

Article

Research on Factors Influencing Intelligent Construction Development: An Empirical Study in China

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Abstract: Intelligent construction (IC) is an innovative development model of the construction industry in which construction is integrated with digital technologies against the backdrop of the new technological revolution. The development of IC involves many influencing factors which are actively promoting IC development. However, investigations focusing on identifying and examining the relationships among the factors necessary for IC development are limited. In contributing to bridging this gap, this paper investigated and analyzed influencing factors for IC development by developing structural equation modeling (SEM) based on 5 variables and 28 measures, including (1) identifying the factors and examining their influence on IC development in China and (2) clarifying the paths and key measures for successful IC development. The results showed that (1) the three variables of government, company, and technology had a direct and significant impact on the development of IC, (2) the three variables of industry, company, and technology actually formed a “closed-loop” within which they interact and promote each other, and (3) it was widely realized and accepted that IC development has bright prospects in China. Furthermore, four paths for IC development were obtained and the key measures of the five variables were further analyzed. This research contributes to the body of knowledge on IC by identifying the factors influencing IC development. The four paths and key measures were proposed to clarify the relationship between factors. Recommendations were put forward to promote IC development.

Keywords: intelligent construction; influencing factors; structural equation modeling



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1. Introduction

The global construction industry is booming, increasing building projects and demand for intellectual development [1]. Furthermore, given the increasingly frequent transfer of technologies such as building information modeling (BIM) and additive manufacturing, the intelligent development of the construction industry is inevitable [2].

At present, the expression “the process or product of construction using emerging digital technologies” primarily refers to “digital construction” [3], “smart construction” [4], or “construction 4.0” [5,6]. “digital construction”, “smart construction”, “intelligent construction”, and “construction 4.0” have similar connotations; that is, the use of emerging technologies to achieve integrated collaboration of project approval decision making, planning and design, construction, and operation and maintenance services. Such integrated collaboration can significantly improve the efficiency and effectiveness of the construction industry. IC is an innovative development model of the construction industry [7]. Especially in China, IC is greatly advocated. In July 2020, the “Guiding Opinions on Promoting the Coordinated Development of Intelligent Construction and Building Industrialization” jointly issued by 13 Chinese government ministries and commissions proposed increasing the application of IC in all aspects of construction to form an IC industry.

In recent years, the application of IC technologies in construction has become increasingly extensive [8,9], and the research on IC has mainly focused on the application

of BIM [10–13], intelligent equipment [14–16], information and communication technology [17], and additive manufacturing [18–20] in the construction industry.

It can be seen from previous studies that most of the research on IC development is concerned with IC technology, and investigations focusing on identifying and examining the relationships of the influencing factors necessary for IC development are limited. However, identifying the factors and their impact is crucial for IC development. Therefore, this paper investigated and analyzed factors for IC development by (1) taking IC development in China as an example and identifying the factors and examining their influence on IC development, and (2) clarifying the paths and key measures for IC development.

2. Theoretical Framework

The conceptual research model is constructed, hypotheses are provided, and the conceptual hypothesis model is presented in this section.

2.1. Conceptual Research Model

Explanatory factors and their relationships are discussed in classical theories of industrial development. A variety of analytical frameworks were proposed to analyze industry development. Bain (1956) proposed the structure-conduct-performance (SCP) analysis paradigm to explore the impact between national policies, technological upgrades, and corporate behavior. Porter (1990) presented four factors for determining industry development, namely production, demand conditions, the performance of related industries and supporting industries, and corporate strategy, structure, and competition in the industry, and claimed that two variables influenced these factors: opportunity and government. Industrial development theory studies the problems of technological innovation, industrial clusters, companies, and product service changes [21]. The theory assumes that the motivation of industrial development includes scientific and technological innovation and other factors related to production, policies, and markets.

In the case of the influencing factors of IC development, Ding [7] proposed that the government needs to actively support IC technology innovation to provide new opportunities, promote the transformation of construction companies to seize market opportunities, and encourage cross-border industries to extend the engineering market. Wang [22] believed that the current IC technology development is unusually rapid and technology upgrading assumes the role of a pioneer, promoting the high-quality development of the construction industry. Chen & Ding [23] also pointed out that the development of domain technology plays a key role in IC development. In July 2020, the “Guiding Opinions on Promoting the Coordinated Development of IC and Building Industrialization” pointed out that IC development involves the transformation and upgrading of technology, company, and industry.

From the above research review, this paper studied the following four factors that influence IC development: government, industry, company, and technology. Moreover, we built a conceptual model, as shown in Figure 1. Then, we clarified how these factors act on IC development by examining their relationships. Finally, we discussed the influencing paths and critical measures for IC development in China.

