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Research on the Key Influencing Factors of Construction Enterprises' Resilience: Based on Principal Component Regression Analysis

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Abstract: In recent years, construction enterprises have faced multiple challenges such as economic fluctuations, complex risks, and intensified competition, and there is an urgent need to improve enterprise resilience to achieve sustainable survival and development. Based on the resource-based view and dynamic capability perspective, this paper explores the influencing factors of construction enterprises' resilience. Selecting samples of 66 listed construction enterprises from 2019 to 2023, a principal component regression model of factors affecting enterprise resilience is constructed using principal component analysis and multiple regression analysis to identify the key influencing factors of construction enterprises' resilience. The results show that enterprise resilience is mainly supported by four dimensions: endogenous capability building centered on human capital and digital transformation is the most critical; external resources and trust foundations represented by corporate reputation and financial capital are crucial; at the same time, the improvement of operational efficiency and the dispersion of supply chain risks also play important roles. These factors together constitute a multi-dimensional capability system for enterprises to resist shocks and achieve recovery.

Keywords: Construction enterprises; Enterprise resilience; Resource-based view; Dynamic capability

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1. Introduction

With the rapid advancement of urbanization, the construction industry has developed rapidly, with the total construction output value increasing from 24.84 trillion yuan in 2019 to 32.65 trillion yuan in 2024. As a pillar industry of the national economy, the construction industry has a long chain, strong correlation, high capital dependence, and relatively low overall risk resistance. In the event of major crises, it is prone to industry operation disruptions. For example, against the background of the COVID-19 pandemic in 2020, affected by epidemic prevention and control measures, a large number of enterprises suspended work, supply chains were broken, and employment positions decreased, bringing considerable operational and survival challenges to construction enterprises. It also exposed the problem that construction enterprises have weak resistance and recovery capabilities in the face of sudden events such as disasters. Therefore, it is particularly important to improve the resilience and recovery capabilities of construction enterprises in the face of sudden events such as disasters. “Enterprise resilience”, as the ability of enterprises to resist and recover to a stable state when impacted, is an important path to enhance enterprises’ risk resistance and recovery capabilities. Strengthening enterprise resilience is of great significance for ensuring the stable development of construction enterprises.

At present, scholars’ research on enterprise resilience mainly starts from two perspectives: static and dynamic. The static perspective divides it into result view and trait view: the former focuses on whether enterprises can quickly recover to their original operational level from shocks; the latter emphasizes whether enterprises have sufficient resources and capabilities to effectively resist destructive events. The dynamic perspective interprets enterprise resilience from two levels: “capability” and “process”. The capability level refers to the ability of enterprises to mitigate and resist the impact of crises; the process level refers to a series of conscious and planned behaviors such as learning, adaptation, transformation, and upgrading carried out by enterprises to survive in the face of environmental changes. At present, most scholars conduct research on enterprise resilience from a single perspective, lacking comprehensive research using both dynamic and static perspectives, and most of them focus on the manufacturing field, with relatively few literatures studying the resilience of construction enterprises. Therefore, this paper comprehensively considers the influencing factors of construction enterprises’ resilience from both static and dynamic levels, and uses principal component regression analysis to explore the key influencing factors of construction enterprises’ resilience.

2. Literature review

2.1. Resource-based view

The resource-based view was proposed by Wernerfelt in the 1980s and has become one of the mainstream theories of modern strategic management [1]. The resource-based view emphasizes that enterprises’ competitive advantages stem from the uniqueness and allocation efficiency of internal resources, and resource types include tangible resources and intangible resources [2,3]. Through these key resources, enterprises can obtain and configure their external environment, and strengthen their ability to adapt to and resist the external environment. In this paper, “resources” are defined as: tangible resources with quantifiable attributes such as human resources and financial resources, as well as intangible resources without physical form such as patents, brands, and organizational experience.

