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What Drives the Intelligent Construction Development in China?

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Abstract: Intelligent construction (IC) integrates intelligent technologies with the construction industry to improve efficiency and sustainability. IC development involves many driving factors, but only the critical factors play essential roles. Thus, it is necessary to identify these key factors to understand and promote IC development thoroughly. Although there are many studies on IC-related technologies, a focus on identifying the driving factors of IC is lacking. We aimed to identify the key driving factors for IC development, analyze the relationship between the key factors and IC, and then produce general laws to guide IC by conducting an empirical study in China. We employed a five-stage research design and proposed the following general laws of how the key factors drive the development of IC: (1) initially, there exits the opportunity that drives companies to generate IC; (2) subsequently, the planning and pressure of a firm strategy, structure, and rivalry further drive companies to try to develop IC; (3) afterward, government policy vigorously promotes IC practices of the participating companies and accelerates the development of IC; and (4) finally, the market forces begin to play a leading role, and companies spontaneously carry out IC activities when the policy effect reaches a certain level. The findings indicate that policies to promote IC development should be consistent with its development stage, and the key driving factors of different stages should be paid attention to. Although the context of this study is China, the findings can provide references for IC's development globally.

Keywords: intelligent construction; driving factors; driving force theory; Porter Diamond Model; grey relation analysis

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1. Introduction

The global construction industry is booming, prompting both an increase in construction projects and a demand for intellectual development [1]. Luckily, the application of emerging technologies has responded to the intellectual development demand. These emerging technologies in the construction industry usually include the four main kinds of business digitalization; computer-integrated design; data acquisition, optimization, and predictive analytics; and robotics and automation [2]. With the increasing application of these emerging technologies to the construction industry, the intellectual development of this industry is inevitable [3,4].

At present, the discussion of "the process or product of the construction using emerging technologies" is mostly limited to "digital construction" [5] or "smart construction" [6] or "Construction 4.0" [7,8] in developed countries. IC is an innovative development model that combines emerging technologies with the construction industry under the background of the new technological revolution [9]. The words "digital construction", "smart construction", "Construction 4.0", and "intelligent construction" have similar connotations. That is, emerging intelligent technologies are used in the construction industry to improve quality, save costs, reduce pollution, and improve the efficiency of the desired processes, further

promoting industrial upgrading [9]. IC is the key to transforming and upgrading the construction industry. 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 (the guiding opinions on promoting the coordinated development of intelligent construction and building industrialization. http://www.gov.cn/zhengce/zhengceku/2020-07/28/content_5530762.htm, accessed on 8 August 2022).

In recent years, applying emerging technologies in the construction industry has significantly promoted IC development. Correspondingly, lots of research focuses on IC-related technologies' applications in construction, such as BIM [10–12], the Internet of Things [13,14], 3D scanning and printing [15,16], computer vision [17], and intelligent equipment [18–20]; and the improvements in safety, quality, scheduling, etc.

The above articles have studied the application of various emerging technologies in IC development from different perspectives. They have made significant contributions to promoting IC development, but it is not enough to only focus on IC technology to promote IC development. IC development is driven by many factors, and some critical factors play an essential role in its development, such as government policies [9] and a labor shortage [21]. These factors and their driving effects may also vary with IC development stages. However, few studies have systematically investigated the driving factors of IC development. Therefore, clarifying the critical driving factors at different stages and grasping the fundamental laws that promote IC development will help to explain IC thoroughly and provide a theoretical basis for guiding IC development in the future. For example, it could help the government and companies clarify the current focuses of IC development and provide a basis for the policy formation and practice acceleration. Due to the importance of research on driving factors of IC development and the lack of existing research, there is an urgent need to study the driving factors to improve the construction industry's performance. Thus, this paper aims to identify the driving factors for IC development, determine the key factors, analyze the relationship between them with IC, and finally, explore the general laws for driving IC development and provide recommendations to promote it.

1.1. Driving Force Theory (DFT)

The concept of "driving force" in physics is mainly used to describe the effect of the force generated in the driving process of a vehicle [22]. In business, the "driving force" refers to the force that makes a company move toward the target direction to a specific state under the internal and external driving environment to achieve a particular goal. Driving factors influence the driving process [23,24].

With the intersection of disciplines, the basic concept of driving force has also been extended to the fields of management science [25,26], sociology [27], economics [28], and environmental science [29]. For example, Chen et al. [25] examined the driving force of co-evolutionary dynamics between multistage overseas merger and acquisition (M&A) integration and knowledge network reconfiguration. Pichlak M. [26] contributed to showing the driving force for technological eco-innovation development. Qin Z. et al. [29] investigated the driving forces of agricultural intensification.

In addition, some scholars have researched explicitly from the perspective of driving factors, such as the driving factors of innovation systems [30,31], the driving factors of land use in development zones [32], and the driving factors of the industrialization of new buildings [33]. In summary, many scholars have researched the driving issues in various disciplines from the aspects of the driving force, driving environment, and driving factors, which provide good references for this paper.

