sustainability

MDPI

Article

Regional Comparisons of Contemporary Construction Industry Sustainable Concepts in the Chinese Context

Liang Ma [1,2], Yun Le [3], Hongyang Li [4,5,*], Ruoyu Jin [6], Poorang Piroozfar [6] and Mingqiang Liu [3]

1 School of Management, Shanghai University, 333 Nanchen Road, Shanghai 200444, China; liangma@shu.edu.cn
2 Shanghai Xixin Information Technology Co., Ltd., 381 Nanchen Road, Shanghai 200444, China
3 School of Economics and Management, Tongji University, Shanghai 200092, China; leyun@kzcpm.com (Y.L.); liu_mq163@163.com (M.L.)
4 School of Civil Engineering and Transportation, South China University of Technology, Guangzhou 510641, China
5 State Key Laboratory of Subtropical Building Science, South China University of Technology, Guangzhou 510641, China
6 School of Environment and Technology, University of Brighton, Brighton BN2 4GJ, UK; R.Jin@brighton.ac.uk (R.J.); A.E.Piroozfar@brighton.ac.uk (P.P.)
* Correspondence: li.terryhy@yahoo.com

Received: 6 September 2018; Accepted: 15 October 2018; Published: 23 October 2018

Abstract: Emerging construction practices such as building information modelling (BIM), prefabrication construction, green building, and integrated project delivery methods are gaining momentum in China, with great potential due to the size of its construction market. Through this, the sustainability level of China's construction industry is expected to be enhanced from the economic, social and environmental perspectives. So far, there has been limited understanding of how BIM, as a digital technology, would affect other contemporary sustainable construction practices from the industry professionals' point of view. Limited studies have been carried out to study the regional differences of these contemporary sustainable practices in China. This study adopted a questionnaire-based approach targeting industry professionals from three different metropolitan cities (Shanghai, Guangzhou, and Wenzhou).The follow-up comprehensive statistical analysis revealed that with regards to these contemporary sustainable construction practices, survey participants held much varied views on the growth of renovation projects, traditional Design–Bid–Build delivery, and conventional on-site construction methods. These three types were also generally perceived to have weak correlation with BIM application. Regional comparison further conveyed information on differences in perceptions among survey respondents from these three cities. For example, respondents from Wenzhou perceived more positive effects of BIM use in conventional construction projects. This research addressed the inter-correlation among these emerging sustainable construction practices, as well as the regional differences in China's construction market. The findings provide insights and the big picture for both governmental authorities and industry practitioners on the latest sustainable practices of China's construction industry. Recommendations are also offered towards improved economic, social and environmental sustainability performance for construction projects in the country.

Keywords: sustainability; building information modelling; contemporary construction; design–build; retrofitting projects; public–private partnership; prefabrication; green building

1. Introduction

Some new practices, such as building information modeling (BIM), prefabrication construction, green building, and integrated project delivery methods are more emphasized in the construction industry across the globe and China is no exception [1]. These practices are proposed to enhance the overall sustainability of China's construction industry. Their developments in different provinces/cities in China are, however, unbalanced. For instance, and as indicated by Jin et al. [2], China has its own regional differences in BIM practice due to its large geographical spread. These metropolitan cities or regions were identified by Jin et al. [3] as the main BIM-leading geographical parts in China, including Shanghai and Canton (where Guangzhou is the capital city). BIM in Wenzhou, a third-tier metropolitan city in China, is less developed. On the other hand, 30% of new buildings should be delivered prefabricated for municipalities/provinces such as Beijing, Jiangsu, Zhejiang, Jiangxi, Shandong, Hunan, Sichuan, etc. by 2020. For western regions in China such as Qinghai province and the Ningxia Hui Autonomous Region, the target is set at 10%. Regional disparity also exists regarding the development of green building in China—while a total of 487 projects with the green building label are delivering or have been delivered in Jiangsu province, the number of sustainable projects in the Xinjiang Uygur Autonomous Region is only seven up to now [4–6].

This study was therefore carried out to comprehensively compare the movements of contemporary construction practices in various regions of China. The perceptions of industry professionals towards BIM's impacts on other contemporary construction practices were also explored. As a result, three representative cities (Shanghai, Guangzhou, and Wenzhou) were selected and a questionnaire survey conducted involving experienced practitioners. The research findings are expected to benefit both the construction industry and the government at large for successful implementation of the latest practices locally and internationally.

2. Literature Review

2.1. The BIM Concept and its Movement in China

BIM is one of the most promising developments that allow the creation of one or more accurate virtual digitally-constructed models of a building to support design, construction, fabrication, and procurement activities through which the building is realized [7]. As a global movement of digital technology in the construction industry, BIM has been defined by multiple institutions. For example, NBIMS (National BIM Standards) [8] defined BIM as a digital representation of physical and functional characteristics of a facility. It creates a shared information and knowledge resource and forms a reliable basis for decisions during its life cycle [8].Similarly, the BIM Task Group [9] and HKIBIM (Hong Kong Institute of Building Information Modelling) [10] also assigned the features of information and data sharing to BIM during the asset life cycle. The collaborational nature of BIM adoption was also emphasized by the BIM Task Group [9]. The information or data in the BIM platform includes building geometry, spatial relationships, geographic information, and quantities and properties of building components [10,11].

Through a comprehensive literature review, Li et al. [12] listed three interconnected items that a holistic BIM concept should cover, namely the model product, modeling process and model application. The advantages of BIM include but are not limited to reduced errors and omissions, collaboration between different project stakeholders, an enhanced organizational image and improved visualization; they have been widely acknowledged by practitioners and academics [13,14]. This led to rapid development of this revolutionary technique in the architecture, engineering and construction (AEC) industries across the globe and in China [15,16].

The government has a dominating role in China's building sector [17]. With the support of governments at various levels, BIM application has been vigorously promoted in China since 2002. At the national level, the Ministry of Housing and Urban–Rural Development of the People's Republic of China (MOHURD) has issued several BIM-related policies since 2011 to guide its further development. These include “the development outline of construction industry informationization during 2011 and 2015” (released in 2011), “suggestions for promoting the development and reformation of the construction industry” (released in 2014), “instructions for promoting BIM application” (released in 2015), “the development outline of construction industry informationization during 2016 and 2020” (released in 2016), etc. At the local level, in Guangdong Province for instance, BIM implementation will be required for all projects with a building area of more than 20,000 m^2 by the end of 2020 [18].

It is widely believed that the popularization of BIM should have a positive influence on the whole construction sector’s sustainability [19]. Marius et al. [20] suggested that BIM promotes sustainability in three classical dimensions including environmental, economic and social sustainability. Wong and Zhou [21], on other hand, emphasized the role of BIM in enhancing environmental sustainability over building life cycles. Although the commitment of the Chinese construction industry to the application of BIM is strong, its practical use in the country is still in the infancy stages [22]. Li et al. [12] identified various barriers to BIM development in China including lack of understanding of the concept, lack of owners’ demand, lack of experienced BIM professionals, high costs of education and training, high costs of hardware and software, lack of applicability and practicability regarding the BIM software, fragmented opinions on cost–benefit analysis of implementing BIM, increased workload and decreased efficiency, lack of standards, codes and regulations, insufficient information sharing, insufficient government lead/direction and resistance to change of culture/thinking mode. Recommendations for improving BIM practices in China were also proposed in terms of drive for adoption, the traditional culture and talent cultivation [12].

