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Positioning and Priorities of Growth Management in Construction Industrialization: Chinese Firm-Level Empirical Research

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Received: 27 March 2017; Accepted: 20 June 2017; Published: 25 June 2017

Abstract: The purpose of this research is to quantitatively evaluate the growth phase, position, and priorities of the industrialization policy management of the construction industry at firm level. The goal is to integrate quantitative dynamics into the policy-making process for sustainable policy development in future China. This research proposes an integrated framework, including growth management model and industrial policy evaluation method, to identify the challenges of construction industrialization and policy management. The research applies the mixed system method, which includes entropy method and average score method, to analyze the growth stage and major impact indexes targeting 327 survey samples. The empirical results show that the proposed conceptual framework and policy evaluation method could effectively determine the growth position and directions of the construction industrialization. For verification purpose, the study uses the local industry data from Shaanxi Province, China. The calculation results substantiate that the construction industry is in the middle section of the third growth phase. The comparison of the results from statistical methods shows that the local construction industry still needs substantial effort in policy management to improve its sustainable industrialization level. As countermeasures, the policy priorities should concentrate on: (1) enhancing effective cooperation among universities, research institutions and enterprises; (2) improving actions towards technology transfer into productivity; and (3) encouraging market acceptance of construction industrialization. This research complements the existing literature of policy evaluation of construction industrialization. Moreover, it provides theoretical and operational steps on industry policy evaluation and growth management framework, with accurate and ample data analysis on firm-level survey. Researchers and policy makers can use this research for further extensions of policy management for construction industrialization.

Keywords: sustainable position; construction industry; industrial policy assessment; growth management model; industrialization

1. Introduction

Studying industrial policies, including the construction industries in developing countries, has caught the interest amongst policy makers around the world in the last decade [1–10]. However, in many areas of industrial policies, rigorous and systematic evaluations are inadequate. Hence, particular methodological challenges exist. As one of the emerging and energetic construction markets, Chinese construction industry has implemented active and industrial-dominated management polices to level its sustainable development. Existing studies are still insufficient on the evaluation of policies for the industry to accelerate its sustainable growth management [1–10]. This research focuses on how to evaluate the current phase of growth management for the construction industry in a developing country.

For policy evaluations, firm-level empirical research is able to analyze growth management effectively. Many studies on industrial policy evaluations often provide data and theoretical supports on a case-by-case basis [11]. Thus, the evaluation processes usually pay attention to local or geographical conditions and are based on firm-level data. The evaluations also use sophisticated and systematic methods with appropriate sample sizes [11]. The approaches of industry policy evaluations usually include: surveys; quasi-natural experiments; statistically constructed control groups; and structural econometric modeling [12]. Evaluation records show that sophisticated, systematic and strategic use of evaluation is essential because the complexities of industrial policies put forward many evaluation challenges [1–10]. Further, it may be unrealistic to transform the results of one policy assessment to a different context considering different circumstances, geographical dimensions and industry policies. For example, institutional differences across countries or at different times may cause an intervention proven to be successful in one setting be ineffective in other circumstances [12]. Therefore, firm-level empirical research on policy evaluation would contribute to the understanding of industrial growth.

This research pays attention to the growth management on firm-level clusters which is the basis or rationale for industry- and macro-level policy actions. The policy actions may support specific companies or stimulate the development of regional market. Studies on industrial policy often depend on survey methods to improve the qualities of their iteration processes. Specifically, the survey methods evaluate the industrial policies on firm-level rather than on industry or macro levels [13,14]. For instance, Edler et al. (2012) reported the results of a survey on 800 companies in the United Kingdom for industrial policy evaluation. The survey included the suppliers of central government and local authorities in the English National Health System in 2010 [13]. To evaluate a public procurement system, Guerzoni (2015) sought to disentangle and compare the effects of innovation-oriented procurement, R&D tax credits and R&D subsidies, using a survey on 5238 companies with 20 employees or more [14]. The survey covered many sectors in the 27 member states of the European Union, plus Norway and Switzerland [14]. Although there are studies of construction industrialization with the focuses on drivers and barriers, government initiatives, and plans of actions [1–10], there needs to be a distinct evaluation framework focusing on the phases, factors, and mechanism of growth management.

The purpose of this article is to fill this gap by providing a conceptual framework and quantitative evaluation to integrate the policy and growth management model. The model will be able to determine the growth position of Chinese construction industry. To meet the requirements of process evaluation on industrial policies, the framework includes the analyses on the data collected from firm level with a confirmed systematic method. The in-depth literature review included in the research corresponds with the interviews and survey data to build the framework, which identifies and validates industrialization policies. The survey data show the status of the construction firms that are active in industrialization projects in China. Particularly, this paper analyzes the process of industrialized construction in China from the perspective of institutional law and stakeholders. It suggests the drivers and obstacles influencing the development of industrialization at present and carries out the research work from enterprise perspective.

From industry organization viewpoint, there are some excellent evaluation models for industry growth management, such as process model for embracing sustainability [15] and growth management model [16]. In this research, we extend the growth management model into the innovation field of the construction industry with two comparative methods, i.e., average method and entropy method, to verify the original method and test the framework [17,18]. It is confirmed that, as a generic framework of growth management [16], the proposed model is valuable for analyzing the growth position of management policies of the construction industry. This research supplements the existing literature of policy evaluation for Chinese construction industrialization. It also provides references to theoretical and empirical research for industrial policy evaluation, sustainable management of Chinese construction industrialization policies, and extended the adoption and implementation of growth management model.

Industrialization in the construction industry is unique. While industrialization in manufacturing or tourism industries may cause overexploitation of natural resources, consumerism or mass tourism [19], industrialized construction projects are able to improve construction performance and promote innovative products and eco-materials [20,21]. Industrialized Building System (IBS) construction has components manufactured in a controlled environment (on or off site). The components are transported, positioned and assembled into a structure with minimal additional site works. IBS construction is with off-site and standardized manufacturing of building parts, or even including whole buildings. It has been shown to improve construction performance (Kamar 2010). For example, industrialized processes implemented in the residential building industries of North American and European countries resulted in a saving of 16% in labor and material costs in on-site construction; 26% less material utilization; and 37% less building time [22–24]. Thus, construction industrialization has positive influences to sustainable development.

