin (TikTok) KOLs to launch a challenge competition, transforming the enthusiasm for binge-watching into the hot sales of "Yellow Rose Latte" (Wang, 2024). This ability to capitalize on trending topics has

kept the brand consistently at the center of public discourse (Li, 2024). From the perspective of short video dissemination patterns, while accelerated dissemination enhances PR efficiency, it also subjects crisis response to unprecedented pressure—crises erupt more suddenly, public sentiment evolves more predictably, and the response window is severely compressed (Da, 2025; Zheng, 2025).

The resolution of potential crises is a particularly noteworthy aspect of Luckin's public relations strategy (Sun, 2025; Zheng, 2025). In August 2024, the joint campaign between Luckin and "Black Myth: Wukong" encountered issues such as unredeemable product coupons and instant sell-out of merchandise, prompting consumer complaints of being "treated like monkeys" (Wang, 2024). Luckin's response can be divided into three levels: first, a prompt response on the official Weibo account stating that the system issue had been resolved; second, hosts explaining in Douyin (TikTok) live streams the limited availability of merchandise and advising customers to switch stores or return items; third, another apology statement issued at noon, clarifying that the high-quality merchandise required a 15-day restocking cycle and promising immediate notification upon arrival (Wang, 2024; Sun, 2025). This swift, transparent, and humanized response helped alleviate user dissatisfaction to some extent (Sun, 2025; Zheng, 2025).

However, in this incident, the remarks made by the CGO (Chief Growth Officer) in his WeChat Moments about "men's purchasing power subverting perceptions" sparked discontent among some female users, exposing the issue of inconsistent internal messaging during crisis communication (Wang, 2024; Zheng, 2025). This case also demonstrates the value of rapid response and the importance of internal coordination (Sun, 2025; Zheng, 2025). According to the Data Index Report, Luckin Coffee faced accusations of "big data price discrimination" and "false delivery" incidents in the past six months, leading to significant fluctuations in net sentiment (Zhao, 2024; Zheng, 2025). These cases indicate that on the Douyin (TikTok) platform, any minor issue can be rapidly amplified, with algorithmic preferences favoring emotionally charged content, compounded by user-generated content, potentially resulting in a "cliff-like" deterioration of public opinion (Wu, 2025; Zheng, 2025).

Theoretical analysis and evaluation: Luckin's crisis response strategy reflects an adaptation to the compressed time frame of short video platforms. The three-tiered response mechanism (official statement → live stream explanation → detailed apology) demonstrates an understanding of platform-specific communication logics: different messages are suited to different formats (text for official records, live video for humanized engagement). The effectiveness criterion is response velocity + message consistency. The Black Myth incident revealed a critical lesson: rapid response is necessary but insufficient without internal alignment. The CGO's off-platform remarks caused disproportionate damage, indicating that in the short video era, every employee utterance is potentially public. The theoretical implication is that crisis communication theory must expand from "organizational-to-public" messaging to "internal coordination as crisis prevention"—a finding that enriches situational crisis communication theory (SCCT) with an internal communication dimension.

4. Effect Evaluation and Potential Challenges

4.1. Strategy Effectiveness Evaluation

In terms of brand image, Luckin Coffee has successfully cultivated a youthful, fashionable, and digitally savvy brand identity (Li, 2024; Gao, 2025). Through continuous collaborations, meme campaigns, and interactive initiatives, the company has earned a reputation among young demographics as "a savvy player" and "a true understanding of youth culture" (Li, 2024; Gao, 2025). The overlapping and complementary demographics between the partner brands in the Duolingo collaboration (aged 24-30) demonstrate Luckin's strong penetration capability within younger demographics (Wang, 2024; Gao, 2025). According to Feigua Pince data, the joint campaign achieved over 30 million impressions within three days of launch, with the co-branded beverage reaching 18.964 million impressions on its debut day (July 6) (Wang, 2024). The A1 audience exposure volume reached 33.391 million impressions, with a conversion rate of 4.02% across audience segments ranging from superficially engaged A2 to deeply interactive A3 groups (Wang, 2024; Huang, 2024).

At the user relationship level, Luckin Coffee has established a highly interactive and engaged user community (Wu, 2025; Zhao, 2024). The Douyin (TikTok) platform contributes 80% of Luckin's total interaction volume (Wu, 2025), with behaviors such as comment section interactions, UGC creation, and challenge participation transforming the brand-user relationship from a one-way transmission-reception dynamic to a two-way interactive relationship (Zhao, 2024). From the perspective of the AIVSA model, consumer interactions in virtual brand scenarios help form a brand culture aligned with the brand's core values, enhance consumers' sense of brand value identification, and improve their brand loyalty (Zhu & Liu, 2024; Huang, 2024).

In terms of market performance, Douyin (TikTok) strategies have a direct promoting effect on new product launches and sales growth (Liu, 2025; Xu, 2024). The "Rose Story of Eight O'Clock Morning People" challenge brought Luckin Coffee over 50 million new 5A customers and 60,000+ new A4A5 purchasing customers (Wang, 2024). The livestream sales for the first launch of Jiangxiang Latte exceeded 10 million yuan within four hours (Wang, 2024). The secondary card strategy converted live-streaming popularity into sustained in-store customer traffic (Xu, 2024). During the reporting period, Luckin Coffee maintained high visibility and interaction levels on the Douyin (TikTok) platform (Wu, 2025; Zhao, 2024).

4.2. Potential Challenges and Risks

The persistent reliance on "internet sensibility" is the primary challenge faced by Luckin Coffee (Li, 2024; Gao, 2025). Douyin (TikTok) content updates rapidly, making users' attention easily shift. Once content innovation weakens and "gags" lose their novelty, users may quickly disengage (Li, 2024). Brands need to continuously maintain content creativity, which places extremely high demands on team capabilities (Gao, 2025). From the perspective of Douyin's social attributes evolution, studies indicate that Douyin's social nature is gradually diminishing, with people becoming accustomed to merely liking and sharing content while showing less

willingness for deeper expression and interaction (Wu, 2025). This trend may impact the depth of brand-user engagement (Wu, 2025; Zhao, 2024).

The risks of excessive entertainmentization and brand dilution warrant vigilance (Wang, 2024; Xu, 2024). Frequent collaborations, meme manipulation, and entertainment-driven content may amplify popularity while obscuring a brand's core identity (Xu, 2024). Striking a balance between meme-driven strategies and preserving the professional coffee brand image remains a persistent challenge for Luckin Coffee (Li, 2024; Xu, 2024). The controversy surrounding CGO's remarks in the "Black Myth: Wukong" collaboration incident partially highlights the risk of brands neglecting user experiences in pursuit of viral appeal (Wang, 2024; Zheng, 2025). From the perspective of core brand values, Luckin Coffee's commitment to "quality supremacy, continuous innovation, and customer-centricity" necessitates maintaining equilibrium between entertainment elements and professional image positioning (Li, 2024; Gao, 2025).

The amplification effect of negative public opinion is an inherent risk of short video platforms (Wu, 2025; Zheng, 2025). The Data Index Report shows that Luckin Coffee faced allegations of "big data price discrimination" and "false delivery" incidents during the reporting period, leading to significant fluctuations in net sentiment (Zhao, 2024; Zheng, 2025). On the Douyin (TikTok) platform, any minor issue can be rapidly magnified. Algorithmic preferences for emotionally charged content, combined with user-generated secondary creations and parody edits, often exacerbate the situation, resulting in a "cliff-like" deterioration of public opinion (Wu, 2025; Zheng, 2025). This places higher demands on brands' public opinion monitoring and crisis response capabilities (Sun, 2025; Zheng, 2025). In the short term, negative events impact brand sentiment; in the long term, neglect of operational details may undermine consumer trust, the cornerstone of brand loyalty (Zheng, 2025; Xu, 2024).

5. Conclusion and Implications

5.1. Research Conclusions

This study finds that the core of Luckin Coffee's public relations strategy on the Douyin (TikTok) platform can be summarized as "user-centered content co-creation" and "deep integration of brand, performance, and sales operations." Through its content strategy, Luckin constructed a brand personality characterized as "playful and daring." Through its interactive strategy, it fostered egalitarian "friendship" relationships with users. Through its sales integration strategy, it achieved a closed loop from communication to conversion. Through its crisis and hotspot response strategy, it demonstrated a rapid, flexible, and humanized image. These four interconnected strategies mutually reinforce each other, collectively shaping Luckin's brand image as youthful, highly interactive, and adept at meme culture.