2.2. Other Contemporary Construction Practices

Besides BIM, other construction practices are experiencing an increase in their application in the international construction industry and these include prefabricated construction, public–private partnership (PPP), design–build (DB) and green building [23–31]. Klotz [32] describes prefabrication as: “... the manufacturing of parts of a building in a factory before being brought to the site for incorporation in the finished structure. Industrialized buildings have as many prefabricated parts as possible” [33].MHC (McGraw Hill Construction) [34] identified the most important driver to promote prefabrication is its ability to improve the overall productivity. Wong et al. [35], based on an empirical analysis, listed the pros of prefabrication in reducing waste and fostering the use of more environmentally-friendly construction materials. On the other hand, Afzal et al. [36] confirmed the positive impacts of implementing prefabrication techniques on the achievement of project sustainable goals from an economic perspective. Nevertheless, obstacles still exist that hinder its more extensive use. These obstacles, according to Liu et al. [37], include insufficient capital investment and lack of standardized processes. Qi and Zhang [38] further offered recommendations for the development of prefabricated construction in China regarding government policy, systematized techniques, stakeholder coordination, economic costs, etc.

Grimsey and Lewis [39] defined public–private partnerships (PPPs) as agreements where the public sector bodies enter into long-term contractual agreements with private sector entities for the construction or management of public sector infrastructure facilities or the provision of services (using infrastructure facilities) by the private sector to the community on behalf of the public sector. Dexter [40] considered it as a generic term used to describe partnerships, which involve more flexible methods of financing and operating facilities and/or services. In most cases, PPP shave been successful to deliver timely, in-budget, and good quality outcomes [41]. Despite the overall uptake of PPP projects in China, weaknesses and threats still exist. According to Li [42], these weaknesses include rather complicated approval procedures, long decision periods, difficulties in coordinating multiple stakeholders involved, lack of relevant laws, regulations and risk distribution mechanisms, trust issues, and inconsistent profits.

Design–Build (DB) is a project delivery method in which the client procures one entity (i.e., a DB firm) to perform both the design and construction of a project [43]. By applying the DB delivery method, the project schedule, quality and cost could be better controlled [44]. Despite the advantages of DB, Zhang and Wang [45] listed some risks from the perspective of the project owner including the relatively lower design and/or build quality, inappropriate project total costs, inadequate construction standards and more project changes.

Olubunmi et al. [46] defined green building as "the practice of using structures and processes that are responsible and resource-efficient throughout a building's life-cycle crossing design, construction, operation, maintenance, and renovation". Issues including energy consumption and air and environmental pollution in the construction industry have raised wide concerns from the government and the public [47]. However, the green building performance during their operation phase is far from being satisfactory [48]. To cope with this, Li et al. [5] suggested seeking more input from various stakeholders during the decision/evaluation process. Li et al. [6] quantified the influencing levels of various stakeholders in decisions/evaluations related to sustainable construction in China. These stakeholder groups included government organizations, owners, end-users, material/technology providers, contractors, designers and non-governmental organizations.

2.3. Interrelationships among Contemporary Construction Practices

BIM enables processing and management in off-site prefabrication and merging discipline-specific models [49]; it not only brings technical benefits to the development process, but also delivers an innovative and integrated working platform to improve productivity and sustainability throughout the project life cycle [50]. Prefabrication fosters sustainable construction by reducing construction waste and encouraging proactive planning for greener designs [51]. Dai [52] identified the values of BIM application in prefabricated construction as improving the design efficiency, decreasing the design errors, facilitating the components tandardized design and optimizing the component production procedure. Li and Zhang [53] and Guo [54], on the other hand, advocated the use of BIM throughout the lifecycle of PPP projects and green buildings. The potential application areas in the periods of decision-making, design, construction, operation and demolition were revealed respectively. Despite this, Wu [55] believed the mode of DB matches promotes BIM implementation through deeper sharing of relevant information. The contractors' BIM capability undoubtedly becomes the most important element ensuring project success.

3. Methodology

This comparative study of contemporary construction practice in China recruited three metropolitan cities in China (Shanghai, Guangzhou, and Wenzhou, which have respectively representative market economics and construction achievement with different sizes and areas) as case studies. Questionnaire surveys were conducted in these three cities during the same period between July and August 2017. Multiple statistical methods were performed to analyze the survey responses.

3.1. Questionnaire Survey

As suggested by Jin et al. [28,29], the questionnaire survey approach was selected based on the facts that: (1) it enabled a quantitative analysis and allowed the cross-city comparison among the three case study cities; (2) it provided a standardized tool that future studies can be built upon and in return offer a higher degree of validity and reliability of the current study. Two major types of questions were designed in the questionnaire, including multiple-choice and Likert-scale questions. The multiple-choice questions aimed to collect background information on AEC survey participants, including their employer type (i.e., contractor, engineering design), as well as their professions (i.e., architect, engineer, or construction management). Two Likert-scale questions were asked. The first Likert-scale question targeted AEC professionals' perceptions of the development/advancement/uptake of different construction practices in their home cities, including four first-level factors and nine second-level sub-factors, such as (1) type of construction (i.e., new construction, renovation projects); (2) procurement methods (i.e., DBB projects, DB, PPP); and (3) construction methods (i.e., prefabricated construction, conventional on-site construction); as well as (4) emerging practices (i.e., green building, BIM application). Survey participants were given the numerical options with *1* meaning that the given item of a project type would be reduced in the next five years, *2* indicating "remaining the same", *3* inferring "low but steady rate of growth", *4* being "a moderate rate of growth", and *5* indicating "a significant growth". The second Likert-scale question focused on professionals' perceptions of BIM's overall impact on the performance of these aforementioned project types. Participants were also given the Likert-scale options, with *1* meaning that BIM had a significant negative effect in the given type of project, *2* indicating "little negative effect", *3* inferring "limited positive effect", *4* having "certain positive effect", and *5* indicating "very positive effect". In both Likert-scale questions, an extra option *6* was also allowed for these who were unsure of the answer to the question given the type of the project. Details of the questions can be found in Appendix A.

Following the sampling procedure described by Xu et al. (2018), the sampling strategy in this research leaned towards purposive sampling, but without intending to construct the sample size to ensure a more desirable outcome. Therefore, as the samples were picked up in specialized events or workshops in the three cities where AEC professionals were expected to attend, the sampling was not stratified any further. The questionnaire was designed in May 2017 and peer-reviewed by local AEC industry professionals in China in June 2017. The procedure of data collection was consistent by following the approach described by Cao et al. [56]. From July to August 2017, the research team members delivered the anonymous questionnaires in Shanghai, Guangzhou, and Wenzhou through local construction industry networking events such as workshops and seminars. Research team members also visited local major AEC firms or organizations that were known to have actively implemented or promoted BIM practice. Questionnaires were also delivered during these visits.

3.2. Statistical Analyses

Following the questionnaire delivery and survey data collection, a few major types of statistical methods were adopted for the regional comparison, including basic statistics (i.e., mean and standard deviation for Likert-scale items), the relative importance index(*RII*) analysis, internal consistency analysis involving Cronbach's Alpha, and the one-way analysis of variance (ANOVA).