Chinese construction industry facilitates active industrialization policies for the purposes of promoting the industry transformation and improvement, undertaking the role of green builders in national energy conservation, and responding to the social attention on air, noise and other environmental issues in the process of building and construction activities [5,25,26]. There are three major phases to classify the industrialization development of Chinese construction industry: (a) the first phase of construction industrialization during the 1980s; (b) housing industrialization from 1999 to 2013; and (c) modern industrialization development of the construction industry after 2013 [5,25,26]. In particular, in the third phase on the national level, the industrialization development program identified the policies to promote modernization in the construction industry in 2013. The program issued the following industrial policies, which were implemented and updated in synchronization on national, industrial, provincial, and local levels. For example, "New National Urbanization Plan (2014–2020)" [27], "Green Building Action Program" (2015) [26], "2014–2015 Energy Saving and Low-Carbon Development Action Plan in Construction Industry" [5], and the latest "2016 Modernization Construction Industry Development Program" [25]. They are issued by the Ministry of Housing and Urban-rural Development of the People's Republic of China (MOHURD), with the purpose of specifying the industrialization of Chinese construction industry in the next 5–10 years.

The rest of the paper is structured as follows. Section 2 reviews the literature of the theoretical frameworks. It also includes the major influence factors of Chinese construction industrialization, growth management model, and industrial policy evaluation. Section 3 provides methodology. Section 4 applies the methodology to analyze the growth stages of the empirical cases. Section 5 summarizes the results, presents the conclusions, and highlights the implications of policy evaluation in other fields.

2. Literature Review

2.1. Review of Chinese Construction Industrialization after 2013

After 2013, China issued a series of plans, actions and programs to speed up the development of construction industrialization on the national, industrial and local levels to improve the environmental quality of the construction industrialization and move up the value chain [5,25,26]. From the government perspective, the keys were technical standards and industrial policies [28]. Some construction companies faced the growing pain of the lack of general technical standards [29,30]. On the other hand, while targeted industrial policies were particularly critical to the propulsion of construction industrialization by favorable financial and tax programs, the policies seemly failed to form a strong incentive to support the promotion and implementation in the pervasion process of current industrialization at firm level. Thus, distinguishing the specific barriers of industrialization is important in the iterations of policy formation to sustain the growth of Chinese construction industry [5,25,26].

Chinese construction industry paid much attention to enhance operational efficiency by industrialization [31,32]. To solve the problems of high consumption, low profit, and low efficiency in Chinese construction industry, researchers [5,25,26] suggested using industrialization to improve quality, safety, efficiency, etc. The recently huge rise of labor costs urged Chinese construction companies to participate in industrialization to alleviate the shortage of labor supply and the gradual disappearance of demographic dividend [33,34]. In order to promote construction process, Chinese government implemented pilot programs and granted policy supports to allow large companies to form leading roles in industrialization. For example, with regard to the 13th 5 Years Plan (13th 5YP) ransition pilot program in the construction sector issued by the central government, Shaanxi Province carried out the pilot reform and development of the construction industry to respond the 2014 guidelines of Ministry of Housing and Urban-Rural Development of the People's Republic of China [5]. Beyond the large range of policies and technical support, the pilot programs created green channels for Architecture, Engineering, Construction and Operation (AECO) projects, and provided specific service, including supervisions on construction contracting, bidding, quality and safety [35,36]. However, different Chinese provinces implemented and promoted construction industrialization in varied scales, with local constraints of capital, technology, and company marketability. Thus, it was appropriate to take laddering-growth pattern to promote industrialization in Chinese construction industry [35,36]. For example, some backward local industries could utilize the experiences learned from pilot provinces to build the growth management framework of transition process, identify the growth position quantitatively from case studies, complement the current policy, explore operational and sustainable management paths, and promote the growth position through the feedback or responses of enterprises. Overall, the current policies of Chinese construction industrialization considered regional differences. The policies granted eligibilities and funding based on geographical criteria.

2.2. Challenges in Industrialization

Existing literature identified a variety of factors that could influence industrialization policies and motivate positive responses from companies. The factors included: (1) general awareness [37–40]; (2) technical field [41–43]; (3) human resource [44–46]; (4) cost field [3,4]; (5) university-and-institution cooperation [47–49]; (6) policy areas [23,50,51]; and (7) industrial management system [52–54]. The first group of factors is reflected in some well-recognized, construction industrialization policies in regard to building kinds and company's stance [55–58]. Due to the constraints of technology, human resource and capital, construction enterprises might take different paths to conduct industrialization processes. Meanwhile, enterprises should pay close attention to government's role, implementation subject, the vigor of industrialization plan, and responsibility awareness of industrialization plan [29,30,59,60].

The second type of factors is about technology fields [3,61–63]. Technology innovations, updates and applications were the central support for the progress of industrialization. In the technology fields, enterprises paid more attention to building quality, operation performance of construction machinery, and maturity of industrialization technology. Furthermore, some research projects focused on information and communication technology in the construction industrialization fields [37,40,64,65]. Experts suggested that the application level of prefabricated components in projects depended on the implementation of construction industrialization technology [37,40,64,65].

The third type of factors relates to human resource pool [66–69]. Industrial policies should focus on talent training to promote structure changes and industrial transformation for the construction industry [66–69]. Human training stood in the core position to promote the micro-operation of industrial policy system [66–69]. Thus, government should establish a talent training mechanism to provide support for construction industrialization. In addition, enterprises should examine the percentages of their professional and technical personnel, and set up corresponding training classes accordingly [32,70–72]. Researchers showed that there was a demand–supply gap for professional and technical personnel to meet with construction industrialization requirements [32,70–72].

The fourth constraint is about building costs in construction industrialization [73–75]. While industrialized building in the international arena became a major trend in the construction market [73–75], there was a slow development China. One of the main reasons was the cost factor [73–75]. The non-scale economies in the production process of the construction industry were due to the fragment status of construction supply chain, low standardization level, and limited integration level [5,26]. Thus there was a significant cost gap in industrialization in Chinese construction industry compared to those in developed countries, such as the US [76,77]. High construction cost led to the reduction of enterprise enthusiasm in market expansion, limited their visions of development, and hindered industrial technology innovation, integration and development. Overall, it resulted in a non-virtuous circle.

The fifth group of factors considered the benefits of corporation–university–institution cooperation for construction industrialization [78–82], which was important to promote the infusion of market forces and scientific research through efficient allocation of resources to sustain industry progress. In the cooperation process, researchers suggested to consider the roles of universities and research institutions in promoting construction industrialization [83–86]. Policies should pay attention to the extent of technology transfer from universities and research institutions to improve productivity in the process of construction industrialization.