2.2. Dynamic capability theory

The dynamic capability theory was developed by Teece and other scholars on the basis of the resource-based view. It is a continuous process of discovering opportunities, acquiring resources in a timely manner, reorganizing internal and external resources, and continuously adjusting strategies to respond to the dynamic environment [4]. The dynamic capability theory makes up for the lack of resource dynamics in the traditional resource-based view, shifting the research focus from static resource ownership to resource management and integration, and focusing on the generation mechanism, evolution path of resources, and their acquisition and reasonable resource allocation in a changing environment. Referring to the research of Mi Li and other scholars, this paper divides dynamic capabilities into three dimensions: environmental sensing capability, learning and innovation capability, and organizational coordination capability [5].

3. Identification of influencing factors of enterprise resilience

In this study, searches were conducted in databases such as CNKI, Wanfang, and Web of Science using keywords such as “enterprise resilience”, “organizational resilience”, “enterprise resilience”, and “organizational resilience”. Literatures with high impact factors were selected, and 41 literatures were finally selected. By sorting out and summarizing these literatures, the influencing factors were summarized and subdivided through the resource-based view and dynamic capability theory. Finally, 15 explanatory variables were determined, as shown in **Table 1**.

Table 1. Influencing factors

Theory basis	First-level indicators	Second-level indicators
Resource-Based View	Tangible Resources	Government Support (X1)
		Human Capital (X2)
		Fixed Assets (X3)
		Financial Capital (X4)
	Intangible Resources	Enterprise Information Transparency (X5)
		Enterprise Labor Productivity (X6)
		Corporate Reputation (X7)
Dynamic Capability Theory	Learning and Innovation Capability	Enterprise R&D and Innovation (X8)
		Digital Transformation (X9)
	Organizational Coordination Capability	Optimizing Supply-Demand Matching (X10)
		Financing Constraints (X11)
		Optimizing Resource Allocation (X12)
		Managerial Myopia (X13)
	Environmental Sensing Capability	Supply Chain Concentration (X14)
		Enterprise Agile Responsiveness (X15)

4. Data sources

This paper selects data of A-share listed construction enterprises from 2019 to 2023 as research samples and conducts the following processing: First, only retain data with complete records for at least 4 consecutive years; second, to reduce the impact of outliers, winsorize all continuous variables at the 1% and 99% quantiles; third, fill in individual missing data using linear interpolation. All variable data are from the CSMAR database. After screening, 66 enterprises that meet the requirements from 2019 to 2023 were finally selected.

4.1. Variable explanation

4.1.1. Explained variable

When constructing the evaluation system, Lu *et al.* selected 12 indicators from four dimensions: defense, resistance, recovery, and growth [6]. On the other hand, Xiao divided enterprise resilience into two levels: high long-term performance growth and low financial volatility, and finally used the entropy weight method to synthesize the two indicators into a comprehensive index of enterprise resilience [7]. In the construction of the evaluation system, this paper integrates the dimension division methods of scholars Lu and Xiao. The specific measurement is shown in **Table 2**.

Table 2. Measurement of enterprise resilience

First-level indicators	Second-level indicators	Calculation method
Defense Capability	Debt-to-Equity Ratio	Debt / Owner's Equity
	Cash Holding Level	Cash and Cash Equivalents / (Total Assets - Cash and Cash Equivalents)
	Uncommitted Slack	Current Assets / Current Liabilities
Resistance Capability	Standard Deviation of Monthly Stock Returns	Standard Deviation of Monthly Stock Returns
Recovery Capability	Return on Equity (ROE)	Net Profit / Average Balance of Shareholders' Equity
	Total Asset Turnover	Operating Income / Ending Total Assets
Growth Capability	Cumulative Growth Rate of Sales Revenue	Cumulative Growth Rate of Sales Revenue of Enterprises within 3 Years

4.1.2. Tangible resources

The details are as follows:

(1) Government Support: Referring to the research of Liu *et al.*, it is measured by taking the natural logarithm of the total annual government subsidies of enterprises plus 1 [8];

(2) Human Capital: Referring to the method of Tian, it is defined as the proportion of employees with a bachelor's degree or above [9];

(3) Fixed Assets: Expressed by the logarithm of fixed assets;

(4) Financial Capital: Expressed by the logarithm of the total assets of enterprises.