- The *RII* has been applied in multiple studies in the field of construction engineering and management, such as Tam [57] and Jin et al. [16], to rank multiple Likert-scale items within each question. *RII* values range from *0* to *1*, and can be calculated according to Equation (1):

$$RII = \frac{\sum \omega}{A \times N} \tag{1}$$

  where w denotes the score from *1* to *5* selected by each respondent, A is the highest possible score (i.e., *5* in this case), and N denotes the number of responses.
- The internal consistency was measured by Cronbach's Alpha value [58]. Ranging from *0* to *1*, a higher Cronbach's Alpha value means that a survey participant who has chosen one numerical score to one item is likely to select a similar score to others within the same Likert-scale question. An overall Cronbach's Alpha value from *0.70* to *0.95* is considered acceptable with high internal interrelatedness [59]. Besides the overall value, there is an individual value associated with each individual Likert-scale item. An individual value is generally lower than the overall one, meaning that this given item contributes positively to the overall internal consistency. Otherwise, an individual Cronbach's Alpha value higher than the overall value would mean that survey participants have differed views on this item as they normally do to the remaining items in the same Likert-scale question. Corresponding to each individual Cronbach's Alpha value, there is

also an item–total correlation, which shows the correlational relationship between this given item and the rest of the items.

- ANOVA was applied in this study to compare these two Likert-scale questions among survey participants from Shanghai, Guangzhou, and Wenzhou. ANOVA is one of the parametric methods, which have been widely applied in empirical studies within construction, engineering and management (i.e., Aksorn and Hadikusumo [60]; Meliá et al. [61]). Before conducting the ANOVA, the Test for Equal Variances adopting Levene's Test was applied to each given Likert-scale item. Based on the level of significance at 5%, it was confirmed that all Likert-scale items from the three different metropolitan cities had consistent variances. The null hypothesis in ANOVA was that AEC professionals from Shanghai, Guangzhou, and Wenzhou held consistent perceptions towards the given Likert-scale item. The A*F* value and a corresponding p value were computed. Based on the *5%* level of significance, a p value lower than *0.05* would reject the null hypothesis and further suggest that there are significant differences in perceptions among survey participants from these three cities towards the given item.

4. Results

By the end of December 2017, *161* totally valid responses were received from the three regions. Among them, *64*, *49* and *48* responses were from Shanghai, Guangzhou, and Wenzhou, respectively. The survey population was studied for their professional background and their perceptions of contemporary construction practices in China. Regional comparisons of perceptions among the three metropolitan cities were also made.

4.1. Professional Background of Survey Participants

The professional background of the survey population is summarized in Figure 1, according to their employer type and professions.

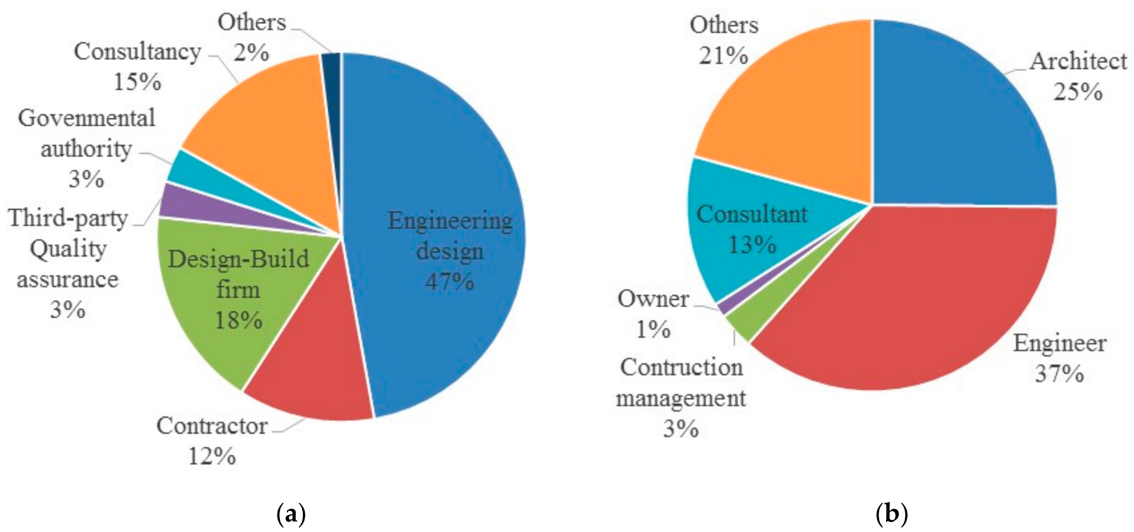

Figure 1. Professional background of survey respondents. (**a**) Employer types of survey participants; (**b**) Professions of survey participants.

Other employer types in Figure 1 mainly included the owner representative and research institutions. Engineers in the survey sample covered multiple disciplines, including structural engineers, building services engineers, and civil engineers. Other job titles included BIM manager, BIM engineer, curtain wall designer, cost engineer, government employee in the construction sector, research fellow, business developer, construction software developer, and engineering document archivist. It can be seen in Figure 1 that nearly half of respondents came from engineering design firms, followed by Design–Build firms. Architects and engineers accounted for the majority of the professions in the survey population. Contractor and construction management professions contributed to a minority of the survey sample.

4.2. Overall Sample Analysis

An overall sample analysis was performed to investigate respondents' perceptions towards the movement of contemporary construction practices as well as the traditional DBB projects and projects built with conventional construction approaches (i.e., site-cast concrete). Statistical analysis in terms of mean Likert-scale score, standard deviation, *RII* values with rankings, and internal consistency analysis are presented in Table 1.

Table 1. Overall sample analysis of survey participants' perceptions on the movement of contemporary construction practices (Overall Cronbach's Alpha = *0.7668*).

Category	Construction Practice	Mean	Std	*RII*	Ranking	Item-Total Correlation	Cronbach's Alpha
Type of construction	New construction	3.777	1.080	0.755	6	0.6049	0.7176
	Renovation of existing buildings	3.313	1.074	0.663	7	0.0959	0.8019
Procurement methods	Design–bid–build projects	2.723	1.117	0.545	9	0.2520	0.7798
	Design–build projects	4.214	0.753	0.843	1	0.5872	0.7298
	PPP projects	4.107	0.863	0.821	5	0.6257	0.7201
Construction methods	Conventional construction methods (i.e., site-cast concrete)	2.866	1.086	0.573	8	0.3654	0.7599
	Prefabrication construction	4.179	0.872	0.836	2	0.5700	0.7279
Emerging practices	Green building	4.125	0.807	0.825	4	0.5624	0.7309
	Projects involving BIM application	4.143	0.815	0.829	3	0.6045	0.7250

Std stands for standard deviation. *RII* stands for relative importance index. The same abbreviations apply to all other tables.

Both mean scores, *RII*, and rankings showed that survey participants believed that the traditional DBB and conventional construction methods would be in lower growth or remain unchanged in the next five years, followed by renovation projects, which were believed to grow at a low rate. Five contemporary practices were believed to grow at a high rate, namely DB projects, prefabrication construction, projects with BIM application, green building, and PPP projects. These five contemporary practices also received lower standard deviations, indicating that respondents held more consistent expectations on their growth in China's construction market. In contrast, respondents seemed to have more variation in their views of new construction, renovation, and DBB projects. The Overall Cronbach's Alpha value at *0.7668* suggests a general internal consistency among items, meaning that a respondent who selected a Likert-scale score to one item in Table 1 would be likely to assign a similar score to the remaining items, except the two items related to renovation and DBB projects. The low item-total correlations and higher individual Cronbach's Alpha values suggest that respondents had different views on these two types of projects. Specifically, they believed that renovation and DBB projects would not undergo high increases in China's future market.