Driving force theory provides a good reference and inspiration for this paper. Industrial philosophy theory suggests that any industry's generation, growth, and maturity are driven by many factors [34]. IC is no exception. Many factors continue to interact in IC

development, which restructure IC's industrial, supply, value, and innovation chains [9]. For IC development, the driving force is the power or impact exerted or imposed on it by the driving factors such as policy, market, competition among enterprises, and opportunities. The power and impact may have different magnitudes, called driving strengths. Therefore, identifying these driving factors and their relationships with IC based on the driving force theory and making targeted improvements are significant to better promoting IC development.

1.2. Driving Factors of IC Development

The literature review showed very few studies on IC driving factors. However, some research indirectly reflects the driving forces and factors of IC. For example, Ding [9] proposed that IC's application could improve resource utilization efficiency, responded to customer needs, and met the requirements of sustainable development. In addition, some research performed some analyses related to IC development, including government policies [35–37], technology [38–40], labor and professionals [21,41], etc. In this article, we identify these as the driving factors of IC. Therefore, the initial list of IC driving factors taken from the literature is shown in Table 1.

Table 1. Initial list of driving factors for the development of IC from previous studies.

Range of Driving Factors	Literature Reference
Perfection and matching of laws, regulations, and standard systems	Liu et al. [35], Mao & Zhang [36], Okpala et al. [37]
Government support and incentive policies	Liu et al. [35], Ding [9], Yue & Li [42], Zhou & Wu [43]
Demonstration projects	Zhang et al. [44], Lin et al. [45], Yang et al. [46], Fan Q.et al. [47]
The dilemma of traditional construction methods	Ding [9], Memari et al. [48], Zhou et al. [49];
Market and consumer demand	Ding [9]
Corporate Strategy	Ding [9], Mao & Zhang [36].
The intelligent technology application system	Okpala et al. [38], Ogunrinde et al. [39], Shi et al. [40]
Support for the industrial system	Mao & Zhang [36]
Talent training system	Kim et al. [21], Heravi & Eslamdoost [41], Liu et al. [50]

The studies above mentioned some factors that drive IC development from different angles, but they were not systematic or complete. Based on driving force theory, this article innovatively and systematically studies the driving factors that promote IC development and provides suggestions.

We arranged this paper as follows: the second section introduces the research method, the third section presents the research results, the fourth section provides the discussion and suggestions, and finally, the conclusions are reached.

2. Research Methodology

Many factors drive IC development, but only a few driving factors play a critical role. In addition, IC development is a gradual process, and its degree of development is related to the driving strength. Generally, when the driving strength is low, the company will be unwilling to carry out activities related to IC, and it is difficult for IC to develop. On the other hand, as the driving strength gradually increases, companies become more active, and IC gradually grows and matures. Moreover, the driving factors that play crucial roles are not the same with different driving strength levels. Therefore, it is imperative to clarify the critical driving factors at various levels, grasp the focuses of IC development in different stages, and drive its development.

Based on the research purpose and the above analysis, we designed the five-stage, comprehensive approach shown in Figure 1. First, we identified and determined the driving factors through a literature review and an expert symposium in stages one and two; secondly, we introduced Porter Diamond Model (PDM) to classify the driving factors based on its advantages in stage three; thirdly, we carried out the investigation in stage four; and

finally, we determined the relationships between the factors and IC development based on grey relation analysis (GRA) according to their use in solving problems in stage five.