The essence of this strategy lies in proactively adapting to public relations transformations in the short-video era. Short videos have not only revolutionized information dissemination channels and pathways but also driven profound adjustments in public relations concepts, methodologies, and value orientations: shifting from text-based formats like press releases and soft articles to immersive experiences composed of visuals, music, rhythm, and special effects; transitioning

from "one-way communication" to "interactive engagement"; and evolving from information dissemination to relationship management. Luckin Coffee's practices demonstrate that public relations in the short-video era has shifted from "information dissemination" to "relationship management" and from "traffic chasing" to "reputation cultivation."

5.2. Theoretical Contributions and Practical Implications

Theoretical contributions: This study does not simply apply existing theories but rather extends and integrates the boundaries of the two-way symmetrical model and the AIVSA model within short video platforms. The findings reveal that on the Douyin (TikTok) platform, the "egalitarian dialogue" between organizations and the public is no longer confined to crisis communication but has become internalized as routine operations such as comment section interactions and challenge co-creation, representing a shift from "strategic dialogue" to "ecological relationship management." Furthermore, this study empirically enriches the AIVSA model: Luckin's case shows that "value identification" not only stems from content appeal but also deeply depends on a sense of ritual created through frequent, egalitarian interactions; "value co-creation" is directly manifested in user-generated content, secondary creations of meme culture, and even active discussions about brand pricing strategies. These findings provide new empirical material for understanding the brand-consumer value co-creation mechanism. The study also extends situational crisis communication theory by highlighting internal coordination as a crisis prevention dimension.

Practical implications: In the short video era, public relations must adopt a more proactive, egalitarian, and integrated approach. Proactivity means swiftly identifying trending topics and promptly addressing user concerns; egalitarianism requires abandoning institutional posturing to engage with audiences as "individual entities"; integration entails breaking down barriers between PR and marketing, considering synergy between communication strategies and conversion goals during content planning stages. Specifically, brands can focus on three key strategies: First, building a differentiated platform content matrix with tailored layouts based on platform characteristics; second, deeply integrating product innovation with content dissemination through frequent collaborations and trending topic generation to maintain brand relevance; third, establishing rapid crisis response mechanisms with internal coordination protocols to seize initiative in minute-level communication rhythms.

Limitations and future research: Future research could conduct comparative analyses with other brands (such as Starbucks and Heytea) on the Douyin (TikTok) platform to explore strategic differences under varying brand tones. Longitudinal tracking studies could observe the continuous evolution and adjustments of Luckin's strategies, particularly how it seeks a balance between "frequent collaborations" and "brand dilution risks." Additionally, user perspectives could be adopted to conduct in-depth analyses of the psychological mechanisms underlying users' brand interaction behaviors. The transformation of public relations in the short-video era continues, and theoretical research needs to evolve in tandem with practical developments.

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Analysis of the Causes of Excessive Manganese and Discussion on Treatment Measures in a Waterworks in Cangnan County

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Abstract

Excessive manganese in the effluent of a waterworks in Cangnan County not only leads to sensory abnormalities of drinking water but also poses a potential threat to human health, which has become an urgent water quality problem to be solved. In this study, flame atomic absorption spectrophotometry was adopted to determine the manganese concentration in water samples at each treatment stage, so as to evaluate the actual effect of different manganese removal processes. Aiming at the problem of excessive manganese in raw water, the waterworks optimized the conventional water treatment process by taking measures such as strengthening pre-chlorination and adding potassium permanganate composite salt. The results showed that both measures could effectively oxidize soluble divalent manganese into insoluble tetravalent manganese, which was then intercepted and removed by the filter, and the manganese content in the final effluent was stably controlled below the limit value of 0.1mg/L specified in GB 5749-2022. This study not only effectively solved the problem of excessive manganese in the waterworks but also provided a practical and feasible technical reference for the treatment of excessive manganese in reservoir water sources of similar waterworks in southern China.

Keywords: Excessive Manganese in Water; Reservoir Water Source; Pre-Chlorination; Potassium Permanganate Composite Salt; Manganese Removal Technology

1. Introduction

The "Sanitary Standards for Drinking Water" (GB 5749-2022) implemented in China clearly stipulates that the limit value of manganese in drinking water is 0.1mg/L (State Administration for Market Regulation of the People's Republic of China, 2022). Manganese is a trace element necessary for the human body, but long-term intake of water with excessive manganese content will cause serious harm to the human body, and also lead to sensory quality problems of water body. In terms of human health hazards, excessive manganese mainly damages the nervous

system, blood system, respiratory system and digestive system of the human body, and even causes manganese poisoning in severe cases, showing symptoms such as muscle spasm, tremor, bradykinesia, anemia, bronchitis, and emotional instability (Cheng et al., 2021; Li, 2022). In terms of water body sensory quality, excessive manganese will cause color, odor and taste abnormalities of tap water, and even form brown precipitates in the water pipeline, which affects the normal use of water by residents. Therefore, effective control of manganese content in drinking water is an important part of waterworks to ensure water supply safety.

A waterworks in Cangnan County, Wenzhou City, with a daily water supply capacity of 20,000 tons, is an important urban water supply facility in the southern part of Cangnan County. The water treatment process adopted by the waterworks is a conventional process of folded plate-inclined tube coagulation and sedimentation + valveless filter filtration + sodium hypochlorite disinfection. The raw water is taken from Tiechang Reservoir and Yunzhe Reservoir in the jurisdiction. Since the summer of 2023, the water quality monitoring data of the waterworks showed that the manganese content in the effluent exceeded the standard seriously, which directly threatened the water supply safety of the residents in the water supply area. Through on-site investigation and sampling analysis, it was found that the main reason for the excessive manganese in the effluent was the serious manganese pollution of the two reservoir water sources, which was closely related to the local geological conditions and seasonal environmental changes.

Aiming at the problem of excessive manganese in the raw water of the reservoir, this study carried out a systematic analysis on the causes of excessive manganese in the water source, and tested and optimized different manganese removal processes on the basis of the original water treatment process of the waterworks. By determining the manganese concentration in water samples at each treatment stage with flame atomic absorption spectrophotometry, the optimal manganese removal process parameters were screened out, and practical and feasible treatment measures were formulated, which realized the stable up-to-standard of manganese content in the effluent of the waterworks. The research results can provide technical reference for the treatment of excessive manganese in similar reservoir water sources in coastal areas of southern China.

2. Test Materials and Methods

2.1. Main Reagents and Materials

Manganese standard sample (1000mg/L, National Institute of Metrology, China, No.: GBW(E) 080157, Batch No.: 21011); Nitric acid (guaranteed reagent, Changshu Zhitang Fine Chemical Co., Ltd.); Experimental water was ultrapure water (18.2MΩ·cm, Sichuan Youpu Purification Equipment Co., Ltd.). All glassware used in the test was soaked in nitric acid solution (1:9, V/V) for 24h, and rinsed with ultrapure water for 3 times before use to avoid manganese contamination.

2.2. Main Instruments and Equipment

AA-6880 flame atomic absorption spectrophotometer (Shimadzu Instruments (Suzhou) Co., Ltd.); Manganese hollow cathode lamp (Shimadzu Corporation); 0.45μm microporous filter membrane (Shanghai Xinya Purification Materials Co., Ltd.); Polyethylene sampling bottle

(500mL, Nanjing Xiangrui Experimental Equipment Co., Ltd.); Digital pH meter (Shanghai Leici Instrument Factory).

2.3. Instrument Working Parameters

In order to ensure the accuracy and precision of manganese content determination, the working parameters of the atomic absorption spectrophotometer were optimized, and the optimal parameters were set as follows: Lamp current 10mA; Determination wavelength 279.5nm; Monochromator slit width 0.2nm; Fuel gas was high-purity acetylene, oxidant gas was compressed air; Fuel gas gauge pressure 0.09MPa, oxidant gas gauge pressure 0.35MPa; Sample injection method was manual continuous sample injection; The measurement mode was absorbance mode.

2.4. Test Operation Steps

2.4.1. Sample Collection and Pretreatment

According to the "Technical Specification for Monitoring of Drinking Water Quality" (HJ/T 91-2002), water samples were collected at the raw water intake, coagulation and sedimentation tank effluent, filter effluent and final effluent of the waterworks (Phase I and Phase II systems). For the determination of dissolved manganese, the water sample was immediately filtered through a 0.45μm microporous filter membrane after collection, and the filtrate was collected in a clean polyethylene sampling bottle. 1.5mL of concentrated nitric acid was added to each liter of filtrate for acidification (to make the pH < 2) for fixation, and the sample was stored in a cool and dark place for testing within 24h.