4.1.3. Intangible resources

The details are as follows:

(1) Enterprise Information Transparency: This study refers to the methods of Xin, Fang, *et al*., and assigns scores from 1 to 4 for evaluation grades A to D in turn. A higher score means higher enterprise information transparency [10,11];

(2) Corporate Reputation: The measurement of corporate reputation refers to the research method of Guan and Zhang [12]. 12 indicators are selected from the perspective of stakeholders, and the comprehensive score is obtained through factor analysis dimensionality reduction. Based on this, the samples are divided into ten groups in ascending order of scores and assigned 1 to 10 points;

(3) Enterprise Labor Productivity: Referring to the research of Niu *et al.*, it is measured by the natural logarithm of per capita operating income [13].

4.1.4. Learning and innovation capability

The details are as follows:

(1) Enterprise R&D and Innovation: The measurement of R&D and innovation refers to the research of Fang, which is carried out from two dimensions: innovation input and output, and the comprehensive value is calculated using the entropy weight method [14];

(2) Digital Transformation: This study refers to the practice of scholars such as Wu extracts keywords from five digital technology dimensions such as "artificial intelligence technology" in the annual reports of listed companies, calculates their total word frequency, and takes the natural logarithm of the word frequency plus 1 [15].

4.1.5. Organizational coordination capability

The details are as follows:

(1) Optimizing Supply-Demand Matching: Referring to the research of Tao *et al.*, the change range of the net inventory value of enterprises in adjacent two years is used as the measurement indicator of supply-demand matching efficiency [16];

(2) Financing Constraints: This paper refers to the research of Ge, and uses the SA index to measure enterprise financing constraints [17]. The index is constructed by two variables: company size (Size) and company age (Age), with the calculation formula: $SA = -0.737 \times Size + 0.043 \times Size^2 - 0.04 \times Age$;

(3) Managerial Myopia: With reference to the research of scholar Hu the proportion of the word frequency of the "short-term horizon" word set to the total word frequency of this part is calculated and multiplied by 100 [18];

(4) Optimizing Resource Allocation: Referring to the framework of Tang *et al.,* enterprise resources are divided into four categories: physical, financial, human, and data resources [19]. The entropy weight method is used to assign weights to each resource indicator and calculate the comprehensive score.

4.1.6. Environmental sensing capability

The details are as follows:

(1) Supply Chain Concentration: Referring to the research of Yan *et al.*, three variables are constructed: upstream supplier concentration, downstream customer concentration, and overall supply chain concentration, and the comprehensive score is calculated using the entropy weight method [20];

(2) Enterprise Agile Responsiveness: This paper refers to the research of Zhou *et al.*, and uses the number of board meetings to represent the enterprise's agile responsiveness [21].

5. Principal component regression analysis

5.1. Suitability of principal component analysis

Before conducting principal component analysis, the KMO and Bartlett's test of sphericity are performed to determine whether the data meets the conditions for principal component analysis. The results show that the KMO statistic is 0.873, indicating that the variables have strong interdependence and are very suitable for principal component analysis; the value of Bartlett's test of sphericity is 2970.011, which is statistically significant, indicating that there are significant correlations among the variables, and dimensionality reduction analysis is required.

4.2. Extraction of principal components

In this study, SPSS27.0 software is used for principal component analysis of the influencing factors of enterprise resilience, and principal component factors are determined according to the variance of each component. Through the linear combination of variables, the total variance explanation table (**Table 3**) and scree plot (**Figure 1**) reflecting the information content of the components are obtained.