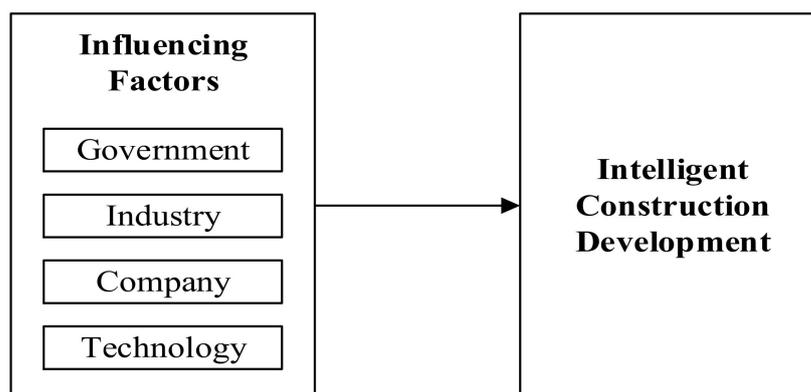


Figure 1. Conceptual research model.

2.2. Research Hypothesis

Based on a review of the research literature and expert interviews, five items including ten research hypotheses were proposed, then the conceptual hypothesis model was constructed.

2.2.1. The Relationship between Various Influencing Factors

(1) The relationship between the government and other factors

The government is an essential driver of IC development. IC development in China is driven by macro-development [24]. The role of the government affects the development of industry, company, and technology: government subsidies reduce economic risks to businesses and boost industry development [25], directly reducing the cost of research and development, encouraging companies to engage in research and development, and improving the degree of technological growth in the industry [26]. On the other hand, subsidy funds help reverse the disadvantage of cash flow shortages, reduce the risk of debt repayment, and provide more protection for the business development of companies [27]. Moreover, subsidies impact technological innovation output [28]. They make a significant contribution to technological advances [29], which also impact technological innovation behavior. Based on the above literature, we made the following assumptions:

Hypothesis 1 (H1). *Government has a positive impact on the industry;*

Hypothesis 2 (H2). *Government has a positive impact on the company;*

Hypothesis 3 (H3). *Government has a positive impact on technology;*

(2) The relationship between industry and other factors

The industry development trend has led to a mandatory structural adjustment on the supply of companies [30]. It has induced companies to carry out technological innovation [31]. According to the questionnaire survey, the industry development has had an important impact on individual companies. Based on the above literature, we made the following assumption:

Hypothesis 4 (H4). *The industry has a positive impact on business development;*

(3) The relationship between the company and other factors

Corporate strategy, innovation expectations, and research and development investment impact technology innovation [32–34]. Under the premise of pursuing their interests, companies have increased their investment in research, forming a virtuous circle that promotes technological progress [35]. For example, with the development of intelligent

technology, architectural design companies need to study intelligent integrated systems to meet design requirements, solve difficulties, improve efficiency, and complete transformation and upgrading [36].

Based on the above literature, we made the following assumption:

Hypothesis 5 (H5). *The Company has a positive impact on technological development;*

(4) The relationship between technology and other factors

Schumpeter [37] argued that technology drove new market demand, incredibly innovative technology combined with marketing, which guides industry development. Many scholars have recognized this conclusion. With the current exponential growth of information technology, digital applications, networked applications, and intelligent integration innovation are the three driving forces of new technology [38]. Based on the above literature, we made the following assumption:

Hypothesis 6 (H6). *Technology has a positive impact on the industry.*

2.2.2. The Relationship between Various Influencing Factors and the IC Development

(1) The relationship between the government and IC development

IC development is a complex system. The government plays a key driving role in industrial development through overall planning and careful arrangements to create an effective environment for development [39]. The principle of market allocation and government guidance should be followed to realize IC development [40], which requires the government to actively cultivate new industries for IC and strengthen the transformation and promotion of scientific and technological achievements [41].

Based on the above literature, we made the following assumption:

Hypothesis 7 (H7). *The government has a positive impact on IC development.*

(2) The relationship between the industry and IC development

Industry development affects the production, development, and structural adjustment of the industry. IC development is not limited to the reform of the traditional construction industry, but other sectors are also gradually entering the field of the IC industry. Therefore, the rise and change of the industry is an important force driving the development of IC. Based on this, we made the following assumption:

Hypothesis 8 (H8). *The industry has a positive impact on the development of IC.*

(3) The relationship between the company and IC development

Companies make up the main body of the IC industry. At present, the intelligent transformation of the construction industry in China still relies on leading companies to drive change. The industry is gradually reaching a higher level of development through the competition and cooperation between companies. Mao et al. believed that traditional companies could use existing emerging technologies to achieve construction and management innovation [42]. While Xia [43] believed that construction companies, as the main body of IC development, should build a combination of production, research, and development of technological innovation systems, scientifically select the path of technological innovation, and carry out construction and exploration.