2.4.2. Sample Determination

Before the test, the exhaust system, gas cylinder and atomic absorption spectrophotometer were turned on in turn, and the manganese hollow cathode lamp was installed for preheating for 30min to ensure the instrument was in a stable working state. The manganese standard solution series with mass concentrations of 0.0mg/L, 0.1mg/L, 0.2mg/L, 0.4mg/L, 0.6mg/L and 0.8mg/L were prepared by gradient dilution, and the standard working curve was drawn by determining the absorbance of the standard series under the optimal instrument parameters. Under the same test conditions, the absorbance of the water sample to be tested was determined, and the blank test was carried out simultaneously to eliminate the system error. The mass concentration of manganese in the water sample was calculated according to the standard working curve and the absorbance value of the sample to be tested.

3. Results and Analysis

3.1. Causes of Excessive Manganese in Reservoir Raw Water

The raw water of the waterworks is taken from Tiechang Reservoir and Yunzhe Reservoir. The geological stratum in the surrounding area of the two reservoirs is rich in manganese-containing minerals, and a large amount of manganese ions are deposited at the bottom of the reservoirs for a long time, mainly in the form of stable manganese-containing complexes, which are not easy to

be naturally oxidized and released into the water body under normal conditions. However, affected by the high temperature climate in summer, the surface water temperature of the reservoir rises rapidly, the water density decreases, and the obvious thermal stratification phenomenon occurs in the water body, which hinders the convection and exchange of the upper and lower water bodies. The dissolved oxygen in the upper water body cannot be transferred to the bottom of the reservoir, resulting in a serious anoxic environment at the reservoir bottom. Under the anoxic condition, the insoluble tetravalent manganese in the bottom sediment is reduced to soluble divalent manganese, which is released from the sediment and floats up to the upper water body with the water flow, resulting in a sharp increase of manganese content in the raw water of the reservoir.

The water quality monitoring data showed that the manganese content in the raw water of Tiechang Reservoir increased to a maximum of 0.8mg/L in summer, and the manganese content in the raw water of Yunzhe Reservoir was about 0.6mg/L under normal conditions. Due to the low water intake height of Yunzhe Reservoir, it is easily affected by the disturbance of water discharge from the bottom outlet of the reservoir. In mid-September 2023, the manganese content in the raw water of Yunzhe Reservoir further rose to more than 1.0mg/L due to the bottom discharge disturbance, which far exceeded the limit value of drinking water and brought great pressure to the water treatment of the waterworks.

3.2. Analysis of Conventional Manganese Removal Oxidants for Waterworks

The core of chemical oxidation manganese removal technology for waterworks is to select appropriate oxidants to oxidize soluble divalent manganese in raw water into insoluble tetravalent manganese dioxide precipitate, which is then removed by coagulation, sedimentation and filtration processes. Common oxidants available for waterworks include aeration, chlorine dioxide, sodium hypochlorite, ozone and potassium permanganate. The advantages and disadvantages of various oxidants in manganese removal application are analyzed as follows (Table 1).

Table 1. Comparison of advantages and disadvantages of common oxidants for manganese removal in waterworks

Oxidant	Advantages	Disadvantages
Aeration	Low cost, simple operation	Low oxidation capacity, limited manganese removal effect for high-concentration manganese; easy to cause physical disturbance and affect flocculation and sedimentation
Chlorine dioxide	Fast oxidation speed, good manganese removal effect	On-site preparation is required; special equipment is needed; easy to cause excessive chlorite in effluent
Sodium hypochlorite	Easy to store and transport, simple dosing	Only effective under high pH (pH>9.5); long reaction time; easy to cause excessive disinfection by-products and aluminum
Ozone	Ultra-fast oxidation speed, no residual pollution	High cost, need special generation equipment; easy to oxidize manganese to heptavalent state if the dosage is too high
Potassium permanganate	Good oxidation effect, short reaction time (completed in a few minutes); high removal efficiency	The dosage must be accurately controlled; excessive dosage will cause "red water" phenomenon in effluent

3.3. Targeted Manganese Removal Measures and Effect of the Waterworks

The waterworks has two sets of independent coagulation and sedimentation tank systems (Phase I and Phase II), which are respectively responsible for the treatment of raw water from Tiechang Reservoir and Yunzhe Reservoir. According to the different manganese content in the raw water of the two reservoirs, the waterworks adopted targeted manganese removal measures: strengthening the pre-chlorination process for the raw water with low manganese content (Phase I), and adding potassium permanganate composite salt for the raw water with high manganese content (Phase II). The original coagulation, sedimentation and filtration process of the waterworks was not changed, and the manganese removal transformation was completed on the basis of the original process, which realized the advantages of low transformation cost and quick effect.

3.3.1. Manganese Removal Measures and Effect of Phase I Water System (Tiechang Reservoir Raw Water)

The water quality test showed that the total manganese content in the raw water of Tiechang Reservoir was 0.45mg/L, and the dissolved divalent manganese content after filtration was 0.32mg/L. The divalent manganese content was relatively low, so it was decided to adopt the measure of strengthening the pre-chlorination process in the Phase I coagulation tank to realize manganese removal, with sodium hypochlorite as the oxidant. The oxidation reaction formula of sodium hypochlorite and divalent manganese is as follows: $Mn_2^{+}+ClO^{-}+H_2O=MnO_2\downarrow+Cl^{-}+2H^{+}$

It can be seen from the reaction formula that the reaction produces H+ ions, which will inhibit the progress of the oxidation reaction. Therefore, the reaction can be accelerated in an alkaline environment. Based on the reaction principle and the actual water quality of the waterworks, the key process parameters of strengthened pre-chlorination were optimized as follows:

(1) Determination of pre-chlorination dosage: According to the reaction stoichiometric ratio, 1mol of divalent manganese requires 1mol of sodium hypochlorite for oxidation. Combined with the actual divalent manganese content of 0.32mg/L in the raw water, and considering the consumption of sodium hypochlorite by other reducing substances in the water, the effective chlorine dosage of pre-chlorination was set to 0.5mg/L, that is, the dosage of 10% sodium hypochlorite solution was increased to 5kg per 1000 tons of water.

(2) Adjustment of raw water pH value: Relevant literature shows that the oxidation reaction of sodium hypochlorite and divalent manganese can proceed rapidly when the pH value is above 9.5 (Li et al., 2023). However, considering that the excessive pH value of the effluent will lead to the problem of excessive aluminum, the raw water pH value was adjusted to 8.5 by adding alkali in advance, which provided a weak alkaline environment for the oxidation reaction and avoided the secondary water quality problem caused by excessive pH value.

(3) Strengthening water quality monitoring: The content of disinfection by-products and aluminum in the filter effluent and final effluent was regularly determined to ensure that all water quality indicators meet the standard while removing manganese.

After the implementation of the above measures, the water quality monitoring results showed that the manganese content in the filter effluent of the Phase I water system decreased from 0.45mg/L of raw water to below 0.05mg/L, which was far lower than the limit value of 0.1mg/L specified in GB 5749-2022, and the disinfection by-products and aluminum content in the effluent were all within the standard range. The strengthened pre-chlorination process achieved an ideal manganese removal effect, and the operation was simple and the cost was low, which was suitable for the long-term operation of the Phase I water system.

3.3.2. Manganese Removal Measures and Effect of Phase II Water System (Yunzhe Reservoir Raw Water)

The water quality test showed that the total manganese content in the raw water of Yunzhe Reservoir was as high as 1.10mg/L, and the dissolved divalent manganese content after filtration was 0.81mg/L. The divalent manganese content was much higher than that of the Phase I raw water, and the strengthened pre-chlorination process could not achieve the standard manganese removal effect. Therefore, it was decided to adopt the measure of adding potassium permanganate composite salt for manganese removal. The mass ratio of potassium permanganate in the composite salt was 50%, which had the advantages of high oxidation efficiency and easy dosing. The oxidation reaction formula of potassium permanganate and divalent manganese under neutral conditions is as follows: $2KMnO_4+3Mn_2^{+}+2H_2O=5MnO_2\downarrow+2K^{+}+4H^{+}$

According to the reaction formula, the theoretical dosage of potassium permanganate is 1.91 times the mass concentration of divalent manganese. Considering that the manganese dioxide precipitate generated in the reaction has an adsorption effect on divalent manganese, and the organic matter in the raw water will consume part of potassium permanganate, the actual dosage of potassium permanganate is generally 1.5~2.5 times the mass concentration of divalent manganese (Ma et al., 2023). In order to determine the optimal dosage of potassium permanganate composite salt, the manganese oxidation stirring test was carried out in the laboratory first, and then the industrial application was carried out according to the test results. The specific implementation measures are as follows:

(1) Laboratory stirring test to determine the optimal dosage: Potassium permanganate composite salt solution with a certain concentration was prepared, and 1L of raw water of Yunzhe Reservoir was taken in each beaker. The potassium permanganate composite salt solution was added to each beaker according to 3~5 times the mass concentration of divalent manganese (0.81mg/L), and stirred at a constant speed for 2min to make it fully react. The reaction solution was filtered with a 0.45μm microporous filter membrane, and the manganese content in the filtrate was determined. The test results showed that when the dosage of potassium permanganate composite salt was 3.6 times the mass concentration of divalent manganese (i.e., 2.9mg/L), the manganese content in the filtrate was the lowest and met the standard. Therefore, the optimal dosage of potassium permanganate composite salt was determined to be 2.9kg per 1000 tons of water.