The sixth group of factors is on the development of policy support [12,87–89]. Government policies and incentives, in particular local promotions with specific goals and intents, played an important role for the up-growth of industrialized buildings [12,88,90,91]. Economic policies, such as tax cuts and subsidies, would conduct a direct impact on cost saving and attract more companies to participate in the production of industrialized buildings. The policy incentives of technology transfer and the standards of technical specifications played a positive effect on the promotion of construction industrialization [12,88,90,91]. Therefore, it was important for construction enterprises to understand the tax cut policies, financial subsidies, building risk protection and environmental contribution awards for construction industrialization [26]. The lack of policy support restricted the advance of industrialization in the Chinese construction industry [7,92–94].

The seventh group of factors relates to the support of industrialization management system. It could help with industrial planning and implementation in the real world, especially for the initial development of industrialization when facing many actual constraints [69,95,96]. With proper market-oriented strategies, enterprises would also receive social acceptance of their projects, complete industrial production chain in the construction industrialization, and bring up professional equipment suppliers [97–99]. Table A1 in the Appendix A shows a framework of the aforementioned issues. This framework serves as the basis for following steps of this research.

2.3. Industry Policy Evaluation: Focuses and Methods

Many researchers showed interests in industrial policies. For example, Ramizo performed a survey for institution challenges on an industrial policy [28]. Lucchese, Nascia and Pianta studied new challenges for industrial policies and technology in Italy [100]. Aiginger proposed a new typology based on the orientation of a policy and studied the policy domain to explain matrix function [101]. However, there was no generally accepted definition of an industrial policy in the literature [84,102–106]. Pack and Saggi [107] defined an industrial policy as "any type of selective intervention or a government policy that attempts to alter the structure of production toward sectors that are expected to offer better prospects for economic growth than would occur in the absence of such intervention." In this research, we adopted the definition of an industrial policy proposed by Pack and Saggi [107], which indicated a few important features listed as follows: (a) An industrial policy included functional or horizontal policies as well as targeted approaches. (b) An industrial policy included goals to alter the structure of economic activities. (c) An industrial policy explicitly had the objectives of productivity, employment, growth, or societal welfare. (d) An industrial policy aimed to switch resources not only to particular sectors but also towards certain technologies (for example ICT or clean-tech).

The industrial policy evaluation developed by the Organization for Economic Co-operation and Development (OECD) focuses on processes and developments. The focal of evaluation should abide by the following guidelines [12,88,108–110]. (a) Both quantitative and qualitative approaches should be used (e.g., growth phase evaluation with the adoption of mixed methods of survey, experiment and entropy). (b) Industrial policy evaluation should shift from short-term policy measures (e.g., focused on the supply side) to long-term, indirect and systemic strategies (e.g., improving regulation environment on firm level). (c) Context dependencies and geographical dimensions should be considered. (d) The rationale for policy adoptions should be clear. (e) Evaluators and policymakers should team together to seek the understanding of policy impacts in real time and be able to adapt the policies in complex and changing environments.

2.4. Growth Management Model (GMM)

Charles McIntyre [16] proposed an Industry Advisory Board (IAB) Growth Management Model (GMM) to inspect the growth stages of organizations. In a GMM model, the relationship between managerial proficiency and outcomes is expressed by a series of management plateau levels which are linked by several lines called transition periods. A GMM model usually has four management plateaus representing the IAB outcomes which can be achieved at each level of managerial proficiency. These plateaus are stability zones where the IAB outcomes match the organization managerial proficiency. Figure 1 shows an example of GMM.

The integration of IAB GMM with Weisbord's six-box model could form a sustainable growth diagnosis framework, which was used effectively to conduct an empirical case study of Chinese Petro sub-company, and formed a basis and reference for follow-up research [17]. In Table A1 (in the Appendix A), there are eight subsystems of policy management evaluation for construction industrialization, which are all primary components of Managerial Proficiency toward sustainable development in construction industrialization. In addition, the outcomes of policy management of construction industrialization (PMCI) are defined as the quantity and quality of best practices conducted by regional construction industry within these eight proficiency systems. Figure 1 shows a new integrated diagnostic model for regional construction industry transition in the stance of organizational sustainable growth management.

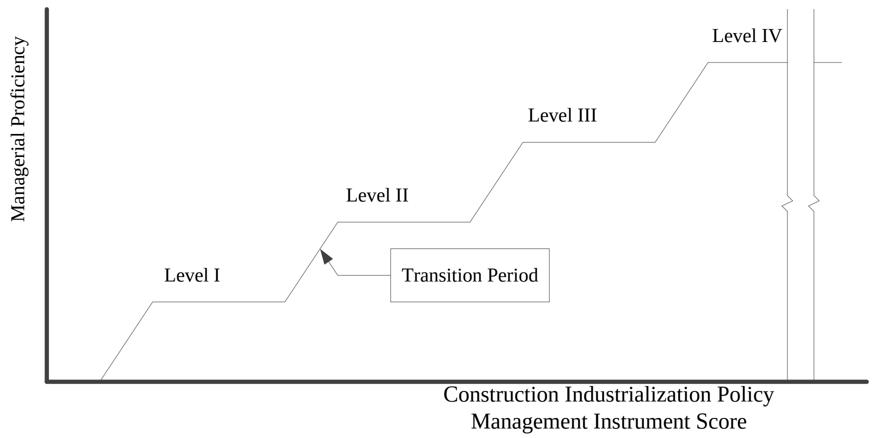

Figure 1. Incorporating GMM into Construction industrialization policy management (adapted from [16]).

In Figure 1, the vertical axis represents Managerial Proficiency and the horizontal axis relates to scores. Scores are marked by grades, which are calculated from the samples. The relationship between managerial proficiency and scores of policy management for construction industrialization is represented by a series of management plateau levels (i.e., level I to level IV, and more levels if possible) linked by transition periods. These plateaus are stable levels of managerial proficiency, while transition periods represent the processes where actions are taken to reach the next level. Figure 2 shows a theoretical framework in this research.