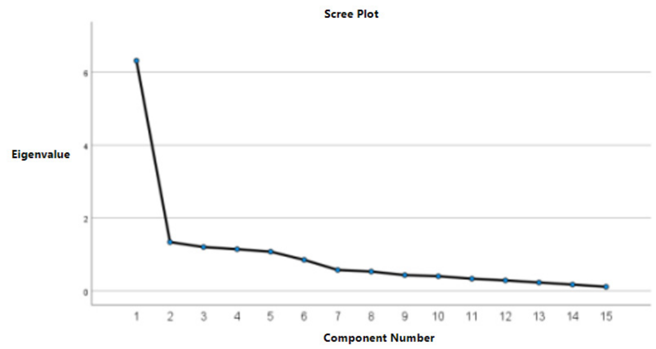

Figure 1. Scree plot.

Table 3. Total variance explanation rate

Principal component	Eigenvalue	Contribution rate (%)	Cumulative contribution rate (%)
1	6.310	42.069	42.069
2	1.263	8.417	50.485
3	1.164	7.758	58.243
4	1.120	7.468	65.712
5	1.038	6.923	72.634
6	0.823	5.484	-

Based on the principle that the eigenvalue is greater than 1 and combined with the scree plot in **Figure 1**, 5 principal component factors are finally extracted in this paper, with a cumulative variance contribution rate of 72.634%, indicating that most of the information of the original 15 variables can be effectively covered. The expressions of principal components F1-F5 and the coefficients of the factor loading matrix are obtained according to the factor results extracted from the factor loading matrix, as shown in **Table 4**.

Table 4. Component score coefficient matrix

Principal component	F1	F2	F3	F4	F5
Government Support (X_1)	0.157	0.043	0.011	0.066	0.013
Human Capital (X_2)	-0.466	0.495	0.194	0.238	-0.211
Fixed Assets (X_3)	0.206	-0.013	0.018	-0.022	-0.050
Financial Capital (X_4)	0.144	-0.044	0.151	-0.011	0.012
Enterprise Information Transparency (X_5)	0.044	0.296	-0.160	-0.071	-0.094
Enterprise Labor Productivity (X_6)	-0.165	-0.119	0.489	0.115	-0.176
Corporate Reputation (X_7)	0.161	-0.096	0.145	0.089	-0.083
Enterprise R&D and Innovation (X_8)	-0.104	0.460	-0.182	0.033	0.124
Digital Transformation (X_9)	0.033	-0.066	-0.040	0.782	0.142
Optimizing Supply-Demand Matching (X_{10})	0.045	-0.038	0.193	-0.016	0.107
Alleviating Financing Capacity (X_{11})	-0.033	-0.204	0.036	0.304	-0.181
Optimizing Resource Allocation (X_{12})	-0.047	-0.003	0.023	0.137	0.803
Supply Chain Flexibility (X_{13})	0.091	0.138	0.017	-0.151	0.008
Managerial Myopia (X_{14})	-0.363	0.091	0.208	-0.145	0.034
Enterprise Agile Responsiveness (X_{15})	-0.150	-0.119	0.448	-0.190	0.300

The expressions of 5 principal components are finally determined from Table 4. Since the variables are standardized data, the expressions use variable names with "Z" and take the following specific form:

$$F1 = 0.147ZX_1 - 0.466ZX_2+0.206ZX_3+0.144ZX_4+0.044ZX_5 - 0.165ZX_6+0.161X_7 - 0.104ZX_8+0.033ZX_9+0.045ZX_{10} - 0.033ZX_{11} - 0.047ZX_{12}+0.091ZX_{13} - 0.363ZX_{14} - 0.150ZX_{15}$$

Similarly, the expressions of principal components F2-F5 can be obtained. The scores of each principal component calculated based on these expressions lay the foundation for subsequent empirical regression analysis.