(2) Determination of reasonable dosing point: The dosing point of potassium permanganate composite salt was selected at the front end of the folded plate reaction tank (before adding alum).

When the pH value of the raw water is above 6.5, the oxidation reaction of potassium permanganate and divalent manganese can be completed in a few minutes (Li et al., 2023). The folded plate reaction tank has a good mixing effect, which can make the potassium permanganate composite salt fully contact and react with the raw water, and the manganese dioxide precipitate generated by the reaction can be adsorbed and flocculated with the alum floc, which is convenient for subsequent sedimentation and filtration removal.

(3) Dosing method and operation control: The potassium permanganate composite salt solution with a certain concentration was prepared in the chemical dosing tank of the waterworks, and a digital metering pump was used to add the composite salt into the raw water pipe according to the raw water flow rate and the optimal dosage. The water sample was taken from the second or third row of the folded plate reaction tank for manganese content determination, and the dosing amount was adjusted in real time according to the test results. If the filtrate showed purple-red, it indicated that the dosage of potassium permanganate composite salt was excessive, and the dosage should be reduced immediately to avoid the "red water" phenomenon in the effluent. At the same time, the normal operation of the valveless filter was ensured, and the backwashing frequency of the filter was appropriately increased to prevent the manganese dioxide precipitate from blocking the filter material and affecting the filtration effect.

(4) Key points of process operation: In the process of adding potassium permanganate composite salt for manganese removal, four key operation points should be grasped: ① Control the turbidity of the filter effluent to be not more than 0.5NTU to ensure that the manganese dioxide precipitate is fully intercepted; ② If there are reducing interfering substances such as sulfide and ammonia in the raw water, sodium hypochlorite should be added first to remove them to avoid affecting the manganese removal effect; ③ Strengthen the continuous monitoring of manganese content in the raw water, folded plate reaction tank effluent and filter effluent, and feed back the monitoring results in a timely manner to adjust the dosing amount; ④ Ensure that the pH value of the raw water is maintained at 6.5~7.5 (neutral range), so as to ensure that the oxidation reaction can proceed normally and generate manganese dioxide precipitate.

After the implementation of the above measures, the water quality monitoring results showed that the manganese content in the filter effluent of the Phase II water system decreased from 1.10mg/L of raw water to below 0.05mg/L, which met the limit requirement of GB 5749-2022 for manganese content in drinking water. The manganese removal effect was stable and ideal, and no "red water" phenomenon and other secondary water quality problems occurred in the effluent, which realized the safe and stable water supply of the Phase II water system.

4. Conclusions and Recommendations

4.1. Conclusions

(1) The main reason for the excessive manganese in the raw water of Tiechang Reservoir and Yunzhe Reservoir in Cangnan County is the combined effect of local geological conditions and seasonal environmental changes. The reservoir bottom is rich in manganese-containing sediments,

and the high temperature in summer leads to thermal stratification of the reservoir water body and anoxic environment at the bottom, which makes the insoluble tetravalent manganese be reduced to soluble divalent manganese and released into the water body, resulting in a sharp increase of manganese content in the raw water.

(2) Aiming at the different manganese content in the raw water of the two reservoirs, the waterworks adopted targeted manganese removal measures on the basis of the original conventional water treatment process, and achieved ideal manganese removal effects. For the raw water with low divalent manganese content (≤0.32mg/L), the strengthened pre-chlorination process (effective chlorine dosage 0.5mg/L, raw water pH adjusted to 8.5) can effectively oxidize divalent manganese, and the manganese content in the effluent is stably controlled below 0.05mg/L; for the raw water with high divalent manganese content (>0.8mg/L), the method of adding potassium permanganate composite salt (optimal dosage 2.9mg/L) can achieve efficient manganese removal, and the manganese content in the effluent is also reduced to below 0.05mg/L.

(3) The core of chemical oxidation manganese removal technology for waterworks is to oxidize soluble divalent manganese into insoluble tetravalent manganese dioxide precipitate, which is then removed by the conventional coagulation, sedimentation and filtration processes. The key to the selection of oxidant is to adapt to the actual water quality of the waterworks and the existing process conditions. Potassium permanganate and sodium hypochlorite are suitable for the manganese removal transformation of small and medium-sized waterworks with the advantages of simple operation, low cost and quick effect.

(4) Flame atomic absorption spectrophotometry has the advantages of high determination accuracy, good precision and simple operation, which can accurately determine the manganese content in water samples at each treatment stage of the waterworks, and provide reliable data support for the optimization of manganese removal process parameters and the evaluation of manganese removal effect.

4.2. Recommendations

(1) Strengthen the early warning monitoring of raw water quality: The waterworks should establish a long-term monitoring mechanism for the manganese content in the reservoir raw water, especially strengthen the water quality monitoring in summer and autumn when the manganese content is easy to exceed the standard, and master the change law of manganese content in the raw water in time. At the same time, the water intake height of the reservoir should be optimized to avoid taking water from the bottom water body with high manganese content as far as possible.

(2) Optimize the manganese removal process parameters dynamically: The dosage of oxidants (sodium hypochlorite, potassium permanganate composite salt) should be adjusted dynamically according to the real-time change of manganese content in the raw water and the water quality indicators such as pH value and organic matter content, so as to ensure the manganese removal effect and avoid the secondary water quality problems caused by excessive dosage.

(3) Strengthen the daily operation management of the water treatment process: For the filter, the backwashing frequency and backwashing time should be adjusted according to the actual filtration effect to ensure that the filter material is clean and the manganese dioxide precipitate is

fully intercepted; for the chemical dosing system, the accuracy of the metering pump should be checked regularly to ensure the accurate control of the oxidant dosage.

(4) Carry out the research and development of combined manganese removal technology: On the basis of the existing chemical oxidation manganese removal technology, the waterworks can carry out the research and application of combined manganese removal technology such as "oxidation + adsorption" and "biological manganese removal", further improve the manganese removal efficiency and stability, and provide a more diversified technical scheme for the treatment of excessive manganese in raw water.

(5) Strengthen the protection of reservoir water sources: Combined with the local environmental governance, the pollution control of the surrounding areas of the reservoir should be strengthened, the input of manganese-containing pollutants into the reservoir should be reduced, and the ecological environment of the reservoir water source should be improved from the source, so as to reduce the occurrence probability of excessive manganese in the raw water.

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Manufacturer Demand and Engineering Adaptation: An Interdisciplinary Study of Suspension System Design and Tuning for Motorcycles and Electric Two-Wheelers

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Abstract

This study investigates the design and tuning of suspension systems for motorcycles, mopeds, and electric two-wheelers from the perspective of manufacturer-driven demand. Rather than focusing solely on technical specifications, the research adopts a practice-oriented and interdisciplinary approach to analyze how engineering decisions are shaped by differentiated product positioning, user expectations, and industrial constraints. Drawing on real-world R&D scenarios, the paper examines the interaction between suspension system parameters and overall vehicle performance, including comfort, handling stability, durability, and cost efficiency. It further systematizes the design logic of key parameters such as load capacity, suspension stroke, stiffness, and structural configuration, and analyzes the iterative tuning process based on real-vehicle testing and feedback mechanisms. Through this process, a demand-driven adjustment framework is established, in which parameter optimization is continuously refined through empirical verification and scenario-based evaluation. The findings indicate that effective suspension system development depends on the coordinated integration of design principles, tuning strategies, and system-level matching with vehicle architecture. Moreover, the study highlights that engineering practices in this field are not purely technical, but are embedded within a broader socio-technical context involving manufacturer requirements, cost constraints, and user-oriented performance expectations. By bridging practical engineering experience with analytical abstraction, this research provides a structured reference for suspension system development and contributes to interdisciplinary discussions on how demand-driven design influences technological implementation in the two-wheeler industry.