Based on the above literature, we made the following assumption:

Hypothesis 9 (H9). *The company has a positive impact on IC development.*

(4) The relationship between technology and IC development

The development of industry relies on the progress of technology. Therefore, the current integration of intelligent technology and construction technology is the key issue of IC development. Chen et al. [44] pointed out that recent IC technology development is unusually rapid and technology upgrading in the construction industry assumes the role of a pioneer, promoting the high-quality development of the construction industry. Chen & Ding [45] proposed that the development of domain technology as a hub connecting the underlying general technology with the upper business can play a key role in the development of IC.

Based on the above literature, we made the following assumption:

Hypothesis 10 (H10). *Technology has a positive impact on IC development.*

2.3. Hypothesis Model

We constructed a conceptual hypothesis model based on the previous assumptions to clarify the relationship between the influencing factors and IC development, as shown in Figure 2. Then we examined the model by conducting empirical research through a questionnaire and a structural equation model in the following sections.

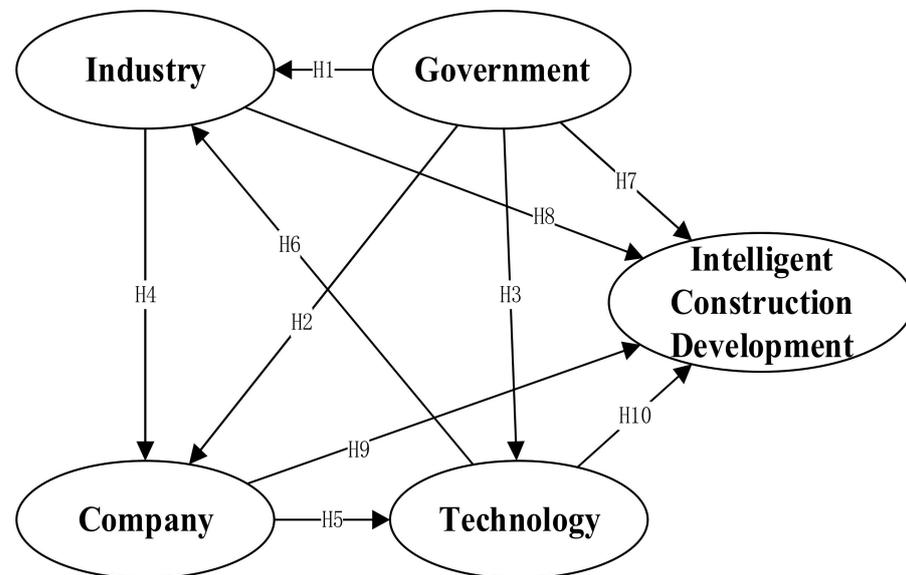


Figure 2. The conceptual model of the structural equation.

3. Research Methodology

We adopted a three-stage approach to achieve the set objectives shown in Figure 3. First, we proposed 28 measures through relevant literature and expert interviews to assess the five variables in the hypothesis model. Second, we conducted the questionnaires using a five-point Likert scale. Third, we analyzed the questionnaire data through the Harman single-factor test, measures statistical analysis, reliability and validity analysis, and structural equation modeling analysis.

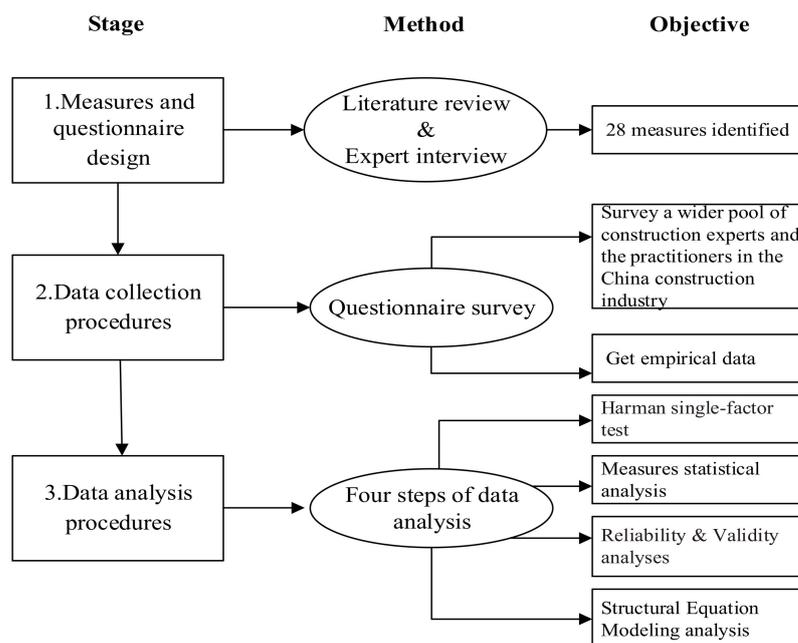


Figure 3. Three-stage research methodology.

3.1. Stage 1: Measures and Questionnaire Design

The influencing factors for IC development are latent. They are not directly measured and thus need to be specified by some measurement indicators. The measures were proposed in several ways, as listed in the following.

- The mature measurement scales are quoted as far as possible; and
- Most measures are designed based on literature reviews.