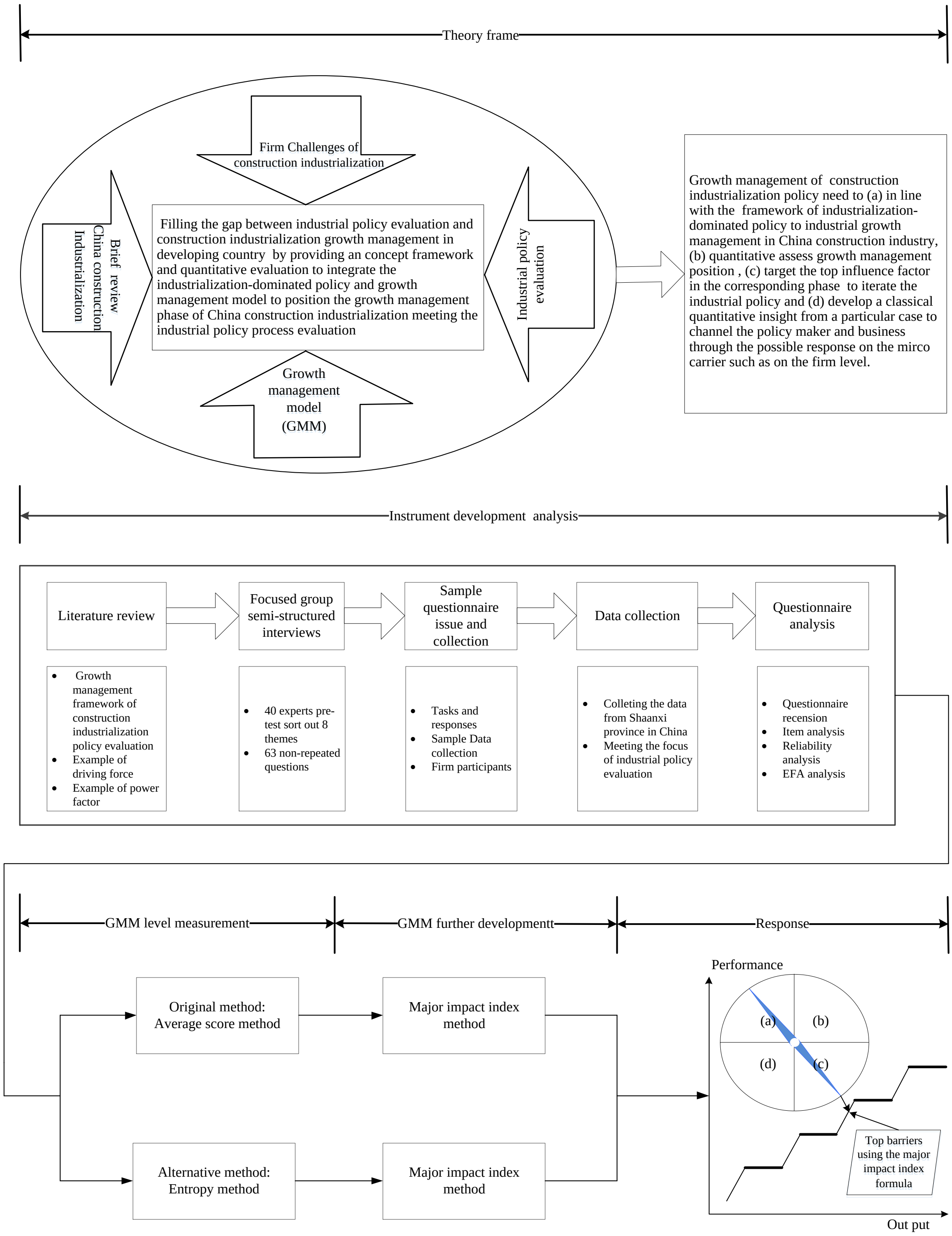

Figure 2. Research framework and steps. Note: Within the research framework in Figure 2, the last phase of Response (a–d) just symbolically inform the refined aspects of construction industrialization after the instrument development with empirical data, which could be adjusted according to the reality.

3. Research Method

This research utilized the following mixed method [17,18]: (a) average score method as the original validation method in growth management model; (b) entropy method as the proposed alternative method to comparatively analysis the growth management position; and (c) major impact index formula to target the top influence factor in the sustainable development of construction industrialization process. The calculation process is shown as follows:

3.1. Average Score Method

(1) Calculating the average score of total sample

Suppose there are m units and n indicators,

$$ZF_i = \sum_{t=1}^{n} f_{s_t} \tag{1}$$

where s = 1, 2, 3ˆm; t = 1, 2, 3ˆn; ZF_s = the score sum of sth sample; f_{s_t} = the tth index score of sth sample. Then, Equation (2) calculates the average score of m units:

$$f = \sum_{s=1}^{m} ZF_s / m \tag{2}$$

(2) Grading GMM level of regional construction industry

Similar to the IABGMM model [16], we suppose level K = 5 (where A = 5 represents strong disagreement to E = 5 represents strong agreement) scaling of each indicator in each unit. There are 5 levels to be graded for the samples. Table 1 shows the scope of each level.

Table 1. The scope of each level in growth framework of construction industry transition management using average score method.

Level	I	II	III	IV
Scope	$n \times [1,2)$	$n \times [2,3)$	$n \times [3,4)$	$n \times [4,5)$

Note: n represents the number of indicators in m units.

3.2. Entropy Method

The following entropy method is able to calculate the GMM level of construction industrialization process with accurate assessment results. This method is also used to compare and verify the calculation results from Average Score Method.

Step 1: Formation of the evaluation matrix

Suppose there are m units and n indicators to be evaluated to establish the original data matrix in Equation (3).

$$R = (\mathrm{r}_{st})_{m \times n}\ (s = 1, 2, \cdots, m; t = 1, 2 \cdots, n) \tag{3}$$

where r_{st} represents the actual value of the tth index of sth unit.

Step 2: Standardization of the evaluation matrix

The following equation is used to normalize the matrix B,

$$B = (\mathrm{b}_{st})_{m \times n}\ (s = 1, 2, \cdots, m; t = 1, 2 \cdots, n) \text{ with } b_{st} = \frac{r_{st} - r_{\min}}{r_{\max} - r_{\min}} \tag{4}$$

where $r_{\max}$ and $r_{\min}$ represent the maximum and minimum values, respectively, for the evaluation unit.

If indicator is the positive tropism (+)

$$b_{st} = \frac{r_{st} - r_{\min}}{r_{\max} - r_{\min}} \tag{4-1}$$

If indicator is the negative tropism (−)

$$b_{st} = \frac{r_{\max} - r_{st}}{r_{\max} - r_{\min}} \tag{4-2}$$

Step 3: Calculation of the entropy

The entropy of the system can be defined by using the following calculations:

$$H_t = -\left(\sum_{s-1}^{m} f_{st} \ln f_{st}\right) / \ln\ m\,(s = 1, 2, \cdots, m;\ t = 1, 2 \cdots, n) \tag{5}$$

where $f_{st} = b_{st} / \sum\limits_{s=1}^{m} b_{st}$; if $f_{st} = 0$, redefine the f_{st} as

$$f_{st} = (1 + b_{st}) / \sum_{s=1}^{m} (1 + b_{st}) \tag{6}$$

Step 4: Calculation of the entropy weight

$$w = (\omega_t)_{1\times n}, \omega_t = (1 - H_t)/(n - \sum_{t=1}^{n} H_t = 1) \text{ with } \sum_{t=1}^{n} \omega_t = 1 \tag{7}$$

Step 5: Use entropy weight to calculate the score of GMM level

$$sf = \sum_{i=1}^{n} \omega_i f_i \tag{8}$$

where ω_i is the entropy weight of the ith index, and f_i is the score of the ith index.