The second question asked survey participants to focus on their perceptions of BIM effects in these construction practices covered in Table 1. The overall sample analysis is summarized in Table 2.

Somewhat similar to the ranking listed in Table 1, these three types of construction practices were ranked lowest in Table 2: renovation, DBB, and conventional projects. The variation of respondents' on DBB projects was also the highest among the eight items. These five types of construction projects were perceived as receiving higher impacts from BIM: DB projects, prefabrication, PPP, new construction, and green building. The Overall Cronbach's Alpha value at *0.8374* showed a higher internal consistency compared to that in Table 1. All individual Cronbach's Alpha values were lower than the overall value, inferring that survey participants had generally consistent perceptions of BIM's effect in all construction practices listed in Table 2.

Based on Tables 1 and 2, the correlation coefficient analysis between the expected growth of BIM applications and the perceived growth of other construction practices were further performed. Table 3 displays the Pearson correlation coefficients (*r*) and corresponding *p* values for the overall sample and the three subsamples from Shanghai, Guangzhou, and Wenzhou.

Table 2. Overall sample analysis of survey participants' perceptions on BIM's effect in contemporary construction practices (Overall Cronbach's Alpha = *0.8374*).

Category	Construction Practice	Mean	Std	*RII*	Ranking	Item-Total Correlation	Cronbach's Alpha
Type of construction	New construction	4.081	0.822	0.816	4	0.6310	0.8101
	Renovation of existing buildings	3.126	0.885	0.625	8	0.4921	0.8285
Procurement methods	Design–bid–build projects	3.288	0.938	0.658	6	0.5669	0.8190
	Design–build projects	4.315	0.713	0.863	1	0.6531	0.8098
	PPP projects	4.117	0.882	0.823	3	0.6744	0.8036
Construction methods	Conventional construction method (i.e., site-cast concrete)	3.288	0.857	0.658	6	0.4442	0.8341
	Prefabrication construction	4.270	0.808	0.854	2	0.5813	0.8166
Emerging practices	Green building	4.063	0.789	0.813	5	0.5231	0.8237

Table 3. Correlation analysis between BIM and other contemporary construction practices.

Category	Construction Practice	Projects Involving BIM Application							
		Overall		Shanghai		Guangzhou		Wenzhou	
		r	*p* Value	*r*	*p* Value	*r*	*p* Value	*r*	*p* Value
Type of construction	New construction	0.357	0.000	0.355	0.006	0.457	0.002	0.200	0.205
	Renovation of existing buildings	0.142	0.095	0.155	0.249	0.110	0.484	0.279	0.085
Procurement methods	Design–bid–build projects	0.040	0.640	0.078	0.567	−0.060	0.703	0.120	0.460
	Design–build projects	0.560	0.000	0.504	0.000	0.820	0.000	0.376	0.014
	PPP projects	0.427	0.000	0.390	0.009	0.419	0.006	0.526	0.001
Construction methods	Conventional construction method	0.172	0.043	0.273	0.036	0.030	0.847	0.105	0.528
	Prefabrication construction	0.603	0.000	0.610	0.000	0.526	0.000	0.669	0.000
Emerging practices	Green building	0.547	0.000	0.454	0.000	0.643	0.000	0.621	0.000

r represents Pearson's correlation coefficient between the expected growth of BIM and the remaining individual construction practices. *A p* value lower than *0.05* indicates a significant relationship between BIM and the given contemporary construction practice.

Consistent with the findings from Table 2, respondents' expectations of BIM application were highly correlated to most other contemporary construction practices. Renovation and DBB projects were the two practices that were found with no significant correlations to BIM application, according to both the overall sample analysis and the three different subsample analyses. Tables 2 and 3 indicate that respondents did not perceive that BIM application would have major impacts on renovation or DBB projects, and they believed that the growth of BIM in the construction industry did not have a causal relationship with the growth of renovation or DBB projects. Besides these two practices, conventional construction methods were also perceived to have a weak correlation with BIM according to the respondents from both the Guangzhou and Wenzhou regions. It is inferred from Table 3 that regional differences might exist in perceiving the relationship between BIM and construction practices (i.e., conventional construction methods). The regional analysis was then further analyzed among the three metropolitan cities.

4.3. Subgroup Analysis of Expected Growth of Contemporary Industry Practices

Regional comparisons among Shanghai, Guangzhou, and Wenzhou were conducted in terms of internal consistency and an ANOVA of perceived growths of construction practices are listed in Tables 4 and 5.

Table 4. Comparison of internal consistency among Shanghai, Guangzhou, and Wenzhou regarding the question of expected growth of multiple construction practices.

Category	Construction Practice	Shanghai (Overall CA = 0.8356)		Guangzhou (Overall CA = 0.7116)		Wenzhou (Overall CA = 0.7438)	
		ITC	CA	ITC	CA	ITC	CA
Type of construction	New construction	0.6925	0.8006	0.6718	0.6369	0.4711	0.7115
	Renovation of existing buildings	**0.2755**	**0.8498**	**−0.1473**	**0.7855**	**0.2390**	**0.7562**
Procurement methods	Design–bid–build projects	**0.3614**	**0.8404**	**0.1851**	**0.7389**	**0.2023**	**0.7615**
	Design–build projects	0.7352	0.8053	0.5482	0.6622	0.4584	0.7161
	PPP projects	0.6120	0.8116	0.6373	0.6405	0.6441	0.6887
Construction methods	Conventional construction method (i.e., site-cast concrete)	0.6006	0.8127	**0.2406**	**0.7152**	**0.2078**	**0.7607**
	Prefabrication construction	0.6856	0.8050	0.4741	0.6705	0.5546	0.7004
Emerging practices	Green building	0.5068	0.8247	0.6741	0.6340	0.6132	0.6918
	Projects involving BIM application	0.6214	0.8120	0.5658	0.6575	0.6428	0.6886

ITC stands for Item-Total Correlation. CA stands forCronbach's Alpha. Bolded CA and corresponding ITC indicate that survey participants held more differed views towards the given item compared to how they perceive other items.

According to Table 4, Shanghai respondents had the highest degree of internal consistency, meaning that a survey participant in Shanghai was more likely to assign a similar Likert-scale score to the items in Table 4 compared to their counterparts from Guangzhou and Wenzhou, where the Overall Cronbach's Alpha values were lower. Consistently among the three subgroups, survey participants tended to have different views on the growth of renovation and DBB projects compared to the remaining construction practices. Similarly to the correlation analysis results in Table 3, Guangzhou and Wenzhou participants also held differed views on the growth of conventional construction as they did to the remaining items in Table 4.

Table 5. ANOVA results for subgroup analysis of survey participants divided by regions in response to the question of expected growth of contemporary construction practices.