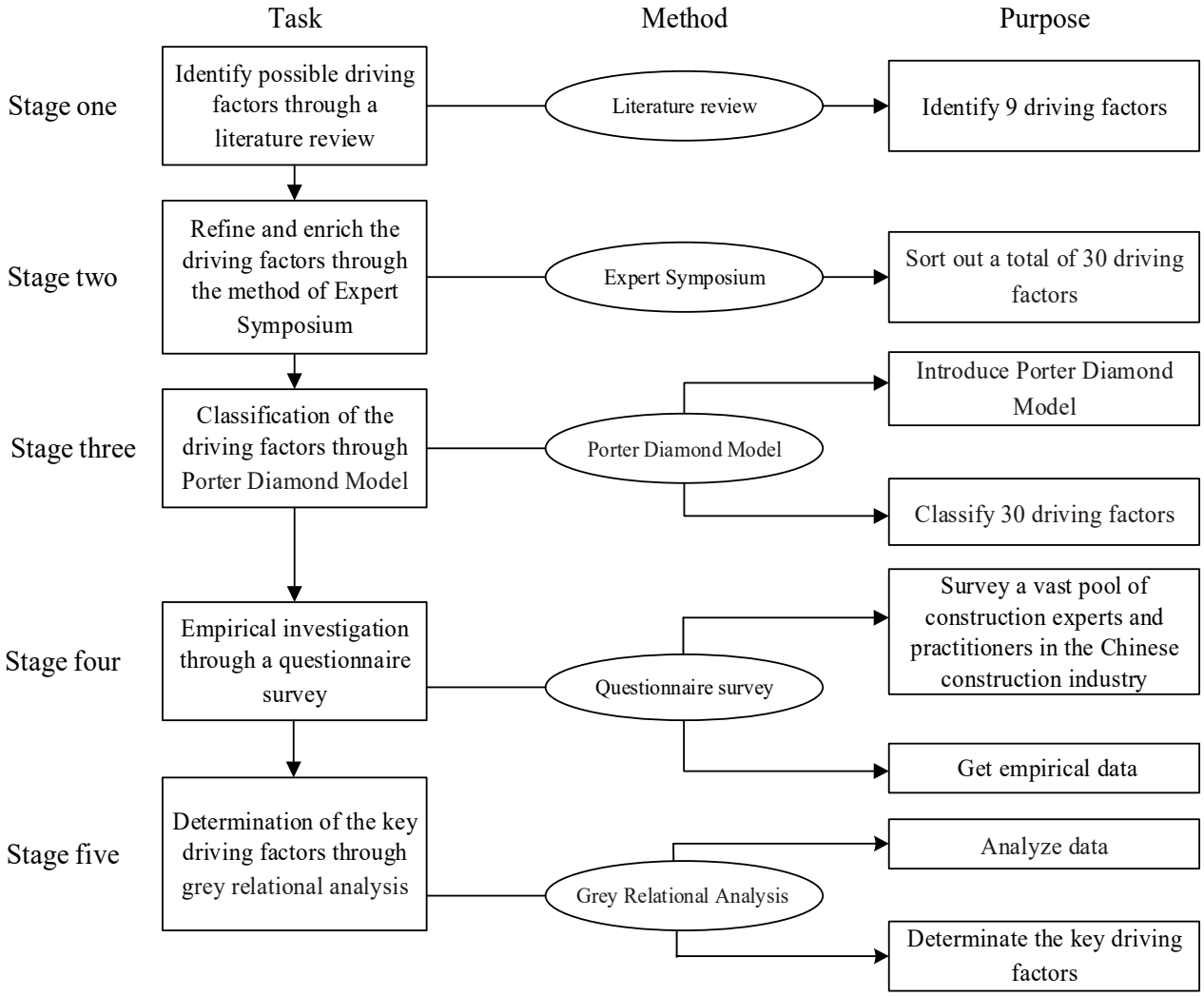

Figure 1. Five-stage research protocol.

2.1. Stage One—Identifying Possible Driving Factors through a Literature Review

This stage involved a literature review for identifying driving factors affecting IC development. First, we searched for the relevant literature published between 2010 and 2021 across various databases with the keywords "intelligent construction", "smart construction", "digital construction", "construction industry development", "emerging technologies in construction", etc., and we roughly searched for literature related to driving factors. Eighteen papers were selected. Next, we closely examined the literature to identify the possible factors. A list of nine driving factors for IC development drawn from the literature review is presented in Table 1. These nine factors formed an initial list of factors.

2.2. Stage Two—Refining and Enriching the Driving Factors through an Expert Symposium

The objective of this stage was to identify the driving factors that specifically facilitated IC implementation in China. After the preliminary identification, we held an expert symposium to refine and optimize the driving factors identified. First, we set the criteria for selecting experts to ensure the quality of the symposium. These experts were to be representative and authoritative. They worked in all aspects of construction activities along the construction lifecycle, and had rich knowledge and practical experience in the construction industry. In addition, they were to have a certain influence in the industry

and have professional insights into Chinese IC development status. Secondly, we invited experts under the set standards through various channels, explained the purpose and significance of this research to them in advance, and won their support. Among the invited experts, six were from design, construction, supervision, and maintenance companies; four were government officials; and five were scholars involved in IC. All invited experts had more than ten years of experience. Then, we held a symposium to discuss IC driving factors in China.

The symposium adopted a hybrid method and was divided into two stages. The first stage used the brainstorming method. The reason for choosing to brainstorm is that these experts were able to discuss in an unrestricted atmosphere, think positively, inspire each other, brainstorm ideas, and fully express their opinions [51]. With the brainstorming method, we can produce high-quality, creative results. In the second stage, the content of the first stage was fully discussed. Finally, a consensus was reached, and a more consistent conclusion was obtained.

The main task of the symposium included disassembling, enriching, and supplementing the driving factors. Some factors were subdivided and disassembled. For example, the role of the government was subdivided into "financial subsidies and tax incentives for IC technology"; "rewards for IC projects"; "mandatory standards in the approval of planning and design schemes" to align with China's situation. Some factors were classified. For example, "government support and incentive policies" and "demonstration projects" were both government-led policy incentives in China and were classified into one category to avoid omission during the optimization. In addition, some factors were enriched and supplemented. For example, some other factors not covered by the nine initial factors were added, such as the reduction of pollution, green development, and less labor that China has advocated for in recent years. Finally, we identified 30 driving factors through the expert symposium, as shown in Table 2.

Table 2. Driving factors of IC development.

Code	Driving Factors
1	The necessity for gradual improvement of the construction industry's industrial structure
2	Innovation and reform of upgrading of the construction industry
3	Severe pollution from construction solid waste
4	Enormous noise pollution during construction
5	Severe air pollution during construction
6	The necessity to improve the existing construction technology
7	Possible economic benefits of IC
8	Willingness to transform the construction process management
9	Decision-makers' expectations for IC benefits
10	Decision-makers' requirements for the construction period and quality
11	Level of decision-makers' awareness of sustainable development
12	Long-term strategic goals for decision-makers
13	Company's resource investment in IC
14	Anticipation of potential market opportunities in the future
15	Competitiveness of related companies
16	Promotion and application of IC technology
17	Financial guarantee for the research and development of IC technology
18	IC technical staffing
19	Building materials and energy consumption
20	Lack of labor force
21	Consumers' needs and preferences for IC
22	Consumers' awareness and understanding of IC
23	Market access system for IC
24	Low labor productivity in the construction industry
25	Continuous increase in labor costs
26	Increase in the number of prefabricated component factories

Table 2. *Cont.*

Code	Driving Factors
27	Information technology serves industry development
28	Financial subsidies and tax incentives for IC technology
29	Rewards for IC projects
30	Mandatory standards in the approval of planning and design schemes

2.3. Stage Three—Classifying Driving Factors through PDM

The objective of this stage was to categorize 30 factors based on the perspective of industry development, which was conducive to a structured questionnaire survey and the analysis below.