Step 6: Grade the level.

Analog to the average score method above, the entropy method to grade the GMM level of construction industry transition management is shown in Table 2.

Table 2. The scope and level of growth framework of construction industry transition management using the entropy method.

Level	**I**	**II**	**III**	**IV**
Scope	[1,2)	[2,3)	[3,4)	[4,5)

Source: IABGMM level proposed by Charles McIntyre (2015) [16].

3.3. *Targeted Solutions with Top Impact Influence Factors*

The top impact barriers and targeted solutions in the current level can promote the sustainable path of the PMCI. This research used the major impact index formula [111–114] to generate and compare the impact extent of the indices, which is shown in Equation (9).

$$A_i = \omega_i d_i / \sum_{i=1}^{n} \omega_i d_i \times 100\% \tag{9}$$

A_i represents the impact extent of an index, ω_i represents the entropy weight of an index, d_i represents the standardization value of an index, and n represents the index number in the evaluation system of GMM in the PMCI. Equation (10) calculates the top impact barrier with the average score.

$$A_i = \frac{d_i}{\sum_{i=1}^{n} d_i} \times 100\% \quad (10)$$

4. Empirical Implementation

4.1. Data Collection

The regional development of Chinese construction industry has a ladder-shaped growth trend from southeast to northwest. The regional development could be classified into four types, as shown in Figure 1 [35,36]. The development type of the construction industry in Shaanxi (a northwest province of China) is within the second type of regional growth [35,36]. At the same time, it is the pilot province for construction industrialization as listed by the MOHURD of China. We collected data from the regional construction companies located in Shaanxi to explain the growth stage of policy management for construction industrialization.

Shaanxi Construction Association hosted the Forum of Transition Management in the Construction Industry annually, which was also supported by the provincial government. With their help, we randomly selected 1200 companies from the Shaanxi Yellow Pages of Commercial/Industrial Telephone Directory in 2014. We made telephone calls to the company executives to explain the purpose of the study and to obtain agreements for survey participations. Of the 1200 companies, 420 agreed to participate. We then hand-delivered questionnaires to company executives. We conducted follow-up telephone calls within two weeks to make sure that it was the executives (i.e., general manager or deputy-general manager) who provided the information. Out of the 420 questionnaires issued, 327 were completed correctly. With an 80.15% (327/420 = 80.15%) response rate, the data collection met the requirement of sample size to analyze the common problems in economic and social areas [115,116].

According to Figure 2 in Section 2.4, we constructed the questionnaire and conducted its development with: (a) item analysis (T-test ($p < 0.05$) [115,116]); (b) reliability analysis (Cronbach's $\alpha > 0.80$); (c) Item-2-Total Correlation analysis, the threshold value of which was conducted above than 0.2 [116]; (4) exploratory factor analysis (EFA) (KMO > 0.9 and Eigenvalue > 1); and (5) principle component analysis (PCA) with SPSS 22 software. In addition, we compared the opinions of early respondents with late respondents on the key constructs to determine whether there was non-response bias in the study. Chi-square tests showed that there were no significant differences between the opinions of the early and the late respondents with regard to firm characteristics. In addition, t-test results indicated that there were no significant differences between the early and the late respondents on the measures of transition management of the construction industry. Thus, non-response bias was not a problem in this study.

The final formal questionnaire of the policy evaluation of construction industrialization was structured to include 24 questions. The formal questionnaire used a five-point Likert scale (1 = not very important and 5 = very important) to evaluate most items. The statistical measurements of instrument development are described in Table A1 in the Appendix A.

4.2. Average Score Analysis

4.2.1. Growth Level Using Average Score Method

Based on Table 3 in Section 4.2.1, using the average score method with Equations (1) and (2) in Section 3.1, the average score of the PMCI of Shaanxi was 80.8. At the same time, Table 4 shows the growth scope for each level calculated from Table 2 in Section 3.2. Thus, the growth stage of PMCI in Shaanxi stood on level III. Analogous to the framework of GMM [16], Figure 3 shows the step and whole process of transition management in the construction industry, which also indicates that PMCI in Shaanxi construction industry on firm level is still in the moving-up stage. Hence, people should pay attention to alleviate the barriers to improve the growth management of the construction industry.

Table 3. Principal component, code and item of formal questionnaire.

Principal Component	Code in Table A1 in Appendix A	Item	Code in Final Questionnaire
F1	25	To what extent do you think that the new materials developed by universities and research institutions are applied in projects with construction industrialization?	F1-1
F1	26	To what extent do you think that the new building structure developed by universities and research institutions are applied in projects with construction industrialization?	F1-2
F1	28	In the current research cooperation process among enterprises, universities, and research institutions, are you satisfied with the technology transfer of the research results?	F1-3
F1	33	How much do the current governmental initiatives related to the promotion of construction industrialization?	F1-4
F1	34	To what degree is tax cuts to promote construction industrialization?	F1-5
F1	35	To what extent do you understand the tax policies introduced by the Government to promote the current construction industrialization?	F1-6
F1	37	To what extent do you understand the current financial subsidies introduced by government for construction industrialization?	F1-7
F1	45	To what degree of acceptance, the current market has for construction industrialization?	F1-8
F1	46	In the projects construction industrialization, what is the impact of social acceptance of the projects to resource inputs?	F1-9
F1	47	To what extent is the popularization of the various channels for the promotion of construction industrialization?	F1-10
F1	49	To what extent do the building structure design and construction standardization affect the user demands?	F1-11
F1	55	How important professional equipment suppliers are for the promotion of construction industrialization?	F1-12
F2	48	To what extent are the developments of construction markets in different regions to carry out construction industrialization?	F2-1
F2	54	How important do you think the quality of construction industrialization is for the promotion of its development?	F2-2
F3	32	To what degree is the influence of the development of the relevant technical specification standards to the promotion of the construction industrialization?	F3-1
F3	51	To what degree of influence do the pilot projects invested by government have to promote construction industrialization?	F3-2
F3	52	To what degree does construction industrialization have in speeding up shantytowns improvement?	F3-3
F3	59	What is the level of your satisfaction with the current government approval procedures for the projects with construction industrialization?	F3-4
F4	60	How important do you think that many-ministries-rule promotes construction industrialization?	F4-1
F4	27	To what extent do you think that the construction methods optimized by universities and research institutions help to promote the construction industrialization?	F4-2
F5	53	Are you willing to participate in the projects invested by government, such as business-to-income housing in shantytowns?	F5-1
F5	50	To what degree is the completeness of the current industrial production chain of the construction industry?	F5-2
F6	30	To what extent technology is transferred into productivity in the process of construction industrialization?	F6-1
F6	58	To what extent is the urgency of the reform of project management system to promote the construction industrialization of new projects?	F6-2

Table 4. Growth level and scope using the average score method.