Category	Construction Practice	Shanghai		Guangzhou		Wenzhou		Statistical Comparison	
		Mean	Std	Mean	Std	Mean	Std	*F* Value	*p* Value
Type of construction	New construction	3.475	1.281	4.105	0.863	3.765	0.955	4.30	0.015 *
	Renovation of existing buildings	3.575	1.059	3.000	1.065	3.353	1.041	2.39	0.095
Procurement methods	Design–bid–build projects	2.725	1.062	2.684	1.276	2.765	1.017	2.12	0.124
	Design–build projects	4.200	0.723	4.184	0.801	4.265	0.751	0.18	0.837
	PPP projects	4.100	0.928	4.132	0.906	4.088	0.753	0.11	0.893
Construction methods	Conventional construction method	2.675	1.163	2.816	1.036	3.147	1.019	5.92	0.003 *
	Prefabrication construction	4.250	0.870	4.289	0.927	3.971	0.797	2.51	0.084
Emerging practices	Green building	4.200	0.687	4.289	0.898	3.853	0.784	2.40	0.094
	Projects involving BIM application	4.100	0.841	4.289	0.835	4.029	0.758	1.15	0.319

* A p value lower than *0.05* indicates significant differences in perceptions among respondents from Shanghai, Guangzhou, and Wenzhou.

Subgroup analysis for participants divided by regions by ANOVA revealed that Guangzhou participants expected more new construction projects in the near future compared to their peers from Shanghai and Wenzhou. Participants from Wenzhou, which represented the third-tier city with less developed BIM practices according to Xu et al. [62], believed in a higher growth of conventional construction in the following years.

4.4. Subgroup Analysis of Perceptions of BIM Effects in Other Contemporary Construction Practices

Regional comparisons were also conducted for the question regarding the BIM effects in contemporary construction practices. Tables 6 and 7 display the internal consistency analysis and ANOVA, respectively.

Table 6. Comparison of internal consistency among Shanghai, Guangzhou, and Wenzhou in response to the question of BIM effects.

Category	Construction Practice	Shanghai (Overall CA = 0.8587)		Guangzhou (Overall CA = 0.8443)		Wenzhou (Overall CA = 0.8233)	
		ITC	CA	ITC	CA	ITC	CA
Type of construction	New construction	0.6802	0.8343	0.7802	0.8029	**0.4275**	**0.8269**
	Renovation of existing buildings	0.6012	0.8429	**0.3442**	**0.8512**	0.5959	0.7960
Procurement methods	Design–bid–build projects	0.6318	0.8383	0.5222	0.8348	0.6370	0.7891
	Design–build projects	0.7486	0.8312	0.6445	0.8181	0.5573	0.8029
	PPP projects	0.6956	0.8301	0.6654	0.8143	0.6999	0.7838
Construction methods	Conventional construction method	**0.4015**	**0.8659**	0.5349	0.8310	0.4894	0.8114
	Prefabrication construction	0.6115	0.8408	0.6332	0.8206	0.6247	0.7963
Emerging practices	Green building	0.5582	0.8476	0.5650	0.8301	0.4681	0.8151

Although all the three subgroups in Table 6 had high Cronbach's Alpha values, indicating high internal consistencies, each subgroup had one individual Cronbach's value higher than its overall value. Differently among the three subgroups, Shanghai participants had different views on conventional methods as they did to other items in Table 6, Guangzhou peers had different perceptions in renovation projects, and Wenzhou respondents held different perceptions of the items related to new construction. Further ANOVA analyses in Table 7 display the regional comparison of perceptions towards BIM effects in these construction practices.

Table 7. ANOVA results for subgroup analysis of survey participants divided by regions in response to the question of expectations of BIM effects in other contemporary construction practices.

Category	Construction Practice	Shanghai		Guangzhou		Wenzhou		Statistical Comparison	
		Mean	Std	Mean	Std	Mean	Std	*F* Value	*p* Value
Type of construction	New construction	4.150	0.770	4.100	0.778	3.968	0.948	0.39	0.676
	Renovation of existing buildings	3.300	0.992	3.075	0.764	2.968	0.875	0.35	0.704
Type of constructionProcurement methods	Design–bid–build projects	3.475	0.933	3.125	0.992	3.258	0.855	0.36	0.696
	Design–build projects	4.225	0.660	4.475	0.816	4.226	0.617	1.49	0.229
	PPP projects	3.950	0.986	4.275	0.905	4.129	0.670	0.91	0.407
Construction methods	Conventional construction method	3.250	0.927	3.150	0.802	3.516	0.811	4.60	0.012 *
	Prefabricated construction	3.975	0.920	4.550	0.749	4.290	0.588	6.68	0.002 *
Emerging practices	Green building	4.125	0.686	4.075	1.047	3.968	0.482	0.45	0.638

* A p value lower than *0.05* indicates the significant differences in perceptions among respondents from Shanghai, Guangzhou, and Wenzhou.

It can be found from Table 7 that compared to Shanghai and Guangzhou participants, Wenzhou respondents held a more positive perception of BIM impacts on conventional construction. Prefabrication construction was perceived by participants with high correlation to BIM. Guangzhou and Wenzhou respondents held even more positive views on BIM's effect on prefabrication as their Shanghai counterparts did.

5. Discussion

This study serves as an extension of Jin et al. [2], who addressed the regional difference of BIM practice in China. Multiple contemporary construction issues (i.e., green building, PPP, and integrated design and construction) were brought together to find out their movement and inter-relationships with BIM. More conventional practices, including DBB, and on-site conventional construction methods were also adopted as comparisons to these contemporary practices. According to BIM Talk [63], there are four main BIM maturity levels, from Level 0 meaning unmanaged data exchange in 2D CAD (two-dimensional computer-aided design), Level 1 with little integration of 2D or 3D common data environment, Level 2 with enhanced 3D, 4D, or 5D data integration, to Level 3 representing a fully integrated and collaborative data environment. The UK government expected the industry to achieve Level 2 by 2016 [64], and more recently, the UK Government's Department for Business, Innovation and Skills [65] has launched the Digital Built Britain program focusing on the development of BIM Level 3. Following the UK's strategic movement of BIM, China has also been setting up its national guidelines and policies in promoting BIM usage across the AEC industry. However, due to its large geographic coverage, China has its own regional differences in BIM implementation levels [2]. Shanghai in this case study represents a forerunner in China's BIM practice, while Wenzhou represent a less BIM-mature metropolitan city [62].

The overall survey sample from these three cities covered participants from engineering design, contractor, design–build firms, consultancy, and other backgrounds (i.e., third-party assurance). The majority of survey participants worked as architects, engineers, and consultants. Other job titles included BIM manager, BIM engineer, government employees, etc. Statistical methods were firstly applied in the overall sample analysis.

MarketLine [66] expected that China, the huge AEC market accounting for nearly half of Asia–Pacific industry revenue, would continue the growth of its construction industry in the years to come. This growth would depend on the type of construction projects, according to the project delivery (i.e., DB or DBB), construction techniques (i.e., on-site or off-site construction), and other factors (i.e., green building). It was perceived that DBB and conventional construction (i.e., on-site construction) would undergo little growth in the next five years. The overall sample's perceptions of renovation projects and DBB tended to be different, as were their opinions on other project types. Renovation projects are still in the early stage in China's construction industry, as China has been creating more new construction projects than renovation of existing buildings. However, as existing buildings age and are in need of repair and improvement, renovation is expected to gain a certain degree of growth in China. According to the survey, AEC professionals held a somewhat neutral perception of growth of this industry sector in the next five years. Also, the relatively high standard deviation indicates that they had somewhat varied perceptions towards the development of future trends of renovation projects.