The appropriate revision and suggestions from a seven-expert group were incorporated to guarantee the rationality and completeness of the questionnaire measures. The seven-expert group included three practitioners in the construction industry, two government officials, and two scholars involved in IC. In the end, we proposed 28 measures to assess the five variables in the hypothesis model: government (four measures), industry (six measures), company (seven measures), technology (four measures), and trends of IC development (seven measures), as listed in Table 1.

Table 1. Influencing factors for IC development.

Code	Influencing Factors	Measures	Literature Reference
1	Government	The degree of government attention (G1)	[24,46]
2		The perfection and matching of regulations and standard systems (G2)	[47,48]
3		Government support policies and incentive policies (G3)	[49,50]
4		Demonstration project (G4)	[51,52]
5	Industry	Industry promotion/guidance measures (I1)	[53]
6		Industry training efforts (I2)	[54,55]
7		Market and consumer demand(I3)	[7,56]
8		The overall level of IC technology application capabilities (I4)	[36,57]
9		The number and type of IC companies (I5)	[58]
10		The degree of industry association (I6)	[59]
11	Company	The degree of attention of the companies (C1)	[53,59,60]
12		Company management system (C2)	[61,62]
13		The resource input of the companies (C3)	[63,64]
14		Company technology research and development capabilities (C4)	[65,66]
15		Vocational training for companies (C5)	[67,68]
16		Employee awareness and engagement with IC (C6)	[69,70]
17		Employee technical application capabilities (C7)	[71,72]

Table 1. Cont.

Code	Influencing Factors	Measures	Literature Reference
18	Technology	The maturity of the intelligent technology application system (T1)	[40]
19		Security issues for data and privacy (T2)	[73,74]
20		Hardware and software facilities (T3)	[40,75]
21		Technology convergence (T4)	[76,77]
22	Trends of IC Development	IC technology has been widely used, and the degree of intelligence has been greatly improved (TICD1)	[7,78]
23		Industry chain upstream, downstream extension, and market expand (TICD2)	[7,21]
24		The industry has achieved industrialization, service, and platform transformation (TICD3)	[7,79]
25		The industry can provide people-oriented, green sustainable products and services (TICD4)	[7]
26		Due to the concentration of industry, the degree of homogenization of companies is intensified (TICD5)	[41,80]
27		Company survival of the fittest, the industry as a whole to enhance innovation capacity (TICD6)	[81,82]
28		The construction industry traditional, and its future is not much different from that of the present (TICD7)	[83,84]

Then we designed the questionnaire based on the 28 measures of the five categories of influencing factors from the Porter Diamond Model Theory. The purpose of the questionnaire was to survey a wider pool of construction experts and practitioners in China's construction industry to obtain empirical data and determine the relationships of the identified factors. We used a five-point Likert scale [85,86] in the questionnaire: 1–5 respectively represented “strongly disagree”, “disagree”, “neutral”, “agree”, and “strongly agree”, and all the measurement indices were declarative sentences.

3.2. Stage 2: Data Collection Procedure

We collected data by questionnaire. A total of 200 questionnaires were distributed online via a web-based platform. After recovery, 160 valid questionnaires were obtained and the effective recovery rate was 80%. The profile of the respondents is presented in Table 2.

Table 2. Respondents' characteristics.

Category	Characteristic	Frequency	Percentage (%)
Nationality	China	160	100
Organization	Construction companies	53	33.12
	Research/teaching institutions	81	50.63
	IC technology development company	4	2.50
	Government departments	6	3.75
	Other	16	10
Position level	Senior management	17	10.63
	Middle-level management	73	45.62
	Low-level physical operators	70	43.75
Working years	Less than 5 years	35	21.88
	5–10 years	38	23.75
	10–20 years	60	37.50
	More than 20 years	27	16.88
Level of understanding of IC	Greatly understand	10	6.25
	Understand	68	42.5
	Moderately understand	70	43.75
	Slightly understand	11	6.87
	Does not understand	1	0.88

3.3. Stage 3: Data Analysis Procedure

We analyzed the data in the four steps shown in Figure 4.