Keywords: Suspension System; Motorcycles; Tuning Methodology; Industrial Practice; System Integration

1. Introduction

Motorcycles, mopeds and electric two-wheelers have become essential modes of transportation for both urban and rural mobility in China, playing a significant role in daily commuting, short-distance logistics and flexible travel (Xie et al., 2025; Scorrano & Danielis, 2025). With the continuous expansion of application scenarios and user groups, the development of such vehicles is no longer limited to basic functional requirements such as power output and endurance, but increasingly emphasizes driving safety, riding comfort and overall user experience. In this context, the suspension system, as the key interface between the vehicle and road surface, has emerged as a critical subsystem that directly influences vibration attenuation, body stability and tire-road interaction.

From an engineering perspective, the performance of the suspension system determines the vehicle's ability to respond to complex and variable road conditions. Insufficient suspension performance may lead to excessive vibration transmission, unstable body posture and reduced tire adhesion, thereby affecting braking performance, cornering stability and overall operational safety (Ferhath & Kasi, 2024; Zang et al., 2025). At the same time, from an industrial perspective, suspension design has become an important factor in product differentiation and market competitiveness, as manufacturers seek to meet increasingly diversified user expectations under constraints of cost, weight and durability.

At present, the demands of main engine manufacturers for suspension systems exhibit clear differentiation across vehicle categories. Fuel motorcycles, particularly high-performance and large-displacement models, emphasize handling precision, high-speed stability and durability under extreme operating conditions. Mopeds, which are primarily used for urban commuting, prioritize cost efficiency, structural simplicity and ease of maintenance, while still maintaining acceptable levels of comfort (Rui & Othengrafen, 2025). In contrast, electric two-wheelers place greater emphasis on fine vibration filtering, riding comfort and energy efficiency, with particular attention to the influence of suspension weight and damping characteristics on vehicle endurance.

Despite these differences, suspension system development is increasingly characterized by a demand-driven engineering paradigm, in which design decisions are shaped by the integration of vehicle positioning, user behavior and industrial constraints. Based on this context, this paper analyzes the key design principles and tuning methodologies of suspension systems from the perspective of manufacturer requirements. By synthesizing practical R&D experience and general engineering logic, the study aims to establish a structured understanding of how demand-oriented design and iterative tuning processes contribute to the optimization of suspension performance in real-world applications.

2. Core Demands of Main Engine Manufacturers for Suspension Systems

2.1. Demand Differences Across Vehicle Categories

The design direction of suspension systems is fundamentally determined by the differentiated requirements of main engine manufacturers, which are closely linked to vehicle type, usage

scenario and target user group (Llopis-Albert et al., 2023; Ferhath & Kasi, 2024). For motorcycles, especially large-displacement sport models, suspension systems are required to achieve a high level of dynamic performance, balancing stability during high-speed operation with responsiveness in cornering conditions. In such cases, suspension design must effectively control body roll, suppress vibration under uneven road excitation and ensure precise tire-ground contact, thereby supporting advanced handling performance.

In contrast, mopeds are typically characterized by compact structure and lower operating speeds, leading manufacturers to prioritize cost control, structural simplicity and ease of installation. The suspension system in this context is expected to provide sufficient shock absorption for daily commuting while maintaining low production and maintenance costs. Electric two-wheelers, driven by the rapid expansion of urban mobility and delivery services, exhibit a different set of priorities. Users of these vehicles place greater emphasis on comfort during prolonged use, requiring the suspension system to effectively filter high-frequency road vibrations and enhance riding smoothness. At the same time, the influence of suspension weight on energy consumption and driving range introduces additional design constraints, making lightweight and efficiency-oriented solutions particularly important.

2.2. Common Demand Characteristics and Engineering Implications

Despite the diversity of application scenarios, main engine manufacturers share several fundamental requirements for suspension systems, which collectively define the baseline for engineering design. Durability is the primary concern, as suspension components are subjected to continuous cyclic loading and complex road conditions over extended periods. Manufacturers therefore require that suspension systems maintain stable performance throughout the product lifecycle, with service life aligned with warranty expectations and minimal risk of failure under typical usage conditions.

Adaptability represents another critical requirement, referring to the ability of the suspension system to achieve effective integration with the overall vehicle architecture (Ferhath & Kasi, 2024; Qiu et al., 2025). This includes compatibility with frame structure, coordination with power system vibration characteristics and alignment with tire performance. Poor system integration may lead to issues such as structural interference, inefficient vibration attenuation or mismatched dynamic response, ultimately affecting vehicle stability and user experience.

In addition, adjustability has become an increasingly important consideration in modern suspension design. Some manufacturers expect suspension systems to provide basic adjustment capabilities, such as preload and damping regulation, allowing performance to be fine-tuned according to different user preferences and operating conditions. This trend reflects a shift toward more flexible and user-oriented design strategies, in which suspension systems are not only required to meet standardized performance criteria but also to accommodate variability in real-world usage.

Taken together, these common requirements illustrate that suspension system design is not merely a technical task, but a process of balancing multiple constraints within a broader socio-technical context. Engineering decisions must simultaneously address performance, reliability,

cost efficiency and user adaptability, highlighting the importance of demand-driven design frameworks in contemporary vehicle development.

3. Design Principles of Suspension Systems

3.1. Basic Parameter Design

The design of suspension systems begins with the definition of core parameters, which are fundamentally derived from the overall vehicle design requirements specified by main engine manufacturers (Trzesniowski, 2023). Among these parameters, load matching represents the primary constraint, as the suspension must be capable of supporting both the curb weight and maximum load of the vehicle under varying operating conditions. For instance, the rear suspension of electric two-wheelers is typically designed to accommodate a load range of 50–80 kg, while mopeds require a broader load adaptation range due to more variable usage scenarios. These load parameters directly influence the selection of structural dimensions and stiffness characteristics, forming the basis of suspension performance.

In addition to load considerations, suspension stroke and stiffness must be carefully configured in accordance with vehicle positioning and road conditions (Kulkarni et al., 2024). Shorter suspension strokes, commonly applied in sport motorcycles, enhance responsiveness and handling precision, whereas longer strokes, often used in electric two-wheelers, improve comfort by increasing the capacity for vibration absorption. Stiffness selection further determines the dynamic response of the suspension system: excessive stiffness reduces comfort and increases vibration transmission, while insufficient stiffness may lead to instability, excessive body roll and bottoming. Therefore, parameter design should be understood as a constrained optimization process in which performance, safety and user experience are balanced within a demand-driven engineering framework.

3.2. Structural and Material Selection

Structural configuration and material selection play a decisive role in determining both the functional performance and economic feasibility of suspension systems (Borase et al., 2024). Designers must balance performance requirements with cost constraints imposed by main engine manufacturers, leading to differentiated structural choices across vehicle categories. Telescopic front suspension systems are widely adopted due to their structural simplicity, reliability and ease of installation, making them suitable for mopeds and electric two-wheelers. In contrast, rear suspension systems exhibit greater diversity, with high-performance motorcycles often employing multi-link or more complex configurations to enhance dynamic control, while cost-sensitive models rely on simplified single-tube or double-tube designs.

Material selection further reflects the trade-off between durability and lightweight design. High-strength steel is typically used for key load-bearing components to ensure structural integrity and fatigue resistance under long-term cyclic loading. Meanwhile, aluminum alloys and other lightweight materials are increasingly adopted in non-critical or semi-structural components to reduce overall vehicle weight, which is particularly important for electric two-wheelers where energy efficiency and range are directly affected by mass. All material choices must comply with relevant technical standards to ensure reliability and safety. In this sense, structural and material

design is not only a technical decision but also an industrial optimization process shaped by performance targets, cost considerations and regulatory requirements.

3.3. Matching Design with Vehicle Overall Systems

The suspension system cannot be treated as an isolated component, as its performance is inherently dependent on its interaction with the overall vehicle system (Wang et al., 2024). Effective design therefore requires a system-level matching approach, in which the suspension is coordinated with the frame structure, power system and tire characteristics. From the perspective of frame integration, installation dimensions must precisely match the interface design to avoid assembly deviations that could compromise stability and durability. Even minor discrepancies in mounting geometry may lead to uneven load distribution or abnormal stress concentrations.

Furthermore, the interaction between suspension dynamics and power system behavior must be carefully considered. In fuel motorcycles, the vibration characteristics of the engine influence the required damping response, necessitating a tuning strategy that minimizes vibration transmission while maintaining control stability. In electric two-wheelers, the torque output characteristics of the motor may affect suspension compression behavior, particularly under acceleration conditions. Tire characteristics also play a critical role, as the grip performance determines how suspension damping should be adjusted to balance comfort and handling. This multi-system coordination reflects a broader system integration principle, in which suspension design becomes a key node within a complex socio-technical system involving mechanical performance, user behavior and environmental conditions.