Level	**I**	**II**	**III**	**IV**
Scope	[24,48)	[48,72)	[72,96)	[96,120]

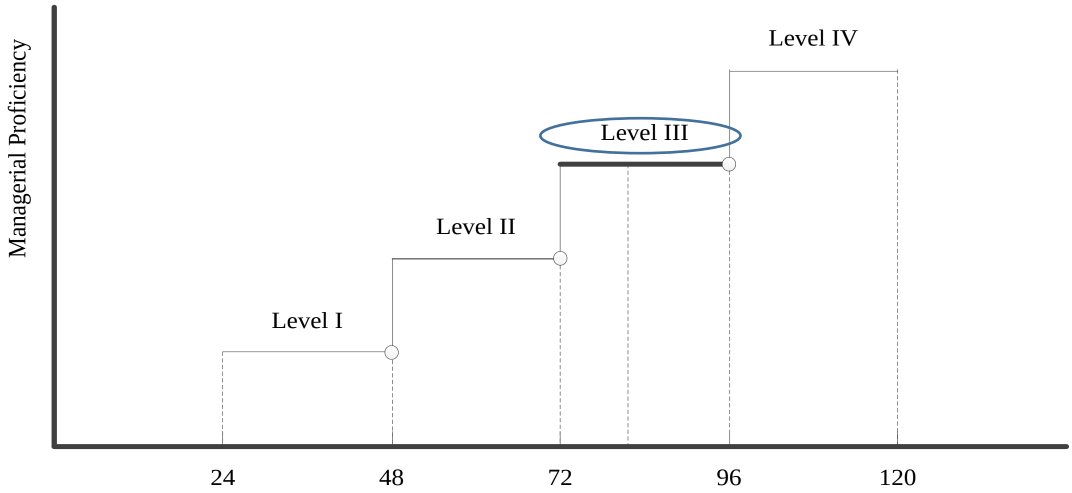

Figure 3. Position of Shaanxi construction industrialization policy management using average score method with GMM framework (adapted from [16]).

4.2.2. Top Influence Factors Using Average Score Method

Table 5 shows the calculation results using Equation (10) to target at the barriers. The smaller is the frequency percent of each index, the stronger is the hindering influence [111,113,117–119]. In Table 6, F1-8 (41.582%) is the smallest frequency value, which indicates that the acceptance degree of the current market for construction industrialization forms a certain obstacle on the firm level in Shaanxi and needs to be improved. The second lowest value in Table 6 is F6-1 (43.189%), which shows that there is a distinct lack of technology transfer into productivity in the process of construction industrialization on the firm level in Shaanxi.

The third lowest values of F1-3 (48.837%) and F3-2 (48.837%) in Table 6 show the cooperation process among enterprises, universities, and research institutions could not be satisfied with the technology transfer on the firm level in Shaanxi. Meanwhile, the pilot projects invested by government to promote construction industrialization could not give satisfactory results with a broad impact on other companies.

Table 5. Top influence indexes using average score method.

Index	F1-1	F1-2	F1-3	F1-4	F1-5	F1-6	F1-7	F1-8
Frequency%	51.163	53.821	48.837	**66.445**	**68.439**	59.468	56.146	41.528
Index	F1-9	F1-10	F1-11	F1-12	F2-1	F2-2	F3-1	F3-2
Frequency%	49.502	51.495	57.475	**69.435**	60.797	61.795	**67.110**	48.837
Index	F3-3	F3-4	F4-1	F4-2	F5-1	F5-2	F6-1	F6-2
Frequency%	49.169	50.831	**69.435**	62.126	62.791	57.807	43.189	58.14

4.3. Entropy Method Analysis

4.3.1. Entropy Weights of Indexes

Table 6 shows the results of index entropy weights of PMCI in Shaanxi using Equations (3) and (4) to standardize the data of final questionnaire, and then using Equations (5)–(7) to generate the entropy weights of 16 indexes.

Table 6. The index entropy weights of policy management of construction industrialization in Shaanxi.

Index	F1-1	F1-2	F1-3	F1-4	F1-5	F1-6	F1-7	F1-8
Entropy Weight	0.043	0.042	0.042	0.04	0.039	0.042	0.043	0.04
Index	F1-9	F1-10	F1-11	F1-12	F2-1	F2-2	F3-1	F3-2
Entropy Weight	0.042	0.043	0.043	0.039	0.042	0.042	0.04	0.042
Index	F3-3	F3-4	F4-1	F4-2	F5-1	F5-2	F6-1	F6-2
Entropy Weight	0.042	0.043	0.039	0.042	0.042	0.043	0.041	0.043

4.3.2. Verification of Growth Level Using Entropy Method

Equation (8) generates $sf = 3.368$. Compared with Table 2 in Section 3.2, we can see that transition steps of Shaanxi construction industry is in the third phase, which also confirmed the growth level result of average score method proposed by Charles McIntyre [16].

4.3.3. Top Influence Factors Using Entropy Method

Table 7 shows the top-impact influence factors calculated by entropy method as shown in Equation (9). In Table 7, F1-2 (44.186%), F1-8 (44.518%,), F1-3 (45.847%) and F6-1 (45.847%) have relatively lower frequency percentages than the other indexes. Thus, combining Table 7 with the principle components in Table 2 and the hindering factors in Table 5, the suggestion for the government is to pay much attention to the acceptable extent of the new building structures developed by universities and research institutions.

Table 7. Top impact influence factor using entropy method.

Index	F1-1	F1-2	F1-3	F1-4	F1-5	F1-6	F1-7	F1-8
Frequency%	47.508	44.186	45.847	70.100	72.757	55.814	46.512	44.518
Index	F1-9	F1-10	F1-11	F1-12	F2-1	F2-2	F3-1	F3-2
Frequency%	46.844	48.173	54.153	75.415	58.140	61.794	70.432	48.837
Index	F3-3	F3-4	F4-1	F4-2	F5-1	F5-2	F6-1	F6-2
Frequency%	47.176	48.505	73.754	62.126	62.791	55.150	45.847	54.153

4.4. Discussion

This research used two methods to conduct top-influence factor comparisons. Tables 8 and 9 compare the results of the factors to confirm the improvement suggestions for PMCI for Shaanxi Province, China.