Similar to the overall sample analysis of the expected movement of different types of construction projects, three types of projects (renovation, DBB, and conventional site-cast construction) were perceived with the lowest degree of positive interactions with BIM. It was stated by Eastman et al. [67] that BIM, sustainability, and prefabricated construction are inherently connected. Generally consistent to the statement, survey participants believed that BIM had the highest positive impact on prefabricated construction and green building, especially the former. DB was the type of project that was believed by participants to receive the highest positive impact from BIM. PPP was also believed to have a positive interaction with BIM, although there have been limited studies on applying BIM in PPP projects so far (i.e., Ren and Li [68]). Further correlation analysis showed that BIM applications were found to have significant correlation with most contemporary practices (i.e., DB, PPP, green building, and prefabricated construction). In contrast, DBB and conventional construction methods (i.e., site-cast concrete) were found to have little correlation to BIM application.

Regional analysis revealed that Shanghai respondents held a higher degree of internal consistency over their expected growth of these different project types. Generally, participants from all three cities perceived DBB projects differently as they did other project types. Conventional site-cast construction was also viewed as a differed project type by Guangzhou and Wenzhou participants as they would view other types of projects. The ANOVA analysis revealed that Guangzhou participants expected higher growth in new construction projects in the next five years. Participants from Wenzhou, which represented less BIM practices [62] and was the region with least-developed contemporary construction practice, believed that there would be a higher growth of conventional construction compared to what Shanghai and Guangzhou participants perceived the condition to be in their home cities. It was inferred that the less-developed regions or cities in China tended to rely more on conventional construction approaches (i.e., site-cast concrete).

Participants from each of the three cities were found to have high internal consistency for the question of BIM effect on other project types. However, participants from each city held varied views on certain project types. For example, Shanghai participants perceived a lower positive impact of BIM on conventional construction approaches as compared to other project types, while Guangzhou participants viewed BIM with less positive effects in renovation projects compared to others. The ANOVA analysis revealed that participants from these three cities held significantly different perceptions of BIM impact on conventional construction methods and prefabricated construction. As an extension of the finding from the first question regarding the movement of different types of projects, Wenzhou participants perceived a higher positive impact of BIM on conventional construction.

6. Conclusions

This comparative study adopted Shanghai, Guangzhou, and Wenzhou as case studies to reflect the current stage of construction industry sustainable practices (i.e., BIM, prefabrication construction, green building, and integrated project delivery) in China. The rationale behind selecting these three metropolitan cities was based on the fact that they had been recognized as representing different development levels of contemporary construction practice.

The overall sample analysis revealed that survey participants had lower expectations on the growth of traditional design–bid–build projects and projects using the conventional construction method. They also held varied and neutral perceptions towards renovation projects. These three types of projects (i.e., design–bid–build, conventional site-cast, and renovation) were believed to be impacted the lowest by BIM. In contrast, the most positive BIM impact was believed to be on prefabrication and design–build. BIM was perceived to have significant correlations with most of the contemporary construction practices in China, including prefabricated construction, design–build project delivery, green building, and PPP projects. In contrast, weak relationships were found between BIM application and traditional project delivery methods (i.e., design–bid–build) and conventional construction methods (i.e., site-cast concrete).

Subgroup comparison for AEC professionals from these three different cities showed somewhat different perceptions among them. For example, professionals from Wenzhou, which represented a less-developed economy compared to Shanghai and Guangzhou, believed that conventional site-cast construction would gain a higher degree of growth in the next five years. Wenzhou participants also believed that there would be a higher impact of BIM on conventional construction. This could be due to the fact that compared to Shanghai and Guangzhou, Wenzhou was a less developed city in terms of the overall economy and contemporary construction practice. Industry professionals working in Wenzhou perceived a higher reliance on conventional construction.

This research contributes to the body of knowledge within contemporary sustainable issues in the construction industry worldwide by linking multiple recent construction practices to each other, including BIM, prefabricated construction, PPP, and green building. It drives more qualitative and quantitative studies on how these contemporary sustainable practices can assist each other in delivering better project performance, i.e., the integration between BIM and off-site construction. This study was based on the perceptions of industry and government professionals regarding the movement of contemporary construction practices and how they would be impacted by BIM. More empirical data (i.e., the growth of prefabricated construction projects) within the next five years could be collected and compared with practitioners' perceptions. Future research would also involve more project-based case studies to evaluate the impact of BIM on the performance of different types of projects (i.e., design–build or prefabricated construction), as well as the advanced sustainable practice application in the industry, such as blockchain technology proposed by Wang et al. [69].

Author Contributions: Conceptualization, R.J.; Investigation, L.M., Y.L., H.L., R.J., P.P. and M.L.; Supervision, Y.L.; Writing—original draft, L.M., Y.L., H.L., R.J., P.P. and M.L.

Acknowledgments: This work was supported by the National Natural Science Foundation of China (Grant No. 71390523, 71501074), the State Key Lab of Subtropical Building Science, South China University of Technology, China (Grant No. 2016ZB16), Major Project of Shanghai Municipal People's Government Decision-Making Research (Grant Numbers: 2017-A-046) and Shanghai Pujiang Program (Grant Number: 16PJ1432400). The authors would also like to acknowledge the Writing Retreat Fund provided by University of Brighton, UK.

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

Appendix A

1. Your organization or employer type: (single choice): A. Engineering design; B. Contractor; C. Design-Build firm; D. Consultancy; E. Governmental authority; F. Third Party quality assurance; G. Other, please specify_______________
2. Your profession (single choice): A. Engineer; B. Construction management; C. Architect; D. Consultant; E. Owner; F. Other, please specify_______________
3. Please select a numerical option representing your perceptions on the expected growth of each of the following types of construction project.

   Note: 1 means that the given item of project type would be reduced in the next five years, 2 indicates "remaining the same", 3 infers "low but steady rate of growth", 4 is "a moderate rate of growth", 5 indicates "a significant growth", and 6 means that you are unsure of the answer.

Category	Construction Practice	1	2	3	4	5	6
Type of construction	New construction						
	Renovation of existing buildings						
Procurement methods	Design–bid–build projects						
	Design–build projects						
	PPP projects						
Construction methods	Conventional construction method						
	Prefabricated construction						
Emerging practices	Green building						
	Projects involving the BIM application						

4. Please choose a numerical value to indicate the effects of BIM on each of the following types of construction practices.

Note: 1 means that BIM has a significant negative effect in the given type of project, 2 indicates "little negative effect", 3 infers "limited positive effect", 4 means BIM has "certain positive effect" on the given type of construction practice, and 5 indicates "very positive effect". The option 6 is available if you are unsure of the answer to the given type of construction practice.