4.3. Regression analysis of principal components and enterprise resilience

To empirically test the direction of the impact of the five principal components (F1-F5) obtained from the principal component analysis on enterprise resilience, this study will conduct an in-depth analysis through the following regression model, as shown in **Equation 1**.

$$ZY_{it} = \alpha_i+\beta 1*F1_{it}+\beta 2*F2_{it}+\beta 3*F3_{it}+\beta 4*F4_{it}+\beta 5*F5_{it}+\varepsilon_{it} \quad (1)$$

The explained variable ZY represents enterprise resilience, α_i is the intercept term, $\beta_i(i=1,2,\ldots,5)$ are the parameters to be estimated, and their parameter estimation results will reveal the direction and intensity of the impact of each principal component on enterprise resilience. ε_{it} is the random error term.

4.3.1. Unit root test

To prevent spurious regression, it is necessary to ensure the stationarity of the data. Therefore, this paper uses Eviews11.0 to comprehensively adopt ADF and LLC methods to conduct unit root tests on each variable, and the results are summarized in **Table 5**. The test results confirm that the data used is stationary panel data.

This paper determines the applicable model through the Hausman test. The *P* value of the test result is 0.008, which rejects the null hypothesis at the 5% significance level. Therefore, this study selects the fixed-effect model for regression analysis.

Table 5. Regression analysis results

Variable	Coefficient	Std. Error	T-Statistic	*P*-Value
C	-9.65E-07	0.004909	-0.000197	0.9998
F1	0.072127	0.02904	2.483757	0.0136
F2	0.078456	0.021529	3.644263	0.0003
F3	0.080139	0.01943	4.124599	0.0001
F4	0.042378	0.010804	3.9225	0.0001
F5	0.006106	0.008325	0.733441	0.464
R^2	0.95511	0.95511	0.95511	0.95511
F-Statistic		78.72289		
P-Value		0.0000		

4.3.2. Regression analysis

The final analysis results are shown in **Table 5**. It can be seen that the overall model, the R^2 of this regression analysis is 0.9551, which indicates that more than 95.51% of the variation can be explained by the explanatory variables. The selected variables have a high degree of explanation, and the model fitting degree is relatively ideal. The F-statistic is 78.72289, and the *P* value is 0.000, which is much less than 0.01. Therefore, the overall effect of the entire model estimation is good.

Through the analysis of the above regression results, the regression results of 4 principal components are significant. Only the *P* value of principal component F5 is 0.464 $>$ 0.05, indicating that principal component F5 has no significant impact on enterprise resilience. Therefore, through the above analysis, the expression of the regression equation for the impact of principal components on enterprise resilience is:

$$ZY = -9.65E\text{-}07 + 0.072127F1 + 0.078456F2 + 0.080139F3 + 0.042378F4$$

Since multiple linear regression is carried out using the principal component method, it is now necessary to transform the fitted regression equation to obtain the linear regression equation between enterprise resilience and influencing factors:

$$Y=0.0184X_1+0.0308X_2+0.0144X_3+0.0186X_4+0.0106X_5+0.0228X_6+0.0195X_7+0.0154X_8+0.0271X_9+0.0151X_{10}-0.0026X_{11}+0.0039X_{12}+0.0124X_{13}-0.0085X_{14}+0.0077X_{15}$$