Table 8. Comparison of top-influence factors using average score method and entropy method.

Ranking	Average Score Method		Entropy Method	
	Top Influence Factor	Frequency%	Top Influence Factor	Frequency%
1	F1-8	41.528	F1-2	44.186
2	F6-1	43.189	F1-8	44.518
3	F1-3	48.837	F6-1	45.847
4	F3-2	48.837	F1-3	45.847
5	F3-3	49.169	F1-7	46.512
6	F1-9	49.502	F1-9	46.844
7	F3-4	50.831	F3-3	47.176
8	F1-1	51.163	F1-10	48.173
...	...	...	...	...

Table 9. Comparison of top-influence factors on the principle components.

Principle Component	Methods	Top Influence Factor
F1	Average score method Entropy method	F1-8 F1-2
F2	Average score method Entropy method	F2-1 F2-1
F3	Average score method Entropy method	F3-2 F3-3
F4	Average score method Entropy method	F4-2 F4-2
F5	Average score method Entropy method	F5-2 F5-2
F6	Average score method Entropy method	F6-1 F6-1

The comparisons in Tables 8 and 9 show that some principle components have different top-influence factors, i.e., F1 and F3. Using entropy method, we could find possible suggestions to target the barriers (e.g., F1-2 and F3-3) in the current growth phase. The other principle components have consistent top-influence factors. Thus, the applications of average score and entropy methods obtain the same results and suggestions. Thus, to improve the growth phases of construction industrialization in Shaanxi Province, China, some aspects of current PMCI should be strengthened to promote the sustainable growth management of construction industrialization. These aspects are listed below.

(1) Technology: PMCI should take actions to support the technology and equipment suppliers in the Shaanxi construction industry. PMCI should support the prefabricated construction enterprises and encourage the firms to invest and improve continuously the packaged technology systems and methods, as well as technical standards. PMCI should publish technology standard to regulate the industrialized market, promote equipment rental business for the construction industry, and develop sustainable construction supply market.

(2) Quality: PMCI should improve the current recognition of the quality of industrialized buildings. Construction firms should strengthen the supervision and management of construction production to improve the product quality. Construction firms and governments can work together to raise the quality recognition and reduce the preconception about the quality of current industrialized buildings.

(3) Standards: PMCI should issue and complete standards and codes. It is critical to establish design and building standards and technical specifications to deepen the standardization for AECO. It is also the foundation to promote the industrialized construction. The cooperation among enterprises, government and institutions is in urgent need of complete technological standards and codes, some of which might be provided by the pilot projects of construction industrialization.
(4) Multi-sector governance: PMCI should take the approach of multi-sector governance to sustain the construction industrialization in Shaanxi Province. For example, the Development and Reform Commission, Bureau of Land and Resources, and Bureau of Finance will encourage the construction industrialization with fiscal support, land planning and priority, and investment to targeted pilot projects. Multi-sector governance can also make appropriate financial subsidy or refund on industrial construction projects possible, for example, using land transfer as a financial subsidy. Multi-sector governance could encourage financial institutions to give loans to construction enterprise in the preparation phases of construction industrialized project.
(5) Pilot projects: PMCI should encourage construction enterprises to actively participate in the pilot industrialized projects. Governments on national, province, regional, and local levels usually invest on these projects. In Shaanxi Province, affordable housing projects in shantytowns for low-income groups are an important component of government invested projects in the current context of new urbanization. Policy makers should value this kind of projects to broaden the market acceptance of industrialized buildings and the implementations of industrialization policies. Moreover, government invested projects should promote industrialization projects in practice [115–117,119,120].
(6) Business processes: Chinese construction industry is improving the adaption of industrialization, such as personnel training of qualifications and the adoption of engineering, procurement and construction (EPC) contracts. Additionally, PMCI should continue to improve the bidding management approaches in construction industrialization projects. It should provide appropriate business processes for qualified industrialized projects, i.e., construction plan review and project qualification. Governments and construction enterprises should establish the mechanism of quality supervision for industrialized projects and manage the quality and safety of prefabricated components in building processes.

5. Conclusions

This research provides a theoretical framework and implements a systematic approach to analyze the successful cases in practice. The results of industrial policy evaluation are integrated into the policy making processes through a bottom-up approach. The framework is helpful for future policy adjustments and improvements and able to sustain the development of construction industrialization.

This research is the first study on the evaluation issues of industrial policies in construction industrialization practice. It identifies the growth phases and clarifies the priorities by evolving and validating a framework for the challenges in sustainable management of the policy evaluation of construction industrialization. This research for the first time interweaves growth management model, industrial policy evaluation and the opinions of construction firms. It shows quantitatively the growth phases and status of PMCI. Moreover, it shows how the policy priorities should be approached to channel the voices from firms.

In order to analyze the growth stages of construction industrialization policies, this research used average score method and entropy method to calculate and confirm the results. The research applied the formula of major impact indexes to target the priorities of top-influence factors. It provided suggestions for the improvement on firm level. With the comparison results of the two methods, this empirical study determined the challenges for construction industrialization. The growth stage of PMCI in Shaanxi Province of China was in between the third phase and the fourth phase. The top-influence factors indicated the following situations. (a) The acceptance level of new building structures with construction industrialization developed by universities and research institutions was low. The low market acceptance formed an evident obstacle. (b) The technology transfer on firm level could not satisfy the cooperation processes among enterprises, universities, and research institutions. The pilot projects invested by governments for the promotion of construction industrialization could not arrive at satisfactory results with a broad impact on other companies. (c) There was a lack of technology transfer into productivity in the processes of construction industrialization on firm level.

The emphasis of this work lies on the application of firm-level empirical research with real data. One limitation of this research is that the data is from regional construction firms. Cautions must be taken when generalizing the findings. It is import to collect the recognition data of construction industrialization on firm level, which was also the focus of this work. With the required data, the proposed framework can be applied to solve a wide range of problems in sustainable management in the AECO industries at large scales. Moreover, the model can be used as a basis for further extensions, such as multi-period PMCI considering time-dependent demands and context constraints. The data were collected through self-reporting by key informants which is another limitation of the study. Future research should use data collected from multiple sources. Future research should also examine the properties of PMCI in the context of other developing or developed countries.