Category	Construction Practice	1	2	3	4	5	6
Type of construction	New construction						
	Renovation of existing buildings						
Procurement methods	Design–bid–build projects						
	Design–build projects						
	PPP projects						
Construction methods	Conventional construction method						
	Prefabricated construction						
Emerging practices	Green building						

References

1. Zhang, J.X.; Schmidt, K.; Li, H. BIM and Sustainability Education: Incorporating Instructional Needs into Curriculum Planning in CEM Programs Accredited by ACCE. *Sustainability* **2016**, *8*, 525. [CrossRef]
2. Jin, R.; Hancock, C.M.; Tang, L.; Wanatowski, D.; Yang, L. Investigation of BIM Investment, Returns, and Risks in China's AEC Industries. *J. Constr. Eng. Manag.* **2017**, *143*. [CrossRef]
3. Jin, R.; Tang, L.; Fang, K. Investigation into the current stage of BIM application in China's AEC industries. *WIT Trans. Built Environ.* **2015**, *149*, 493–503.
4. Green Building Map. The Ranking of Provinces Regarding the Number of Projects with Green Label. Available online: http://www.gbmap.org/top/top10-gplv.php (accessed on 17 October2018).
5. Li, H.; Ng, S.T.; Skitmore, M. Stakeholder impact analysis during post-occupancy evaluation of green buildings—A Chinese context. *Build. Environ.* **2018**, *128*, 89–95. [CrossRef]
6. Li, H.; Zhang, X.; Ng, S.T.; Skitmore, M. Quantifying stakeholder influence in decision/evaluations relating to sustainable construction in China—A Delphi approach. *J. Clean. Prod.* **2018**, *173*, 160–170. [CrossRef]
7. Eastman, C.; Teicholz, P.; Sacks, R.; Liston, K. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
8. NBIMS (National BIM Standards) Committee. *National BIM Standard: Version 2*; NBIMS: Washington, DC, USA, 2012; Available online: https://www.nationalbimstandard.org/faqs (accessed on 22 February 2018).
9. BIM (Building Information Modelling) Task Group. *What Is BIM?* BIM: Cambridge, UK, 2015. Available online: http://www.bimtaskgroup.org/bim-faqs/ (accessed on 22 February 2018).
10. HKIBIM (Hong Kong Institute of Building Information Modelling). *BIM Project Specification*; HKIBIM: Hong Kong, China, 2011.
11. Song, Y.; Tan, Y.; Song, Y.; Wu, P.; Cheng, J.C.; Kim, M.J.; Wang, X. Spatial and temporal variations of spatial population accessibility to public hospitals: A case study of rural–urban comparison. *GIsci. Remote Sens.* **2018**. [CrossRef]
12. Li, H.; Ng, S.T.T.; Skitmore, M.; Zhang, X.; Jin, Z. Barriers to building information modelling in the Chinese construction industry. *Munic. Eng.* **2017**, *170*, 105–115. [CrossRef]
13. MHC (McGraw Hill Construction). *The Business Value of BIM for Construction in Major Global Markets: How Contractors Around the World Are Driving Innovation with Building Information Modeling*; MHC: Bedford, MA, USA, 2014.
14. MHC (McGraw Hill Construction). *The Business Value of BIM for Owners*; MHC: Bedford, MA, USA, 2014.
15. Jin, R.; Hancock, C.M.; Tang, L.; Chen, C.; Wanatowski, D.; Yang, L. An empirical study of BIM-implementation-based perceptions among Chinese practitioners. *J. Manag. Eng.* **2017**, *33*. [CrossRef]
16. Jin, R.; Li, B.; Zhou, T.; Wanatowski, D.; Piroozfar, P. An empirical study of perceptions towards construction and demolition waste recycling and reuse in China. *Resour. Conserv. Recycl.* **2017**, *126*, 86–98. [CrossRef]

17. Sha, K. Professionalism in China's building sector: An economic governance perspective. *Build. Res. Inf.* **2013**, *41*, 742–751. [CrossRef]
18. DHURDGP (Department of Housing and Urban-Rural Development of Guangdong Province). *Application of BIM Technology*; DHURDGP: Guangzhou, China, 2014.
19. Wong, K.-D.; Fan, Q. Building information modelling (BIM) for sustainable building design. *Facilities* **2013**, *31*, 138–157. [CrossRef]
20. Reizgevičius, M.; Ustinovičius, L.; Cibulskienė, D.; Nazarko, V.K.L. Promoting Sustainability through Investment in Building Information Modeling (BIM) Technologies: A Design Company Perspective. *Sustainability* **2018**, *10*, 600. [CrossRef]
21. Wong, J.K.W.; Zhou, J. Enhancing environmental sustainability over building life cycles through green BIM: A review. *Autom. Constr.* **2015**, *57*, 156–165. [CrossRef]
22. DDA (Dodge Data & Analytics). *The Business Value of BIM in China*; DDA: Bedford, MA, USA, 2015.
23. Woolthuis, R.J.A.K. Sustainable entrepreneurship in the Dutch construction industry. *Sustainability* **2010**, *2*, 505–523. [CrossRef]
24. Hwang, B.G.; Shan, M.; Phua, H.; Chi, S. An exploratory analysis of risks in green residential building construction projects: The case of Singapore. *Sustainability* **2017**, *9*, 1116. [CrossRef]
25. Chan, A.P.C.; Darko, A.; Effah, E.A. Strategies for promoting green building technologies adoption in the construction industry—An international study. *Sustainability* **2017**, *9*, 969. [CrossRef]
26. Li, H.; Ding, L.; Ren, M.; Li, C.; Wang, H. Sponge city construction in China: A survey of the challenges and opportunities. *Water* **2017**, *9*, 594. [CrossRef]
27. Durdyev, S.; Zavadskas, E.K.; Thurnell, D.; Banaitis, A.; Ihtiyar, A. Sustainable construction industry in Cambodia: Awareness, drivers and barriers. *Sustainability* **2018**, *10*, 392. [CrossRef]
28. Jin, R.; Gao, S.; Cheshmehzangi, A.; Aboagye-Nimo, E. A Holistic Review of off-site Construction Literature Published between 2008 and 2018. *J. Clean. Prod.* **2018**, *202*, 1202–1219. [CrossRef]
29. Jin, R.; Zou, P.X.W.; Li, B.; Piroozfar, P.; Painting, N. Comparisons of Students' Perceptions on BIM Practice among Australia, China and U.K. *Eng. Constr. Archit. Manag.* **2018**. submitted.
30. Zhu, J.; Shi, Q.; Wu, P.; Sheng, Z.; Wang, X. Complexity Analysis of Prefabrication Contractors' Dynamic Price Competition in Mega Projects with Different Competition Strategies. *Complexity* **2018**. [CrossRef]
31. Wang, T.; Wang, J.; Wu, P.; Wang, J.; He, Q.; Wang, X. Estimating the environmental costs and benefits of demolition waste using life cycle assessment and willingness-to-pay: A case study in Shenzhen. *J. Clean. Prod.* **2018**, *172*, 14–26. [CrossRef]
32. Klotz, H. *Vision der Moderne: Das Prinzipconstruktion, Ausstellungskatalog des DeutschenArchitekturmuseums*; Prestel: Munich, Germany, 1986.
33. Piroozfar, P.; Farr, E.R.P. Evolution of Nontraditional Methods of Construction: 21st Century Pragmatic Viewpoint. *J. Architect. Eng.* **2013**, *19*, 119–133. [CrossRef]
34. MHC (McGraw Hill Construction). *Prefabrication and Modularization: Increasing Productivity in the Construction Industry*; MHC: Bedford, MA, USA, 2011.
35. Wong, P.S.P.; Kanellopoulos, M.P.; Edmonson, L. An Empirical Analysis of the Effect of Prefabrication on Fostering Sustainable Construction. In Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate; Chau, K., Chan, I., Lu, W., Webster, C., Eds.; Springer: Singapore, 2018.
36. Afzal, M.; Maqsood, S.; Yousaf, S. Performance Evaluation of Cost Saving Towards Sustainability in Traditional Construction Using Prefabrication Technique. *Int. J. Eng. Sci.* **2017**, *5*, 73–79.
37. Liu, J.E.; Liu, H.L.; Guo, Z.L. Obstacle Analysis and Solution of Application Popularization Based on AHP in Fabricated Buildings. *Value Eng.* **2018**, *37*, 31–34. (In Chinese)
38. Qi, B.K.; Zhang, Y. Prefabricated Construction Development Bottleneck and Countermeasures Research. *J. Shenyang Jianzhu Univ. (Soc. Sci.)* **2015**, *17*, 156–159. (In Chinese)
39. Grimsey, D.; Lewis, M.K. Evaluating the risks of public private partnerships for infrastructure projects. *Int. J. Proj. Manag.* **2002**, *20*, 107–118. [CrossRef]
40. Dexter, W. Private Finance Initiative and Public Private Partnerships: What future for public services. In *Public Services or Corporate Welfare: Rethinking the Nation State in the Global Economy*; Pluto Press: London, UK, 2001.