PDM, as a theoretical model, explains why the industry is competitive and is widely used in research on competitive advantages in industry [52–55]. It states that four elements determine the development of a specific industry: factor conditions; demand conditions; related and supporting industries; and firm strategy, structure, and rivalry. In addition, there are two variables: opportunity and government, both of which are closely related to the development of the entire industry and affect four significant factors (see Figure 2). Therefore, PDM is also used for the analysis of the characteristics of factors [27,56,57].

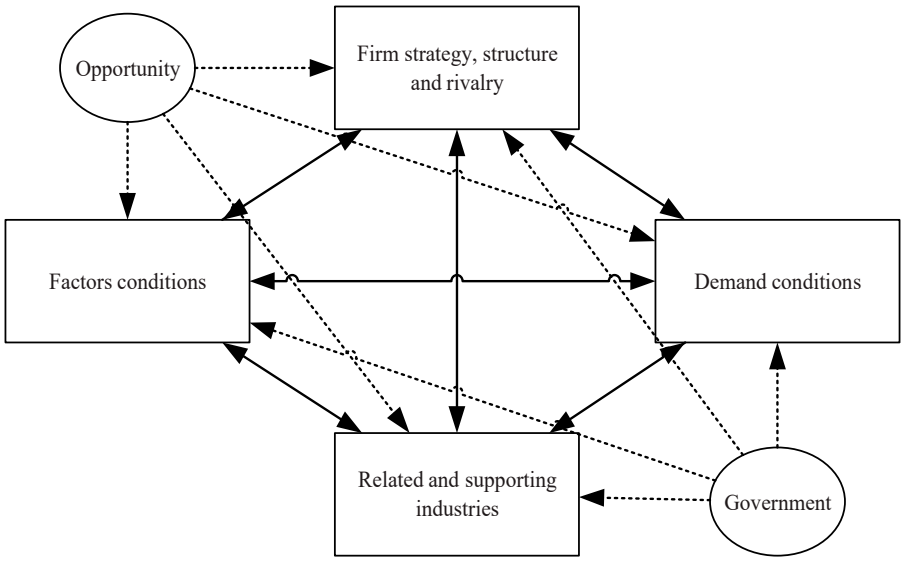

Figure 2. Porter Diamond Model (source: Porter, M. E. [52]).

Based on PDM, the four elements and two variables in IC development were identified as follows: (1) Opportunity refers to the construction industry urgently needing to transform and upgrade the status quo, and IC has the advantages of high efficiency and sustainability; (2) the firm strategy, structure, and rivalry refer to the corporate strategy and organizational structure of the company formulated for the development of IC. In addition, competition in the same industry affects some factors, such as the decision-making and market share of the company; (3) the factor conditions mainly refer to the primary conditions required for IC, including natural resources, infrastructure, human resources, etc.; (4) the demand conditions refer to the market's demand for IC; (5) the related and supporting industries refer to the synergy between upstream and downstream companies of IC; and (6) government actions and government policies form the governmental roles: participating in IC projects, leading the development of IC projects, promoting market demand, promoting industrial development, etc.

Based on the definitions of the four elements and two variables in PDM, the 30 driving factors were classified in Table 3.

Table 3. Classification of driving factors for the development of IC.

Category	Driving Factors
Opportunity	The necessity for gradual improvement of the construction industry's industrial structure of (OT1) Upgrading innovation and reform of the construction industry (OT2) Severe pollution from construction solid waste (OT3) Enormous noise pollution during construction (OT4) Severe air pollution during construction (OT5) The necessity to improve the existing construction technology (OT6) Possible economic benefits of IC mode (OT7)
Firm strategy, structure, and rivalry	Willingness to transform the construction process management (FS1) Decision-makers' expectations for the benefits of IC (FS2) Decision-makers' requirements for the construction period and quality (FS3) Level of decision-makers awareness of sustainable development (FS4) Long-term strategic goals for decision-makers (FS5) Company's resource investment in IC (FS6) Anticipation of potential market opportunities in the future (FS7) Competitiveness of related companies (FS8)
Factors conditions	Promotion and application of IC technology (FC1)Financial guarantee for the research and development of IC technology (FC2)IC technical staffing (FC3) Building materials and energy consumption (FC4) Lack of labor force (FC5)
Demand conditions	Consumers' needs and preferences for IC (DC1) Consumers' awareness and understanding of IC (DC2) Market access system for IC (DC3)
Related and supporting industries	Low labor productivity in the construction industry (RS1) Continuous increase in labor costs (RS2) Increase in the number of prefabricated component factories (RS3) Information technology serves industry development (RS4)
Government	Financial subsidies and tax incentives for IC technology (GM1) Rewards for IC projects (GM2) Mandatory standards in the approval of planning and design schemes (GM3)