Acknowledgments: This research is supported by the National Natural Science Foundation of China (No. 71301013); Humanity and Social Science Program Foundation of the Ministry of Education of China (No. 13YJA790150); Shaanxi Nature Science Fund (No. 2014JM2-7140); Shaanxi Social Science Fund (No. 2017Z028, No. 2016ZB017, No. 2016Z047, No. 2015Z071, No. 2015Z075 and No. 2014HQ10); Xi'an Social Science Fund (No. 17J169); Xi'an Science Technology Bureau Fund(No. CXY1512[2]); Fundamental Research Fund for Graduate Student Education Reform of Central College, Chang'an University (No. jgy16062, No. 310623176201, No. 310623176702, No. 310623171003, No. 310628176702, No. 310628156109, No. 310628156108 and No. 310628161406); Fundamental Research Fund for the Central Universities (Humanities and Social Sciences), Chang'an University (No. 310828160661 and No. 310823170215); National Engineering Degree Graduate Funding Project of China (No. 2016-ZX-390).

Author Contributions: Jingxiao Zhang and Hui Li conducted the interviews, analyzed the data and contributed to drafting the paper. Zhang and Li contributed to the concept and design of the paper, and Sally Haiyan Xie contributed useful advice and modified the paper. Zhang was in charge of the final version of the paper. The authors gratefully acknowledge valuable suggestions by the expert panel, and give special thanks to design managers and senior architects of design firms who completed the survey. The authors also wish to acknowledge two anonymous reviewers for their valuable suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

GMM	Growth Management Model
IAB	Industry Advisory Board
OECD	Organization for Economic Co-operation and Development
PMCI	Policy Management of Construction Industrialization

Appendix A

Table A1. A framework of industrialization-dominated policies for growth management in the construction industry.

General Awareness	1. In your opinion, what is the implementation result of construction industrialization in high-rise public buildings? 2. What is the implementation result of the industrialization in multi-story residential buildings? 3. What is the implementation result of the industrialization in high-rise residential buildings? 4. What kind of role should the government play in the process of construction industrialization? 5. Who should be the implementation subject in the process of construction industrialization? 6. What is your level of understanding of construction industrialization? 7. What is the degree of attention of the government to promote the construction industrialization? 8. What is the degree of awareness of the government to construction industrialization?
Technical Field	9. What is the level of the application of prefabricated components in the projects of your company? 10. What is the current level of maturity of the construction technology for building new-type industrialization? 11. What is the status of quality control in the current construction industrialization? 12. What is the ability level of mechanical operators in the project sites with construction industrialization? 13. On average how much time percentage has been used for BIM detailing in the current projects? 14. What is the relationship between construction site management and the promotion of project information management? 15. How important is the application of BIM technology in promoting construction industrialization?
Human Resources	16. In order to meet construction industrialization requirements, how much percentage of the professional and technical personnel of the company needs to go through the corresponding training? 17. In your opinion, how large in the current demand for professional and technical personnel gap to meet construction industrialization requirements? 18. How much is the possibility that construction industrialization will lead to the relative surplus of labor?
Cost field	19. To what extent the high construction costs for the promotion of construction industrialization impact? 20. To what extent would construction industrialization help to reduce the consumption of labor, equipment, and material resources and to improve construction efficiency? 21. To what extent would construction industrialization impact the economic benefits enterprises? 22. To what extent would the scale effect of construction enterprises impact the project costs with construction industrialization?
Cooperative Field	23. What do you think is the role of universities and research institutions in promoting the process of construction industrialization? 24. To what extent the current universities' academic achievements bond with construction industrialization practice? 25. To what extent do you think that the new materials developed by universities and research institutions are applied in projects with construction industrialization? (Principal Component = F1; Code in Original Questionnaire = P2-5-3; Code in Original Questionnaire = F1-1) 26. To what extent do you think that the new building structure developed by universities and research institutions are applied in projects with construction industrialization? 27. To what extent do you think that the construction methods optimized by universities and research institutions help to promote the construction industrialization? 28. In the current research cooperation process among enterprises, universities, and research institutions, are you satisfied with the technology transfer of the research results? 29. To what extent do you think that universities and research institutions influence government's policy? 30. To what extent technology is transferred into productivity in the process of construction industrialization?

Table A1. *Cont.*

Policy Areas	31. In the current industrialization of the construction sector, to what the degree is technical standards in? 32. To what degree is the influence of the development of the relevant technical specification standards to the promotion of the construction industrialization? 33. How much do the current governmental initiatives related to the promotion of construction industrialization? 34. To what degree is tax cuts to promote construction industrialization? 35. To what extent do you understand the tax policies introduced by the Government to promote the current construction industrialization? 36. To what extent the financial subsidies promote construction industrialization? 37. To what extent do you understand the current financial subsidies introduced by government for construction industrialization? 38. To what extent the expanded financing channels promote construction industrialization? 39. To what extent do you understand the current construction financing for construction industrialization? 40. How difficult is the pre-financing business in the project with construction industrialization? 41. Is it complete enough that the risk protection offered government to promote construction industrialization? 42. To what extent do you think that the environmental contribution awards stimulate the enthusiasm of enterprises to participate in construction industrialization? 43. To what extent do you think that business will benefit from the series of government policies of construction industrialization? 44. To what reward extent is the current industrialization policies to actively promote the participation of companies?
Markets	45. To what degree of acceptance the current market has for construction industrialization? 46. In the projects construction industrialization, what is the impact of social acceptance of the projects to resource inputs? 47. To what extent is the popularization of the various channels for the promotion of construction industrialization? 48. To what extent are the developments of construction markets in different regions to carry out construction industrialization? 49. To what extent do the building structure design and construction standardization affect the user demands? 50. To what degree is the completeness of the current industrial production chain of the construction industry? 51. To what degree of influence do the pilot projects invested by government have to promote construction industrialization? 52. To what degree does construction industrialization has in speeding up shantytowns improvement? 53. Are you willing to participate in the projects invested by government, such as business-to-income housing in shantytowns? 54. How important do you think the quality of construction industrialization is for the promotion of its development? 55. How important professional equipment suppliers are for the promotion of construction industrialization? 56. What is the impact of the current market environment to promote construction industrialization? 57. How much does the construction industry welcome construction industrialization?
Management System in the Field	58. To what extent is the urgency of the reform of project management system to promote the construction industrialization of new projects? 59. What is the level of your satisfaction with the current government approval procedures for the projects with construction industrialization? 60. How important do you think that many-ministries-rule promotes construction industrialization? 61. About the establishment of the connection between enterprise qualification and its level of industrialization, how important is such a system to promote construction industrialization? 62. To what extent is the influence of the promotion of construction industrialization to the contents of project supervision? 63. To what extent is the current embodiment of the bidding process promotes the construction industrialization?

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