In principal component F1, corporate reputation has the greatest impact on enterprise resilience with a coefficient of 0.0195, which is positively correlated with enterprise resilience. When a crisis occurs, a good reputation helps enterprises maintain customer loyalty and gain support from partners, thereby winning key buffer space and external resources for enterprises and improving enterprise resilience. The coefficient of financial capital is 0.0186, which is positively correlated with enterprise resilience, indicating that the more abundant the financial capital, the stronger the enterprise resilience; the coefficient of government support is 0.0184, indicating a positive correlation between government support and enterprise resilience, indicating that the government enhances enterprises' ability to resist external shocks through financial subsidies, tax reductions and exemptions, policy-based loans, etc.; the coefficient of fixed assets is 0.0144, indicating that it has a positive impact on enterprise resilience. Fixed assets improve enterprise resilience through multiple paths such as ensuring the operational autonomy of enterprises, enhancing financing capacity, forming cost advantages, and building professional barriers; the coefficient of optimizing resource allocation is 0.0124, which is also positively correlated with enterprise resilience. By dynamically allocating limited resources to core businesses, it improves overall operational efficiency, enabling enterprises to quickly dispatch resources when facing shocks, thereby enhancing resilience. The coefficient of supply chain concentration is -0.0085, reflecting a negative relationship between this variable and enterprise resilience. This means that once key nodes are interrupted due to external shocks such as epidemics and geopolitical conflicts, enterprises will face the serious threat of supply chain disruption or operational disorders, thereby inhibiting enterprise resilience.

In principal component F2, human capital has the most significant positive impact on enterprise resilience with a coefficient of 0.0308. High-quality employees usually have the ability to learn quickly, adapt to changes, and handle complex problems, transforming challenges into innovative opportunities, thereby improving enterprise resilience. The coefficient of enterprise R&D and innovation is 0.0154, which has a positive impact on enterprise resilience. Continuous R&D investment helps enterprises accumulate new technologies and processes, improving their ability to quickly adjust strategies and develop new markets in crises. The coefficient of information transparency is 0.0106, which is positively correlated with enterprise resilience. Higher information transparency helps enhance investor confidence, reduce financing costs, and consolidate partnerships, creating more favorable internal and external conditions for enterprises to respond to external shocks. The impact coefficient of financing constraints on enterprise resilience is -0.0026, which is negatively correlated with enterprise resilience, indicating that constrained enterprises usually have weak cash reserves and high financial leverage, and are prone to liquidity crises, thereby inhibiting enterprise resilience.

In principal component F3, enterprise labor productivity is the most critical factor affecting resilience with a coefficient of 0.0228. A high enterprise labor productivity indicates high cost control and resource integration capabilities, which can invest more resources in enterprise business adjustment, transformation, and strategic transfer, thereby improving enterprise resilience; the coefficient of optimizing supply-demand matching is 0.0151, which is positively correlated with enterprise resilience, indicating that optimizing supply-demand ratio can reduce resource waste and consumption, enabling enterprises to have strong adaptability to sudden changes, thereby enhancing enterprise resilience; the coefficient of enterprise agile responsiveness is 0.0077, which is proportional to enterprise resilience. Enterprises can quickly adjust construction plans, flexibly mobilize internal resources for reasonable combination, and flexibly respond to sudden situations, thereby improving enterprise resilience.

The coefficient of digital transformation in principal component F4 is 0.0271, and digital transformation is positively correlated with enterprise resilience. With the help of data-driven decision-making, automated processes can timely obtain changes in the external environment, adjust enterprise operations in a timely manner, and thereby improve resilience.

5. Conclusion

Based on the results of the principal component regression model and the analysis conclusions, the following suggestions are put forward to improve the resilience of construction enterprises: (1) Promote the digitalization of project management and on-site operations, popularize the application of technologies such as BIM and smart construction sites, and realize construction visualization and decision-making dataization; Improve the skill training mechanism, cultivate professional trades and interdisciplinary management talents, and stabilize the core personnel of the project. (2) Strengthen financial management capabilities, do a good job in financial capital control and multi-channel financing; in terms of social relations, ensure safety and quality, take the initiative to openly share ESG practices, and win the trust of customers, financial institutions, and other parties with a long-term, stable, and responsible corporate image. (3) Implement lean construction to reduce project construction costs and time. In terms of the supply chain, reserve emergency supply funds for important materials and build a localized and diversified supplier system.

Disclosure statement

The author declares no conflict of interest.

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