4. Tuning Processes and Methods of Suspension Systems

4.1. Preparations

The tuning process of suspension systems begins with systematic preparation, which establishes the foundation for subsequent adjustments. This stage involves the comprehensive collection of vehicle-level data provided by main engine manufacturers, including parameters such as vehicle mass, center of gravity distribution, tire specifications and intended operating conditions. These data define the initial boundary conditions for tuning and ensure that parameter adjustments are aligned with actual application scenarios.

Based on this information, initial parameter settings are determined, including preload and damping values. These initial configurations are not arbitrary but are derived from both engineering experience and vehicle positioning. For example, electric two-wheelers typically adopt moderate preload settings to prioritize comfort in daily use, while sport motorcycles require higher preload values to ensure stability during high-speed operation. This preparation phase reflects the transition from theoretical design to practical implementation, where standardized design logic is translated into initial tuning configurations.

4.2. Steps of Real Vehicle Tuning

Real vehicle tuning represents the core phase of suspension development, characterized by an iterative process combining empirical testing and parameter optimization. The process begins with road testing under representative conditions specified by main engine manufacturers, including smooth, rough and irregular road surfaces. During these tests, key performance indicators such as vibration transmission, body roll behavior and rider perception of comfort are systematically recorded.

Based on the feedback obtained, targeted parameter adjustments are carried out. For example, excessive stiffness can be mitigated by reducing damping forces, while insufficient stability may require increased stiffness or preload. Issues such as rapid rebound and oscillation are addressed by adjusting rebound damping characteristics. Each adjustment is followed by repeated testing to verify its effectiveness, forming a continuous feedback loop. This iterative tuning mechanism highlights the empirical nature of suspension optimization, where performance improvements are achieved through the integration of standardized methods and real-world observations.

4.3. Key Considerations in Tuning

The tuning process must adhere to several critical principles to ensure that performance optimization does not compromise overall system integrity. One of the most important considerations is the balance between comfort and handling. Excessive emphasis on comfort may result in reduced vehicle stability, while prioritizing handling can lead to a harsh riding experience. Achieving an optimal balance requires careful calibration based on vehicle positioning and user expectations.

In addition, durability verification must be conducted alongside performance tuning. Long-term fatigue testing is necessary to ensure that parameter adjustments do not introduce new failure risks, such as accelerated component wear or damping degradation. Cost control also plays a crucial role in the tuning process, as main engine manufacturers operate under strict budget constraints. Therefore, optimization strategies must prioritize cost-effective solutions that achieve the desired performance without unnecessary complexity. These considerations demonstrate that tuning is not merely a technical adjustment process, but a comprehensive decision-making activity within an industrial and economic context.

5. Conclusion and Prospect

This study, grounded in the practical demands of main engine manufacturers, systematically analyzes the design principles and tuning methodologies of suspension systems for motorcycles, mopeds and electric two-wheelers. The findings indicate that demand differentiation across vehicle categories serves as the primary driver of suspension design, requiring targeted adjustments in parameters, structural configurations and tuning strategies. At the same time, effective suspension development depends on balancing multiple factors, including durability, adaptability, comfort, handling performance and cost efficiency, all of which must be aligned with real-world production and application scenarios.

Looking forward, the evolution of the electric two-wheeler industry is expected to further reshape the technical requirements for suspension systems. Emerging trends such as intelligent adjustment, adaptive damping and lightweight design will play an increasingly important role in improving vehicle performance and user experience. In this context, suspension systems are likely to evolve toward more integrated and responsive solutions that can dynamically adapt to varying driving conditions. By organizing existing engineering practices within a structured analytical framework, this study provides a practical reference for suspension system development while also contributing to broader discussions on demand-driven engineering and technological adaptation in modern manufacturing systems.

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Hongqin Wu contributed to the conceptualization, methodology of the study, and supervised the overall project, and coordinated the research process of the study. Xuhui Yang performed data analysis and conducted the first draft of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Profitability Transformation under Income Contraction: Financial Performance Analysis of Nanjing High-Tech Co., Ltd. (2022-2024)

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Abstract

This study focuses on Nanjing High-Tech Co., Ltd., conducting a systematic analysis of its profitability using financial data from 2022 to 2024. Key evaluation metrics include sales profit margin, cost-profit ratio, earnings per share, price-to-earnings ratio, and profit structure. The research reveals that despite a significant revenue decline in 2024, the company achieved notable improvements in key indicators by increasing investment returns, strengthening cost control, and optimizing business structures. Findings indicate that Nanjing High-Tech maintained robust profitability despite revenue contraction, demonstrating structural improvements. Through scaling back low-margin traditional real estate operations, refining cost structures, and expanding high-margin sectors like industrial park services, pharmaceutical sales, and equity investments, the company significantly enhanced gross profit margins, operating profit margins, and cost-profit ratios, leading to substantial improvements in earnings quality. Net profit and earnings per share continued to grow, while the price-to-earnings ratio steadily increased, reflecting positive market expectations for its profitability and strategic transformation. Overall, Nanjing High-Tech's profitability growth stems not from revenue expansion but from optimized business structures and operational efficiency improvements, demonstrating inherent sustainability and providing valuable insights for similar enterprises undergoing transformation.

Keywords: Profitability Analysis; Profit Structure Optimization; Business Transformation; Investment Returns

1. Introduction

Against the backdrop of rapid economic growth and profound industrial restructuring, the profitability of listed companies has become a key benchmark for evaluating corporate value, operational quality, and sustainable development capabilities. Compared to revenue growth models solely reliant on scale expansion, finding more stable and efficient profit models in complex economic environments has increasingly become a focal point in modern business

management. This is particularly true for the traditional real estate sector, where cyclical fluctuations have intensified and profit margins continue to shrink (Ren, 2004). Under these circumstances, corporate strategies involving business restructuring, cost optimization, and diversified portfolio development to transform profit models carry significant practical and research value (Jiang, 2010).

Current research predominantly analyzes corporate profitability through single financial indicators or traditional core business perspectives, focusing on revenue scale and cost control. However, studies examining how companies enhance profitability through business restructuring and high-quality investments amid declining operating revenues remain scarce. Particularly for state-owned listed companies navigating economic downturns in traditional industries, the underlying mechanisms driving their transformation strategies warrant further exploration.

Nanjing High-Tech Co., Ltd., a state-controlled listed company, has long focused on real estate development, municipal infrastructure construction, and industrial park operations as its core businesses. Through equity investments, the company has progressively expanded into strategic emerging industries. Despite fluctuations in revenue, it has achieved significant improvements in both profit scale and profitability quality in recent years, serving as a representative case study for optimizing corporate profit structures and driving business transformation.

This study employs case study methodology, taking Nanjing High-Tech Co., Ltd. as the primary research subject and integrating financial ratio analysis to construct a three-dimensional analytical framework encompassing profitability levels, profit quality, and profit structure. Key indicators selected include sales profit margin, cost-profit margin, earnings per share (EPS), price-to-earnings ratio (P/E ratio), and business and geographic structure. Specifically: First, trends in corporate profitability are analyzed through metrics such as sales profit margin and cost-profit margin. Second, the contribution of profit models to shareholder value and market reactions are evaluated using EPS and P/E ratio indicators. Third, profit sources are examined from two dimensions: business structure and regional distribution. The indicator selection adheres to standard profitability analysis paradigms while incorporating Nanjing High-Tech's transformational characteristics ─ including high investment returns, contraction of traditional businesses, and expansion into emerging sectors ─ to ensure analytical relevance and data reliability. The study systematically analyzes the intrinsic logic and structural features of profitability transformation under revenue contraction conditions at Nanjing High-Tech Co., Ltd.

2. Overall Corporate Status

Nanjing High-Tech Co., Ltd., established in 1992 and listed on the Shanghai Stock Exchange in 1997, is under the control of the Nanjing Municipal People's Government State-owned Assets Supervision and Administration Commission. The company has developed a synergistic business model integrating real estate development, municipal infrastructure, and equity investments. In real estate and municipal sectors, it holds national Class A property development licenses and property management certifications, with operations spanning residential development, municipal engineering projects, and industrial park management, establishing itself as a regional industry

leader. Its equity investments focus on technology-driven fields including healthcare and information technology, leveraging four specialized investment platforms to facilitate initial public offerings for multiple portfolio companies. Financial performance shows robust growth: revenue reached 2.4 billion yuan in the first three quarters of 2025, with net profit attributable to shareholders hitting 2.438 billion yuan ― a year-on-year increase of 58.11% and 32.64% respectively. By implementing an industrial synergy model combining production and investment, the company achieves balanced economic and social benefits while continuously creating value for stakeholders and society.

3. General Profitability Analysis

3.1. Sales Profit Margin

Table 1 data reveals that while the company's operating revenue in 2024 declined significantly compared to 2023, multiple profitability metrics showed improvement. This indicates that despite shrinking revenue scale, the company has achieved enhanced profit quality.