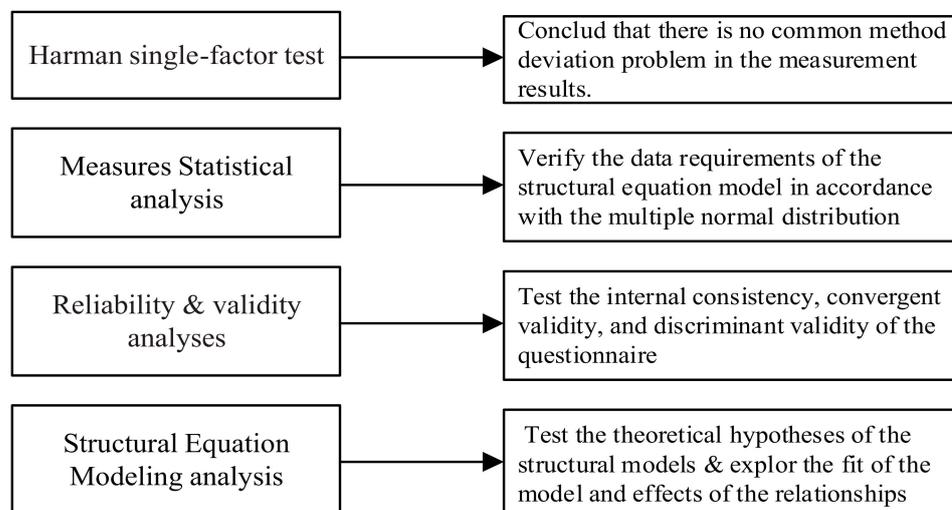


Figure 4. Four steps of data analysis.

First, all questionnaire questions were analyzed for gender factors through the Harman single-factor test. The variance interpretation rate of the first principal component obtained in the absence of rotation was 10.642%, which did not account for the majority. From the result of the composition matrix, the load of no question on the first main component exceeded 0.5. Therefore, it can be concluded that there was no common method deviation problem in the measurement results.

Second, we examined the correlation, collinearity, and normality of the variables. The thresholds of absolute skewness, absolute kurtosis, and variance inflation factor (VIF) were all less than or equal to 2, 7, and 5, respectively [87,88]. Finally, since the parameter estimation method in structural equation model analysis requires sample data to satisfy the multiple normal distributions, we tested the survey results for normal distribution. Table 3 shows the data that meet the requirements of the structural equation model under the multiple normal distributions.

Table 3. The result of measures statistical analysis.

Question	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Kolmogorov–Smirnov D	<i>p</i>
1	5	1	0.758	1.958	6.167	0.298	*
2	5	1	0.798	1.706	4.886	0.276	*
3	5	1	0.881	1.830	3.954	0.332	*
4	5	1	0.886	1.117	1.864	0.255	*
5	5	1	0.737	1.654	6.255	0.303	*
6	5	1	0.774	0.877	0.851	0.268	*
7	5	1	0.723	0.779	0.587	0.247	*
8	5	1	0.782	1.438	4.354	0.279	*
9	5	1	0.800	1.586	4.590	0.311	*
10	5	1	0.839	0.885	1.790	0.287	*
11	5	1	0.853	1.566	3.609	0.260	*
12	5	1	0.746	0.107	−0.467	0.264	*
13	5	1	0.895	1.632	3.140	0.310	*
14	5	1	1.000	1.190	1.641	0.252	*
15	5	1	0.845	1.019	2.085	0.289	*
16	5	1	0.969	1.110	1.592	0.297	*
17	5	1	0.903	1.122	1.736	0.282	*
18	5	1	1.009	1.323	1.869	0.284	*

Table 3. Cont.

Question	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis	Kolmogorov–Smirnov D	<i>p</i>
19	5	1	0.824	0.686	−0.003	0.242	**
20	5	1	0.849	1.071	2.134	0.244	*
21	5	1	0.857	1.215	2.366	0.245	**
22	5	1	0.961	0.757	0.451	0.250	*
23	5	1	0.926	0.643	−0.367	0.240	**
24	5	1	0.818	0.579	−0.114	0.251	**
25	5	1	0.958	0.974	0.904	0.268	*
26	5	1	0.866	0.661	1.055	0.253	*
27	5	1	0.895	0.777	−0.135	0.237	**
28	5	1	1.337	0.446	−1.119	0.290	**

Note: * means $p > 0.05$, ** means $p > 0.01$.

Third, we used the Kaiser-Meyer-Olkin (KMO) measure and Bartlett samples to test whether the data are suitable for factor analysis and the validity of the data. Experience showed that a KMO greater than 0.7 is suitable for factor analysis and KMO below 0.5 indicates unsuitable [89,90]. KMO and Barclay spherical significance tests of the study data were performed using SPSS and the results are shown in Tables 4 and 5, indicating that the research data were suitable for the principal component analysis.

Table 4. The result of Kaiser-Meyer-Olkin.

The Scope of the Inspection	KMO
The questionnaire as a whole	0.817
Government	0.719
Industry	0.742
Company	0.753
Technology	0.605
Trends of IC Development	0.851

Table 5. The result of Bartlett.

The Scope of the Inspection	Bartlett's Test of Sphericity Approx.		
	Chi-Square	df	Sig.
The questionnaire as a whole	1350.185	105	0.000
Government	34.767	10	0.000
Industry	214.632	30	0.000
Company	131.871	30	0.000
Technology	82.213	30	0.000
Trends of IC Development	380.407	30	0.000

Reliability is the overall consistency of a measure [91]. Cronbach's alpha test was performed to check the reliability of questions or items, which is much higher than the threshold of 0.70 [92], indicating internal consistency of the items and high data reliability. The Cronbach values of the five variables were higher than 0.7, as shown in Table 6, which denotes the high robustness and stability of the questionnaire.