2.4. Stage Four—Empirical Investigation through the Questionnaire

We developed a questionnaire in this stage to obtain empirical data to determine the critical factors by surveying a vast pool of construction experts and practitioners. Excluding the initial respondent information, the questionnaire was divided into six parts according to the driving factors, and the 30 questions corresponded to the 30 driving factors. These respondents were required to rate the strengths of the identified IC driving factors using a five-point Likert scale with options ranging from "1" to "5", with "1" being the weakest rating and "5" being the highest rating. At the beginning of the questionnaire, we explained the definition and scope of IC to ensure understanding by the respondents.

This research adopted a simple random sampling method to conduct surveys using relevant personnel in high, medium, and low positions from organizations related to IC development, such as construction companies, research institutions, government departments, and IC technology developers, scattered in different cities in China. We distributed the questionnaires online via a Web-based platform. At the end of the survey, 150 questionnaires were returned, and 132 had valid data.

As is shown in Table 4, 100% of the respondents were Chinese. The findings also show that 10.61% of respondents were senior management staff, 45.45% were middle-level management staff, and 43.94% were low-level management staff in their organizations. Further analysis of their work experience revealed that 78.03% of the respondents possessed a minimum of 5 years of experience in the construction industry, and 16.67% had more than twenty years of experience. In addition, 92.42% of the respondents acknowledged they understood IC above a moderate level. We designed this question to obtain the re-

spondents' subjective personal views on IC to judge the respondents' background. Besides the respondents' information, we got empirical data to analyze in stage five.

Table 4. Respondent's characteristics.

Category	Characteristic	Frequency	Percentage (%)
Nationality	China	132	100
Organization	Construction companies	44	33.33
	Research institutions	67	50.76
	IC technology development company	3	2.27
	Construction Industry Association	0	0
	Government departments	5	3.79
	Other	13	9.85
Position level	Senior management	14	10.61
	Middle-level management	60	45.45
	Low-level physical operators	58	43.94
Working years	Less than five years	29	21.97
	5–10 years	31	23.48
	10–20 years	50	37.88
	More than 20 years	22	16.67
Level of understanding of IC	Thoroughly understand	8	6.06
	Understand	56	42.42
	Moderately understand	58	43.94
	Slightly understand	9	6.82
	Does not understand	1	0.76

2.5. Stage Five—Determine the Critical Driving Factors through Grey Relation Analysis (GRA)

Not all 30 driving factors described above play a key role in IC development. Identifying the key driving factors in various stages of IC development is beneficial for policy formulation and corporate strategic planning in IC development.

GRA is specially applied in fuzzy problems with uncertain relations [58–60]. It is an analysis method that measures the importance of factors by using the order of the relevance degree influenced by other factors. For example, it is used in measuring sensitive factors for landslides and concrete structures' durability [61,62], travel modes and their influence factors [63], and sources of risk for abnormal driving on expressways in a port city [64]. This research was carried out the survey data by grey relation analysis to measure the driving factors and the relationships between the critical driving factors and IC development.

First, we accumulated the evaluation results under different factors' driving strengths. Therefore, we obtained five sets of cumulative data from the lowest to the highest driving strength. We performed the grey correlation analysis as follows:

The reference sequence X_0 or the development status of IC, also known as the parent sequence, was established.

The comparison series $x_i(k)$ using the 30 driving factor indicators, in which $i = 1, 2, \ldots, 30$, $k = 1, 2, \ldots, 5$, was set.

Data collection was initialized and calculated, as shown in Formula (1):

$$X_i(k) = \frac{x_i(k)}{x_i(1)} \quad (1)$$

The correlation coefficient between the reference sequence and the comparison series was calculated—that is, the driving effect of each driving factor on the development of

IC under different driving strengths. The correlation coefficient $\xi_{i(k)}$ was calculated with Formula (2), where the resolution factor is generally taken as $\rho = 0.5$ [3,65]:

$$\xi_i(k) = \frac{\min\limits_i \min\limits_k |X_0(k) - X_i(k)| + \rho \max\limits_i \max\limits_k |X_0(k) - X_i(k)|}{|X_0(k) - X_i(k)| + \rho \max\limits_i \max\limits_k |X_0(k) - X_i(k)|} \quad (2)$$

The grey relationship degrees were arranged from small to large. The calculated grey relationship degree is a relative weighted value. When the value is large, it indicates that the factor is essential, and the designer should focus on it. In contrast, the smaller the value is, the less critical the factor, which can be temporarily considered an unimportant reference under cost.

3. Results

The comparison of driving factors considering five levels of driving strength was calculated through GRA, and the results are shown in Table 5.

Table 5. Driving effects of the driving factors for IC development.