In terms of gross profit margin, the figure reached 21.87% in 2024, marking a significant increase of 9.54 percentage points from 12.33% in 2023, with a growth rate of 77.35%. This indicates a substantial rise in the amount available for covering expenses and generating profits after deducting operating costs from every 100 yuan of operating revenue. The substantial improvement in gross profit margin has laid a crucial foundation for enhancing overall profitability.

Meanwhile, all key profit margin indicators demonstrated significant growth. The EBIT margin increased from 33.80% to 87.13%, operating margin rose from 28.94% to 76.20%, and net profit margin on sales climbed from 31.37% to 83.09%. Despite a 58.22% decline in operating revenue, net profit still achieved a 10.65% growth, reflecting effective adjustments in cost control, expense management, and business structure optimization.

The inverse relationship between revenue and profit margins reflects Nanjing High‐ Tech’s revenue structure optimization in 2024The inverse relationship between revenue and profit margins reflects Nanjing High‐ Tech’s revenue structure optimization in 2024. The company has maintained long-term equity holdings in high-quality assets such as Bank of Nanjing and Qixia Construction. As shown in Table 1, Nanjing High-Tech's investment income reached 2.294 billion yuan in 2024, up 16.28% from 1.965 billion yuan in 2023. These gains—generated through dividend distributions, partial financial asset disposals, and substantial investment returns ― are directly recorded as profits rather than operating revenue, enabling sustained profit growth despite declining operating income. Concurrently, the company strategically reduced operations in the low-margin traditional real estate sector, cutting operating costs from 4.144 billion yuan in 2023 to 1.543 billion yuan in 2024 ― a 62.77% decrease exceeding the revenue decline rate. This strategic adjustment explains the improved gross profit margin compared to 2023.

Overall, Nanjing High-Tech achieved improved profit quality in 2024 despite significant revenue contraction, with the core driver being optimized revenue structure adjustments.(Shen,

2016) This improvement primarily stems from two factors: First, investment income contributed substantially, with a 16.28% growth rate that directly expanded profit margins; second, cost structure optimization through substantial contraction of low-margin traditional businesses resulted in operating cost reductions exceeding revenue declines. These characteristics indicate that the company's profitability enhancement reflects distinct structural adjustment attributes.

Table 1. Calculation Table of Sales Profit Margin for Nanjing High-Tech Company Amount

(Unit: Billion Yuan)

project	2024	2023	Scale changes		2022
			Increase or decrease amount	Growth Rate	
operating receipt	19.75	47.27	-27.52	-58.22%	44.82
cost of sales	15.43	41.44	-26.01	-62.77%	36.49
gross profit on sales	4.32	5.83	-1.51	-25.90%	8.33
EBIT	17.21	15.98	1.232	7.71%	28.35
operating profit	15.05	13.68	1.37	10.01%	26.50
total profit	15.08	13.70	1.38	10.07%	26.52
net margin	16.41	14.83	1.58	10.65%	24.80
gross profit margin	21.87%	12.33%	9.54%	77.35%	18.59%
EBIT margin	87.13%	33.80%	53.33%	157.80%	63.26%
operating profit margin	76.20%	28.94%	47.26%	163.31%	59.13%
net profit margin on sales	83.09%	31.37%	51.72%	164.84%	55.33%
yield	22.94	19.65	3.20	16.28%	24.05

3.2. Cost Expense Profit Margin

As shown in Table 2, Nanjing High-Tech's cost-profit margin has exhibited a fluctuating trend over the past three years, initially declining before rebounding. The margin dropped to 30.01% in 2023 but surged to 76.08% in 2024, marking a 46.07 percentage point increase. This growth occurred despite a 58.22% revenue decline, while total profits rose by 10.07% during the same period. This dynamic interplay between revenue contraction and profit expansion demonstrates

the company's effective cost control measures and strategic business restructuring efforts, reflecting tangible operational improvements.

Table 2. Financial Data in Nanjing High-Tech Company's Income Statement Amount

(Unit: Billion Yuan)

project	2024	2023	Scale changes		2022
			Increase or decrease amount	Growth Rate	
cost in business	15.43	41.44	-26.01	-62.77%	36.49
tax and surcharge	-0.24	0.37	-0.61	-167.00%	-0.35
selling expenses	0.79	0.26	0.53	200.68%	0.31
general & admin expenses	1.34	1.24	0.10	8.22%	2.62
research and development expenditure	0.41	0.14	0.27	198.41%	0.13
financial expenses	2.09	2.20	-0.11	-5.17%	1.77
Total cost expenses	19.82	45.65	-25.83	-56.58%	40.96
total profit	15.08	13.70	1.38	10.07%	26.52
cost margin	76.08%	30.01%	46.07%	153.52%	64.75%

From the perspective of cost structure, Nanjing High-Tech's operating costs in 2024 amounted to 1.543 billion yuan, representing a 62.77% decrease compared to 4.144 billion yuan in 2023. This significant reduction in total costs primarily reflects the company's proactive downsizing of low-margin or capital-intensive operations, consistent with the observed trend of declining revenue coupled with rising profit margins. Regarding period expenses, sales expenses and R&D expenditures increased by 200.68% and 198.41% respectively, indicating substantial investments in market expansion and technological innovation as the company transitions toward high-value-added business models. Financial expenses saw a modest 5.17% decrease, reflecting stable financing cost control. Administrative expenses rose by 8.22%, remaining within reasonable levels overall.

Particular note is the shift from positive to negative figures in tax and surcharge items. As shown in Table 2, these items recorded a deficit of 24 million yuan in 2024. Factors such as tax incentives, input tax credits, and land value-added tax settlements contributed positively to corporate profits. (Xu & Luo, 2017)Against the backdrop of shrinking revenue, total costs and expenses decreased by 56.58%—far exceeding the profit growth rate—demonstrating that the company achieved cost reduction and efficiency improvements through structural adjustments, resulting in significant enhancement of cos profit margins.

4. Special Profitability Analysis

4.1. Basic Earnings Per Share

4.1.1. Earnings Per Share Analysis of Nanjing High-Tech

Earnings per share showed a slight downward trend, with basic earnings per share rising from 0.902 yuan in 2023 to 0.997 yuan in 2024, representing a growth rate of approximately 10.53%. This aligns closely with the increase in net profit attributable to parent company shareholders, indicating that despite the fixed and largely unchanged capital stock size, the company has demonstrated enhanced capacity to convert net profit growth into tangible earnings per share and improved shareholder value creation capabilities.

Despite a significant decline in operating revenue, the company achieved synchronized growth in total profits and net profits through optimized cost structures and strategic transformation of high-margin businesses, driving steady improvements in earnings per share. Notably, the substantial increase in cost-profit margins demonstrated that net profit growth stemmed not only from revenue structure adjustments but also from enhanced overall cost control and operational efficiency. This approach has endowed corporate profitability with strong endogenous characteristics and sustainable growth potential (Yang, 2016).

Table 3. Earnings Per Share Calculation Table of Nanjing High-Tech Group Amount

(Unit: Billion Yuan)

project	2024	2023	Scale changes		2022
			Increase or decrease amount	Growth Rate	
net profit attributable to shareholders of the parent company	17.25	15.6	1.65	10.58%	24.02
Number of Common Shares (10 thousand)	173033.96	173033.96	0	0	173033.96
Basic earnings per share (RMB)	0.997	0.902	0.095	10.53%	1.388

4.1.2. Comparison with Competitor Companies in the Same Industry

Both China Fortune Land Development and Nanjing High-Tech Group are listed companies operating in the real estate and industrial park sectors. Given their distinct development trajectories and profit models under comparable market conditions, this study conducts a comparative analysis of these two enterprises.

A comparison with China Fortune Land Development reveals in Table 4 that the net profit attributable to parent company shareholders decreased from 1.588 billion yuan in 2022 to-6.028 billion yuan in 2023. Although showing some recovery in 2024, the figure remained negative, with negative earnings per share recorded over the past three years. These data indicate China

Fortune Land Development is undergoing business restructuring. In contrast, Nanjing High-Tech has maintained positive net profits attributable to parent company shareholders for three consecutive years. Despite occasional declines, the company achieved a rapid rebound in 2024 with a 10.58% increase. While basic earnings per share exhibited fluctuations, they remained stable overall and consistently positive over the past three years. Compared to peers in the industry, Nanjing High-Tech has maintained profitability for two consecutive years, demonstrating strong financial performance and sustained operational improvement. Amidst significant industry-wide pressures, Nanjing High-Tech's superior profitability outperforms competitors, reflecting tangible progress in its transformation strategy within the short term.