Table 6. Results of measuring model validity.

Variables	Measures	CITC	Cronbach's α
Government	G1	0.659	0.840
	G2	0.751	
	G3	0.759	
	G4	0.548	

Table 6. Cont.

Variables	Measures	CITC	Cronbach's α
Industry	I1	0.686	0.883
	I2	0.616	
	I3	0.767	
	I4	0.731	
	I5	0.751	
	I6	0.710	
Company	C1	0.735	0.921
	C2	0.561	
	C3	0.808	
	C4	0.729	
	C5	0.835	
	C6	0.848	
	C7	0.771	
Technology	T1	0.792	0.892
	T2	0.745	
	T3	0.764	
	T4	0.762	
Trends of IC Development	TICD1	0.762	0.877
	TICD2	0.789	
	TICD3	0.798	
	TICD4	0.821	
	TICD5	0.783	
	TICD6	0.808	
	TICD7	0.207	

Fourth, as SEM is an appropriate technique for multivariate analysis that integrates factor analysis, path analysis, and multiple regression analysis [17,93], we used it to create the conceptual model and test the theoretical hypotheses of the structural models.

4. Research Results

We tested the aforementioned hypothesized model (Figure 2) with the SEM technique.

First, we used the standardized factor loading test for the measures, then we estimated the path coefficient by the maximum likelihood method and removed the path data indexes. Furthermore, we tested the model by factor analysis and repeated the above steps until the indexes were qualified. Finally, we got the verified model.

4.1. Data Results

First, through the calculation results, the 28 measures in which the loadings of the measurement variables and potential variables are more than 0.6 were retained. The revised indicators and the standardized load of each index are shown in Table 7.

Second, the maximum likelihood method was used to estimate the path coefficient, in which C.R. (i.e., t -test value) is the critical ratio. (1) in H1, $T = 2.612$, $p = 0.319 > 0.05$, indicating that the government has no direct relationship to industry development; (2) in H3, $T = 0.124$, $p = 0.409 > 0.05$, indicating that the government has no direct relationship to technology; (3) in H8, $T = -1.012$, $p = 0.317 > 0.05$, indicating that the industry has no direct relationship to the development of IC. Therefore, H1, H3, and H8 were removed, and the revised model test results are shown in Table 8, where all hypothesis tests passed.

The revised model was again tested for factor analysis. Each fitted indicator is shown in Table 9, and each indicator was within the standard range, so it could be considered that the model's overall fit is acceptable without the need for another correction.

Three main indices of the overall model fit were adopted in this paper to confirm the measurement model: the relative χ^2 ($\chi^2/\text{degree of freedom}$), root-mean-square error of approximate (RMSEA), and comparative fit index (CFI). The upper thresholds of the relative χ^2/df and RMSEA were 3 and 0.08, respectively, while the lower threshold of CFI

was 0.90 [94]. As shown in Table 9, χ^2/df of the model was less than 3; RMSEA was less than 0.08, indicating that the model was reasonable and not affected by the sample size; and CFI was greater than 0.9, meaning that the sample was stable.

Table 7. Results of the measures.

Variables	Measures	Standardized Factor Loading
Government	G1	0.925
	G2	0.814
	G3	0.878
	G4	0.904
Industry	I1	0.809
	I2	0.796
	I3	0.932
	I4	0.812
	I5	0.946
	I6	0.898
Company	C1	0.726
	C2	0.618
	C3	0.895
	C4	0.837
	C5	0.861
	C6	0.879
	C7	0.749
Technology	T1	0.863
	T2	0.814
	T3	0.941
	T4	0.938

Table 8. Results of the model test.

X	Path	Y	Hypothesis	T	p	Standardized Path Coefficients	Conclusion
Government	→	Company	H2	2.369	*	0.653	support
Industry	→	Company	H4	3.153	**	0.308	support
Company	→	Technology	H5	2.781	**	0.245	support
Technology	→	Industry	H6	6.572	***	0.735	support
Government	→	IC development	H7	9.454	***	1.180	support
Company	→	IC development	H9	0.336	*	0.144	support
Technology	→	IC development	H10	3.013	**	0.691	support

Note: *, **, and *** indicate that the statistics are at the levels of 0.05, 0.001, and 0.001, respectively, and the effect is significant.

Table 9. Calculation results of the fitting index of the modified model.

Index	Outcome
χ^2/df	2.662
GFI	0.847
RMR	0.057
CFI	0.935
NFI	0.657
NNFI	0.838
IFI	0.952

4.2. Verified Model

The hypothesis model was verified through SEM, as shown in Figure 5.