Code	Category	Driving Factors	Driving Strength				
			5 (Highest)	4	3	2	1 (Lowest)
1	Opportunity	OT1	0.183	0.496	0.784	0.958	1
2		OT2	0.173	0.593	0.791	0.972	1
3		OT3	0.203	0.426	0.701	0.885	1
4		OT4	0.208	0.412	0.654	0.891	1
5		OT5	0.201	0.412	0.686	0.899	1
6		OT6	0.191	0.478	0.782	0.961	1
7		OT7	0.251	0.543	0.837	0.961	1
8	Firm strategy, structure, and rivalry	FS1	0.156	0.537	0.832	0.973	1
9		FS2	0.199	0.600	0.849	0.921	1
10		FS3	0.248	0.539	0.877	0.948	1
11		FS4	0.236	0.512	0.791	0.953	1
12		FS5	0.188	0.527	0.852	0.929	1
13		FS6	0.232	0.448	0.671	0.889	1
14		FS7	0.244	0.590	0.866	0.946	1
15		FS8	0.226	0.501	0.793	0.855	1
16	Factors conditions	FC1	0.242	0.506	0.847	0.949	1
17		FC2	0.219	0.489	0.721	0.952	1
18		FC3	0.169	0.489	0.729	0.939	1
19		FC4	0.144	0.452	0.783	0.931	1
20		FC5	0.319	0.661	0.831	0.946	1
21	Demand conditions	DC1	0.240	0.483	0.700	0.90	1
22		DC2	0.174	0.456	0.700	0.85	1
23		DC3	0.221	0.496	0.781	0.877	1
24	Government	GM1	0.248	0.631	0.815	0.923	1
25		GM2	0.218	0.658	0.796	0.908	1
26		GM3	0.246	0.614	0.773	0.901	1
27	Related and supporting industries	RS1	0.342	0.531	0.831	0.959	1
28		RS2	0.371	0.672	0.860	0.963	1
29		RS3	0.212	0.532	0.805	0.920	1
30		RS4	0.241	0.530	0.819	0.936	1

According to the GRA method, the index value in each column in Table 5 represents the closeness of the correlation between the factor and the driving strength, which is a relative value and reflects the degree of the driving effect. As at level 1, each factor is not closely related to the driving degree, this column was set as the reference sequence, and

the value was set to one during the calculation process. From level 2 to level 5, the close relationship changes. Therefore, we can compare the values of each column vertically.

Table 5 shows that the different driving factors have different driving effects under various driving strength levels. For example, at level 2 of driving strength, the 30 driving factors have different driving effects. Among them, FS1 ranks number 1 with the value of 0.973, and OT2 ranks number 2 with the value of 0.972. Therefore, we can obtain the critical driving factors under different driving strengths. To achieve this aim, we sorted and analyzed the top ten driving factors with the most apparent driving effects under different driving strength levels, as shown in Figure 3.