Table 4. Calculation Table of Earnings Per Share of China Fortune Land Development

(Unit of Amount: Billion Yuan)

project	2024	2023	Scale changes		2022
			Increase or decrease amount	Growth Rate	
net profit attributable to shareholders of the parent company	-48.17	-60.28	12.11	20.09%	15.88
Number of common shares	389335.51	389335.51	0	0	389335.51
basic earnings per share	-2.52	-1.75	-0.77	-44.00%	-0.69

4.2. Price-to-Earnings Ratio

The price-to-earnings ratio (P/E ratio) reflects investors 'willingness to pay per yuan of net profit, serving as a tool to evaluate investment returns and risks. As shown in Figure 1, Nanjing High-Tech's P/E ratio increased from 4.26x in 2022 to 6.39x in 2023, then further rose to 7.5x in 2024—a year-on-year growth of 17.37 percentage points. This notable increase indicates growing market optimism toward the company (Xin, 2022).

The improvement in profitability exhibits a positive correlation with valuation enhancement. As analyzed above, despite declining operating revenue, the company achieved steady growth in net profit and earnings per share through cost control and business restructuring. The improvement in fundamentals provided support for the increase in price-to-earnings ratio.

Overall, the sustained rise in Nanjing High-Tech's price-to-earnings ratio is closely linked to its structural improvement in profitability, gradual advancement of strategic transformation, and market reassessment of its development model, reflecting market trust and investor confidence (Xin, 2022).

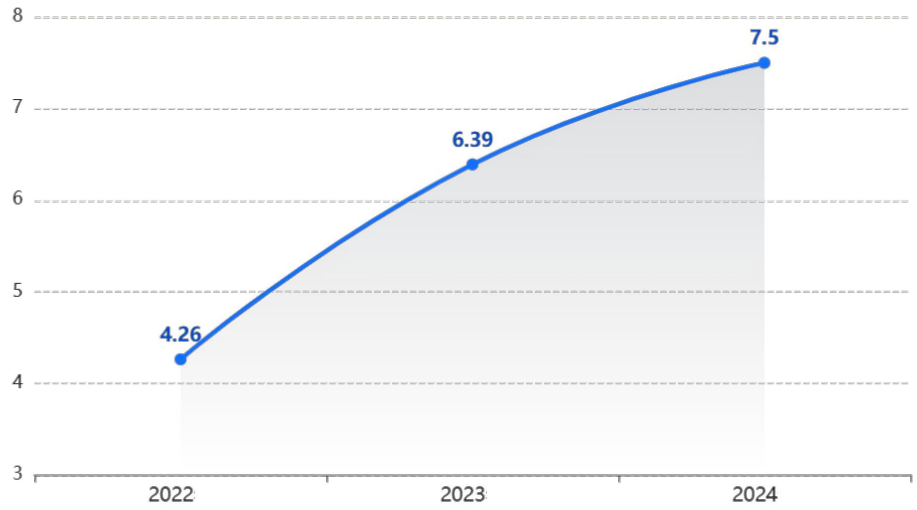

Figure 1. Price-to-Earnings Ratio Trend Chart of Nanjing High-Tech from 2022 to 2024

5. Profit Quality Analysis

5.1. Profitable Business Structure Analysis

From the perspective of profit-driven business structure, Nanjing High-Tech's operating revenue in 2022-2023 primarily stemmed from three major sectors: real estate development and sales, municipal infrastructure construction, and park management and services, with real estate development and sales holding the dominant position.

Since 2024, the company's business structure has undergone significant transformations. Firstly, traditional operations experienced contraction, with real estate development and sales revenue plummeting from 3.503 billion yuan in 2023 to 808 million yuan in 2024—a staggering 84.1% decline. This reflects Nanjing High-Tech's proactive efforts to diversify revenue streams and reduce reliance on conventional real estate ventures. Secondly, the company made its first foray into pharmaceutical sales in 2024, generating 264.4 million yuan in revenue with a 44.54% gross margin. Through substantial investments in biopharmaceutical firms like Shuo Shi Bio and Rendu Bio, the company is expanding its profit growth drivers. Meanwhile, park management and services demonstrated steady growth, achieving a 34.70% gross margin in 2024—second only to pharmaceutical sales—highlighting its strong growth potential. The combined revenue share of high-margin businesses surged from 7.2% in 2023 to 30.9% in 2024, significantly optimizing the corporate profit structure.

Overall, Nanjing High-Tech achieved structural optimization in its profit model in 2024 through significant scaling back of low-margin traditional real estate operations while actively expanding high-margin emerging businesses. Pharmaceutical sales and industrial park management emerged as key growth drivers, reflecting phased achievements in corporate transformation. Moving forward, the company should maintain close monitoring of revenue-cost alignment across business segments, with particular focus on the profitability sustainability and

growth momentum of new ventures to comprehensively evaluate the long-term effectiveness of strategic transitions (Xu, 2021).

Table 5. Profitable Business Structure Analysis of Nanjing High-Tech Group Amount

(Unit: Billion Yuan)

year	type of service	operating receipt	cost in business	gross profit rate
2024	Municipal infrastructure construction	8.08	7.397	8.50%
	real estate development and sales	5.573	4.314	22.59%
	Park Management and Services	3.457	2.258	34.70%
	Pharmaceutical sales	2.644	1.466	44.54%
2023	real estate development and sales	35.03	———	0%
	Municipal infrastructure construction	8.04	———	0%
	Park Management and Services	3.376	———	0%
	bulk development and transfer of land parcels	0.82	———	0%
2022	real estate development and sales	36.47	———	0%
	Municipal infrastructure construction	5.204	———	0%
	Park Management and Services	3.15	———	0%

5.2. Regional Structure Analysis of Profitability

From a geographical perspective of profit distribution, Nanjing High-Tech primarily targets the Nanjing market within Jiangsu Province. In both 2023 and 2024, the company's total revenue was entirely derived from Nanjing, accounting for 100% of its income, demonstrating strong regional dependence. This reflects the company's deep-rooted presence in the local market and established reputation among local enterprises, but also highlights operational risks associated with excessive geographic concentration. Since 2024, the company has begun generating revenue outside Nanjing, with income from other regions reaching 12.83% of total revenue. This indicates the company's strategic expansion efforts. Local revenue has shown significant contraction, declining from 4.727 billion yuan in 2023 to 1.722 billion yuan in 2024—63.57% decrease consistent with the overall revenue decline trend, likely attributable to contraction in traditional core business operations (Liu & Guo , 2021).

Overall, Nanjing High-Tech initiated a strategic transition from deep specialization to market expansion in 2024. This shift is closely linked to its business restructuring and optimized profit models, reflecting the company's deliberate strategic realignment. Should regional operations

maintain consistent growth momentum, it will enable Nanjing High-Tech to further reduce geographical dependence and diversify operational risks (Yang, 2009).

Table 6. Regional Revenue Structure Analysis of Nanjing High-Tech Group Revenue Amount

(Unit: 100 million yuan)

regions	2024	2023	2022
Jiangsu Nanjing	17.22	47.27	44.82
Other regions	2.54	——	——

6. Conclusion

This study utilizes financial data from Nanjing High-Tech Co., Ltd. covering 2022-2024 to conduct a systematic analysis of its profitability evolution through multiple dimensions including sales profit margin, cost-profit margin, earnings per share, price-to-earnings ratio, and profit structure. The findings reveal that despite significant revenue declines, Nanjing High-Tech maintained stable profitability while achieving substantial improvements in profit quality through strategic business restructuring and cost optimization. The company proactively reduced its traditional real estate operations while increasing investments in high-margin sectors such as industrial park services and pharmaceutical sales. By leveraging equity investments to expand profit bases, key metrics including gross sales margin, cost-profit margin, and earnings per share demonstrated progressive improvements, highlighting the structural nature of its profitability enhancement.

Further analysis reveals that Nanjing High-Tech's improved profitability stems not from revenue scale expansion, but rather from optimized revenue structure, strengthened cost control, and rational investment allocation. This demonstrates the company's practical approach to transformational development through "quality enhancement and efficiency improvement" during industry adjustments. Compared with peers in the same sector, its relatively stable profitability highlights notable anti-cyclical resilience and the effectiveness of strategic adjustments.

However, it should be noted that the improvement in corporate profitability depends to some extent on investment returns and non-recurring factors, and its long-term sustainability still requires further observation in conjunction with future profit growth trends. Additionally, this study primarily relies on publicly available financial statement data for analysis, failing to adequately incorporate external factors such as macroeconomic conditions and industry policy changes. Future research could explore the long-term effects and risks of profit structure transformation in state-owned listed companies through expanded sample sizes, multi-company comparisons, or integrated qualitative analysis methods.

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