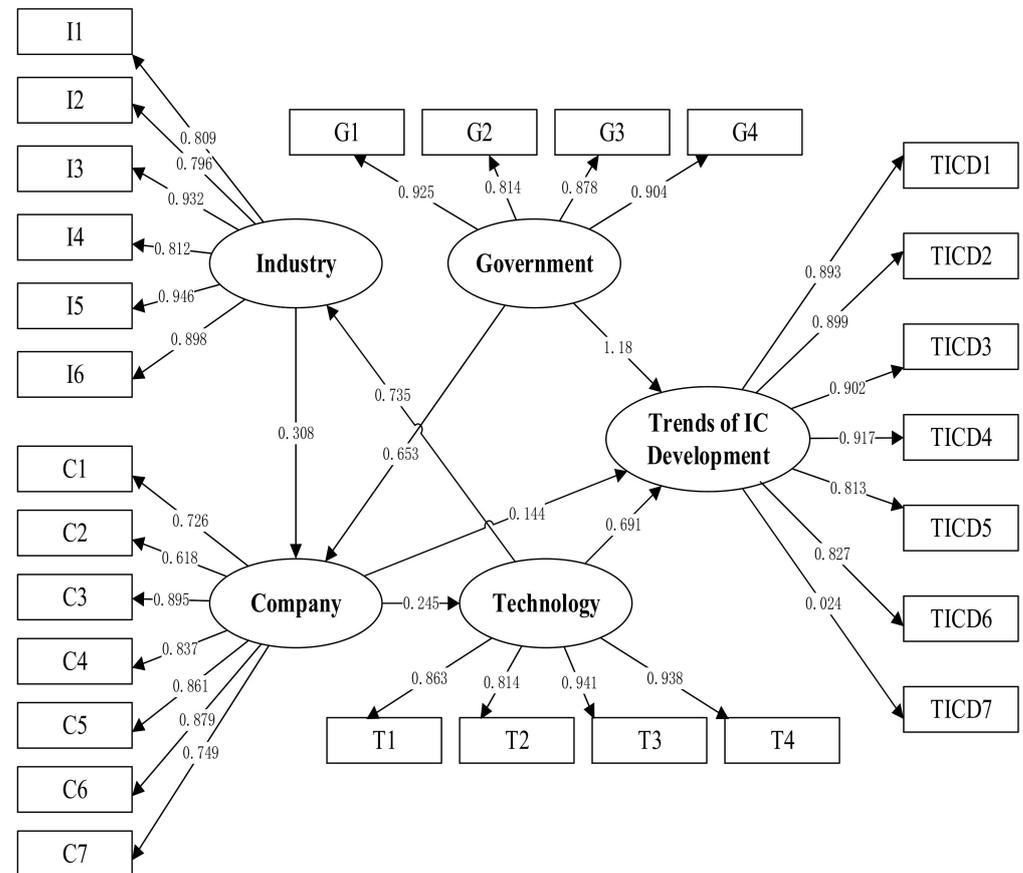


Figure 5. Influencers acting on the IC development mechanism model.

Taking into account these results of the model test, we summarized further conclusions as follows:

- (1) The three variables of government, company and technology directly and significantly impacted IC development. These path coefficients were 1.18, 0.144, and 0.691, respectively. Although each path was significant, the coefficient load values were generally low, especially the impact of company, which means that the impact of company on IC was still at a low level.
- (2) Industry did not directly affect the development of IC but rather indirectly affected the development of IC through company and technology. These three endogenous variables of industry, company, and technology form a “closed-loop” within which the three elements interact and promote each other.
- (3) The standardized factor loading of TICD7 was 0.024 and less than the factor loadings of the trend of IC development, which shows that it was widely accepted that IC development has a bright outlook in China and IC can certainly change the relative backwardness of China’s construction industry through the upgrading of technology, industry, and company.

5. Discussion

Based on the final model, we further summarized the paths among factors and identify key measures, hoping to provide a reference for the government and companies to formulate development strategies.

5.1. Path Analyses

- (1) Government→Company→Technology→IC development. On the one hand, the introduction of policies forces companies to carry out IC development; on the other hand, preferential subsidies support companies in carrying out IC activities. As a result, companies vigorously carry out relevant practical activities, form a new industrial system, stimulate construction activities and the application of innovative technology, and improve the basic endowment of the development of the construction industry. The emergence of innovative technology also contributes to the development of the construction industry.
- (2) Government→Company→Industries→IC development. The government's initiation and support has given birth to various companies with new business in the field of IC, increasing the complexity of corporate relations and the degree of competition within the industry. In contrast, this trend forces companies to change their management models and improve effectiveness to adapt to environmental changes. The adjustments and changes in corporate relationships reconstruct the industrial ecology, including the business model, business philosophy, market form, and industry management, creating a new steady state of IC industry development.
- (3) Technology→Industry→Company→Technology→IC development. The iterative application of technology innovation affects the adjustment and development status of the industry's development. Therefore, industry development trends guide the direction of company development and companies adjust their development strategies, paying attention to investment in technological innovation and application and gradually forming a certain scale and level of economic benefits of IC and development of new industrial forms.
- (4) Company→Technology→Industry→Company→IC development. Companies are the core of technological innovation and development. Intelligent technologies change the traditional working model of the construction industry which provides a realistic basis for IC development. Following the trend, more companies participate in the intelligent transformation.