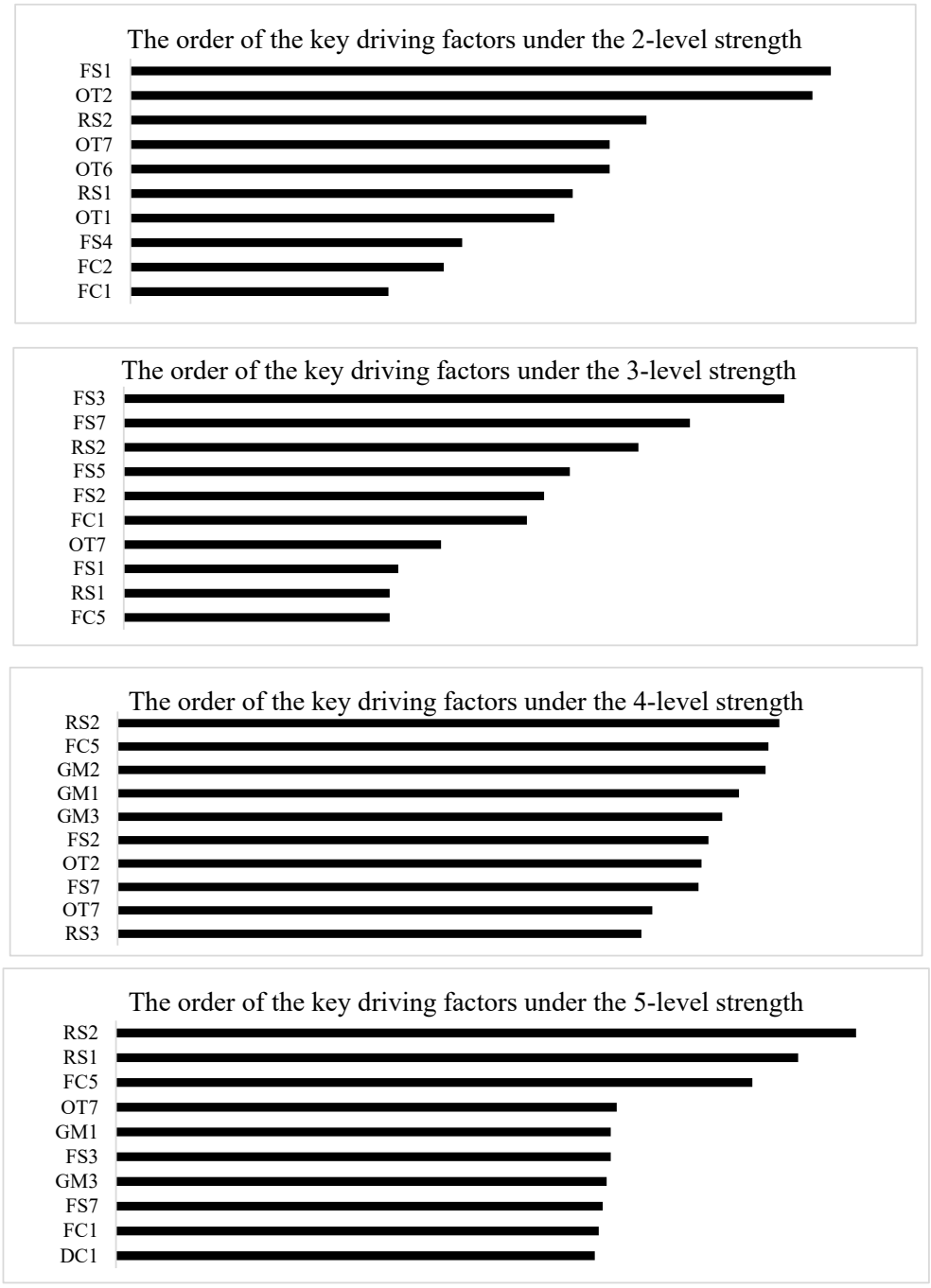

Figure 3. Ranking of critical driving factors under different drive strengths.

We draw the following conclusions about the relationships between the critical driving factors and IC development based on Figure 3:

(1) Under level 2 driving strength, four key driving factors belong to the category of opportunity; two key driving factors belong to the category of firm strategy, structure, and rivalry; two key driving factors belong to the category of factor conditions; and two key driving factors belong to the category of related and supporting industries. Among them, "the willingness to transform the construction process management" and "upgrading innovation and reform of construction industry" have the most significant impacts.

(2) Under level 3 driving strength, five key driving factors belong to the category of firm strategy, structure, and rivalry; two key driving factors belong to the category of factor conditions; two key driving factors belong to the category of related and supporting industries; and one key driving factor belongs to the category of opportunity. Among them, decision-makers' requirements on the construction period and quality have the greatest impact.

(3) Under level 4 driving strength, three key driving factors belong to the category of government; two key driving factors belong to the category of firm strategy, structure, and rivalry; two key driving factors belong to the category of opportunity; two key driving factors belong to the category of related and supporting industries; and one key driving factor belongs to the category of factor conditions. Among them, the continuous increase in labor costs, the lack of a labor force, and the rewards for IC projects have the most significant impacts.

(4) Under level 5 driving strength, the numbers of key driving factors under the element categories are balanced. The continuous increase in labor costs has the most significant impact and has opened a gap for other key driving factors.

4. Discussion

4.1. The General Laws for Driving IC Development

We found a certain regularity for various driving factors driving IC development. That is, the stage of IC development impacts driving strength levels, and the critical driving factors that play leading roles change with the stage, as shown in Figure 4.

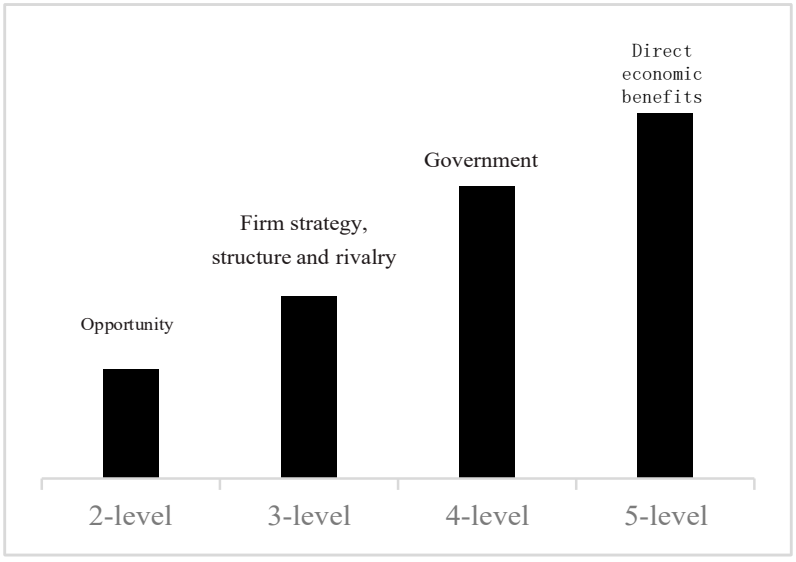

Figure 4. Key factors that play leading roles at different driving strengths.

(1) To drive IC development, the driving factors of opportunity are essential to achieve driving strength of level 2. Level 2 is a low driving strength level which can only trigger the initial motivation for the company to engage in IC. As an advanced construction mode, IC can solve the development difficulties of the traditional construction mode. Therefore, IC presents a significant opportunity for companies in the construction industry and is involved in the industry's development trends.

(2) When the company has the initial motivation, the factors of firm strategy, structure, and rivalry are critical to reaching level 3 driving strength. Upon reaching level 3, the company will transform the motivation for IC into practice. The company needs to recognize and respond to industry trends and transform its motivations into corporate practices. This is mainly affected by the firm's strategy, structure, and rivalries, which include factors such as the company's expectations for future potential market opportunities, the expectations of decision-makers for IC benefits, the willingness to transform the construction process, the long-term strategy for company development, and cooperation and competition with peer companies.