41. Leviäkangas, P.; Ye, Y.; Olatunji, O.A. Sustainable public–private partnerships: Balancing the multi-actor ecosystem and societal requirements. *Front. Eng.* **2018**, *5*, 347–356.
42. Li, Y.Y. A study of the PPP development based on SWOT analysis. *Pioneering Sci. Technol. Mon.* **2017**, *3*, 119–121. (In Chinese)
43. Bogus, S.M.; Migliaccio, G.C.; Jin, R. Study of the relationship between procurement duration and project performance in Design-Build projects: Comparison between Water/Wastewater and Transportation Sectors. *J. Manag. Eng.* **2013**, *29*, 382–391. [CrossRef]
44. Molenaar, R.K.; Songer, D.A.; Barash, M. Public-sector design/build evolution and performance. *J. Manag. Eng.* **1999**, *15*, 54–62. [CrossRef]
45. Zhang, Y.C.; Wang, Y.M. A study of the advantages and owner's risks of EPC mode based on a university student apartment project. *Eng. Econ.* **2016**, *26*, 65–68. (In Chinese)
46. Olubunmi, O.A.; Xia, P.B.; Skitmore, M. Green building incentives: A review. *Renew. Sustain. Energy Rev.* **2016**, *59*, 1611–1621. [CrossRef]
47. Shao, Q.G.; Liou, J.J.H.; Weng, S.S.; Chuang, Y.C. Improving the Green Building Evaluation System in China Based on the DANP Method. *Sustainability* **2018**, *10*, 1173. [CrossRef]
48. Yu, L.; Ding, R.; Gao, W.; Wang, H.; Feng, G. The Practice Research Based on the POE System of Environmental Performance of Green Residential Building. *Procedia Eng.* **2016**, *146*, 204–209. [CrossRef]
49. Sacks, R.; Pikas, E. Building information modeling education for construction engineering and management. I: Industry requirements, state of the art, and gap analysis. *J. Constr. Eng. Manag.* **2013**, *139*, 04013016. [CrossRef]
50. Elmualim, A.; Gilder, J. BIM: Innovation in design management, influence and challenges of implementation. *Archit. Eng. Des. Manag.* **2014**, *10*, 183–199. [CrossRef]
51. Osmani, M.; Glass, J.; Price, A. Architect and contractor attitudes to waste minimisation. *Proc. Inst. Civil Eng. Waste Resour. Manag.* **2006**, *159*, 65–72. [CrossRef]
52. Dai, W.Y. Research on Prefabricated Construction Based on BIM Technology. Master's Thesis, Wuhan University, Wuhan, China, 2017. (In Chinese)
53. Li, J.H.; Zhang, Z.Z. Research on the Application of BIM in PPP Project. *J. Eng. Manag.* **2018**, *32*, 109–114. (In Chinese)
54. Guo, Y.P. Research on the BIM Technology Strategy in the Whole Life Cycle of Green Building. Master's Thesis, Harbin Institute of Technology, Harbin, China, 2013. (In Chinese)
55. Wu, Y.M. A study of the BIM use based on EPC mode. *Sichuan Archit.* **2015**, *35*, 94–98. (In Chinese)
56. Cao, D.; Li, H.; Wang, G.; Huang, T. Identifying and contextualising the motivations for BIM implementation in construction projects: An empirical study in China. *Int. J. Proj. Manag.* **2016**, *35*, 658–669. [CrossRef]
57. Tam, V.W.Y. Comparing the implementation of concrete recycling in the Australian and Japanese construction industries. *J. Clean. Prod.* **2009**, *17*, 688–702. [CrossRef]
58. Cronbach, L.J. Coefficient alpha and the internal structure of tests. *Psychometrika* **1951**, *16*, 297–334. [CrossRef]
59. DeVellis, R.F. *Scale Development: Theory and Applications*, 2nd ed.; SAGE Publications, Inc.: Thousand Oaks, CA, USA, 2003.
60. Aksorn, T.; Hadikusumo, B.H.W. Critical success factors influencing safety program performance in Thai construction projects. *Saf. Sci.* **2008**, *46*, 709–727. [CrossRef]
61. Meliá, J.L.; Mearns, K.; Silva, S.A.; Lima, M.L. Safety climate responses and the perceived risk of accidents in the construction industry. *Saf. Sci.* **2008**, *46*, 949–958. [CrossRef]
62. Xu, J.; Jin, R.; Piroozfar, P.; Wang, Y.; Kang, B.G.; Ma, L.; Wanatowski, D.; Yang, T. An Initiated BIM Climate-based Framework Incorporating Regional Comparison. *J. Constr. Eng. Manag.* **2018**, *144*, 04018105. [CrossRef]
63. BIM Talk. Levels of BIM Maturity. Available online: https://bimtalk.co.uk/bim_glossary:level_of_maturity (accessed on 30 August 2018).
64. UK Government Construction Strategy Board. *A Report for the Government Construction Client Group*; BIM Task Group: London, UK, 2011.
65. UK Government's Department for Business, Innovation and Skills. Launch of Digital Built Britain. Available online: https://www.gov.uk/government/organisations/innovate-uk (accessed on 15 February 2018).

66. Construction in China. Available online: https://store.marketline.com/report/ohme5225--construction-in-china/ (accessed on 18 October 2018).
67. Eastman, C.M.; Jeong, Y.S.; Sacks, R.; Kaner, I. Exchange model and exchange object concepts for implementation of national BIM standards. *J. Comput. Civ. Eng.* **2010**, *24*, 25–34. [CrossRef]
68. Ren, G.; Li, H. BIM based value for money assessment in public-private partnership. In *18th IFIPWG 5.5 Working Conference on Virtual Enterprises*; PRO-VE, 2017; Afsarmanesh, H., Camarinha-Matos, L.M., Fornasiero, R., Eds.; Springer: New York, NY, USA, 2017; Volume 506, pp. 51–62.
69. Wang, J.; Wu, P.; Wang, X.; Shou, W. The outlook of blockchain technology for construction engineering management. *Front. Eng.* **2017**, *4*, 67–75. [CrossRef]