5.2. Measures Analyses

The measures of the variables in the model were further analyzed. The standardized factor loading indicates the relationship between the variables and the measure; the higher the loading is, the closer the relationship with the corresponding variables. The indicator can be used as the basis for ordering the importance of the observed variables, and the order is shown in Table 10.

- (1) Among the government measures, the degree of government attention was the most important. This result is in line with the current state of IC development in China. At present, most companies have recognized the necessity of upgrading and have a positive attitude toward development prospects. However, companies directly engaged in IC projects need to pay huge costs, so most have been in a wait-and-see state. In the above environment, the government was the most critical stakeholder. Survey data and the state of IC development in China showed that IC development depends on government policies. On the one hand, the government has a certain mandatory role; on the other hand, it provides preferential subsidies to encourage companies to carry out IC activities to protect companies motivated to undertake IC.
- (2) Among the industry measures, the number and type of IC companies were of the utmost importance. In the infancy of IC development, most IC technology still belongs to the companies of developed countries. There is an urgent need for more companies to improve the ability to develop IC technology with independent intellectual property rights.
- (3) Among the company measures, the resource input of companies was the most important. Most Chinese construction companies did not pay attention to IC in the past. Therefore, there currently exists a huge gap between actual development and the

- vision of IC. In contributing to bridging this gap, a significant amount of resource input is needed to compensate for the backward development caused by traditional production methods so that it is possible to meet the current stage of IC development.
- (4) Among the measures of technology, hardware and software facilities were the most important. Since most of the core technologies related to IC still belong to companies in developed countries, the application of IC technologies is limited. It is difficult for companies in China to find suitable hardware and software services companies to assist in construction projects.

Table 10. Order of measures.

Variables	Measures	Standardized Factor Loading	Order of Importance
Government	G1	0.925	1
	G2	0.814	4
	G3	0.878	3
	G4	0.904	2
Industry	I1	0.809	4
	I2	0.796	6
	I3	0.932	2
	I4	0.812	5
	I5	0.946	1
	I6	0.898	3
Company	C1	0.726	6
	C2	0.618	7
	C3	0.895	1
	C4	0.837	4
	C5	0.861	3
	C6	0.879	2
	C7	0.749	5
Technology	T1	0.863	3
	T2	0.814	4
	T3	0.941	1
	T4	0.938	2

5.3. Recommendations

Based on the above analysis, we propose the following strategies to enhance IC development:

- (1) Understand the general path driving the development of IC. The process of influencing the development of IC has a certain regularity. Therefore, it is necessary to understand the influencing factors that employ the important role for its maximum utility and vigorously promote the development process of IC.
- (2) Emphasize and play the role of policies. It is necessary to promulgate effective policies to ensure and encourage the willingness of relevant entities to practice IC, develop and improve the market, and establish a long-term force to promote IC development. In addition, the government should pay attention to the development and changes of IC to make corresponding policy adjustments to form a virtuous circle.
- (3) Increase investment in research and development and overcome technical barriers. Different companies need to formulate appropriate integrated development plans and policy choices according to their business characteristics and foundation and carry out innovative research and development to promote the coordinated development of the IC industry.

6. Conclusions

IC is the key to adapting to the trend of intelligent development of the global construction industry, which involves multiple factors. This paper contributed to identifying and determining these factors through literature analysis and clarifying paths and key measures through SEM, which can help the government and companies better understand

IC development and provide a basis for the later introduction of policies and practice acceleration. Simultaneously, this paper offered a generalizable reference for other countries to develop IC.

In this paper, we analyzed the influence paths and key measures affecting IC development by SEM. This paper achieved the following results:

- (1) We identified the following four variables that influence IC development: government, industry, company, and technology. Moreover, we built the conceptual model.
- (2) Based on SEM method, we obtained four influence paths: (1) Government→company→technology→IC development; (2) Government→company→industries→IC development; (3) Technology→industry→company→technology→IC development; and (4) Company→technology→industry→company→IC development, which indicates that the government has a significant direct impact on the development of IC.
- (3) We further analyzed the key measures of government, industry, company, and technology: the degree of government attention, the number and development capability of IC technology development companies, resource input, and hardware and software facilities.
- (4) We proposed some recommendations to promote IC development.

This research contributed to the body of knowledge on IC by identifying the factors that influence IC development. The four paths and key measures were proposed to clarify the relationship between factors. Recommendations were put forward to promote IC development. Construction industries globally can leverage the factors influencing IC development in this research, which provides a valuable reference for further contextual investigations in their regions. Although the context of this study was China, the study findings can provide references for IC development in the construction industry globally, especially in those countries whose construction industries are in similar stages of development.

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