(3) When the company attempts to implement IC practices further, the factors of government are essential for achieving level 4 driving strength. Driven at this level, the company is genuinely implementing IC practices in a wait-and-see state of practice. The government plays a key role. The survey data and the IC status quo in China show that most IC practices depend on government policies. On the one hand, government policies force all companies to develop IC. On the other hand, they provide preferential subsidies and policy support to encourage companies to develop IC. The government's policies offer guarantees for companies with specific motives.

(4) When a company develops IC on a large scale, the market will play a huge role. The pursuit of interests by the company drives IC development. The direct economic factors driving the company to conduct IC activities spontaneously are essential indicators of achieving level 5 drive strength. For example, it is difficult to achieve the quality, cost, and construction period goals of construction products with traditional construction methods, resulting in a decline in corporate profits, reduced competitiveness, and even corporate decline. Therefore, companies will spontaneously practice IC based on its advantages for improving efficiency and quality, resource-friendliness, and sustainable development under the pressure of pursuing profits.

IC development under the influence of driving factors is a gradual and regular process. First, there must be an opportunity to drive the company's willingness to conduct IC. Second, the corporate strategy, structural adjustment, and competition in the industry drive companies to try more to develop IC. Furthermore, the support of the government vigorously promotes IC practices. When the government guides this promotion to a certain level, the market begins to play a leading role, so companies spontaneously carry out IC activities because economic interests drive them. This analysis is in line with the general state of China's IC development.

4.2. Suggestions for IC Development

At present, opportunities already exist for IC development in Chinese companies. On the one hand, most companies are aware of the development prospects of IC. A few of them have raised IC to the level of corporate strategy. On the other hand, although labor costs and shortages have become irreversible trends, the current impact on profits is still within the company's bearable range. However, Chinese construction companies have always been confined to traditional production methods and lack industrialization and digital development.

IC implementation requires substantial input and investment, but whether IC can generate more profits for companies remains to be further investigated. Therefore, some companies still doubt IC and are in a wait-and-see state. Under the above environmental characteristics, government policies are currently the most critical driving factor. Therefore, stimulating companies' vitality and promoting them to transform their wishes into IC practices will be the most direct and effective way to drive China's IC development.

There are significant differences in various regions of China regarding IC development. Due to diverse and complex regional development conditions, construction companies have apparent differences in development planning, innovation capabilities, willingness, and strength to develop IC. As the Chinese government has issued corresponding guidelines, some regional governments have actively formulated implementation opinions to respond.

However, some regions are not sensitive to these policies and trends, which leads to uneven regional development. Local governments and companies should adjust local policies, perceive the regional IC development status, seize opportunities, and clarify the current key driving factors. The government must play important guiding and supporting roles, and companies should formulate strategic plans.

Based on the above analysis, this paper proposes the following policy strategies:

(1) Understand the general laws driving IC development. It is necessary to understand the key driving factors at different stages of IC development, employ the driving role for its maximum utility, and vigorously promote the IC development process.

(2) Emphasize the role of government policies. The government must ensure and encourage relevant entities to practice IC, develop and improve the market, establish a long-term force to promote IC development, and make corresponding policy adjustments according to IC development status to form a virtuous environment.

(3) Implement various IC development strategies. Different regions must formulate suitable IC development plans and policy choices according to their characteristics and foundations. That is, they should take different implementation priorities according to their conditions.

5. Conclusions

IC is the key to adapting to the intellectual development trends of the global construction industry. The advancement of IC involves multiple factors and is inseparable from the driving forces of various driving factors. However, a focus on identifying the driving factors and the relationships between these factors and IC development was lacking. In this manuscript, we designed a five-stage method to compensate for this research gap. We obtained the key driving factors and arranged them, and we summarized and compared the key factors of levels 2–5. On this basis, the general laws that drive IC development were outlined and confirmed in combination with the current situation in China. Finally, we put forward relevant policy recommendations.

This paper contributes to identifying and determining the critical driving factors for IC development and clarifying the general laws of the relationship among them. It will help the government and companies understand the current focus of IC development and provide a basis for the policy formation and practice acceleration. This paper achieves the following:

(1) Identification of driving factors from the literature, which were refined and enriched through an expert symposium, and categorized based on PDM;

(2) Analysis of the key driving factors of IC development in China through the GRA method and clarification of the relationships between the key driving factors and the stages of IC development under different driving strength levels;

(3) Summarization of the general laws of the driving effect on IC development;

(4) Recommendations for IC development based on the general law, combined with the analysis of the current overall development status and regional development status of IC in China.

Even though the analysis of driving factors was performed from the Chinese perspective, some basic principles apply to many other countries, especially some developing countries, as the external environment of IC development is similar. Moreover, IC development all of over the world also follows some similar general rules. Therefore, the global construction industry can leverage the outcomes of this study.

At the same time, this manuscript did limit its range of applicability with its focus. Differences exist in IC development in the various countries of the world, and even different regions in the same country may have significant differences. Therefore, countries and regions should adapt to local conditions, understand their IC development status, identify the current critical driving factors, and take different measures to deal with them. Future research can investigate the driving factors of specific countries or regions of the world and conduct comparative studies.

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