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DOI
10.1061/(ASCE)CO.1943-7862.0001947

Publication date
2021

Document Version
Final published version

Published in
Journal of Construction Engineering and Management

Citation (APA)
Wu, H., Qian, Q. K., Straub, A., & Visscher, H. (2021). Stakeholder Perceptions of Transaction Costs in Prefabricated Housing Projects in China. *Journal of Construction Engineering and Management*, *147*(1), Article 04020145. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001947

Stakeholder Perceptions of Transaction Costs in Prefabricated Housing Projects in China

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Abstract: Prefabrication has the potential to improve the efficiency and sustainability of housing production. However, there are various challenges in the realization of prefabricated housing (PH) from the stakeholder's perspective. Transaction costs (TCs) theory provides a particular angle that explains the invisible costs within transactions. This study aims to explore how perceptions of TCs vary for stakeholder groups and show the potential to reduce TCs in China. The distribution of TCs related to stages and stakeholders was investigated by a literature study and validated by expert interviews. Further, an existing framework of TCs was adopted to conduct a questionnaire survey for collecting perceptions of TCs from six stakeholder groups. The findings show that assembly, detailed design, and design change are the most highlighted TCs of PH. In particular, the component suppliers complained of TCs from the points of detailed design and hiring skilled labor. The local government emphasized TCs on monitoring and enforcement in assembly, architectural design, and component transportation. This research contributes to the construction management community by acknowledging stakeholders in understanding their TCs, which also inspires the policy makers to reduce significant TCs to smooth transactions for the future of China's PH market. **DOI: 10.1061/(ASCE)CO.1943-7862.0001947.** *© 2020 American Society of Civil Engineers.*

Author keywords: Prefabricated housing (PH); Transaction costs (TCs); Stakeholder perceptions; Challenges; Construction.

Introduction

From a social-economic perspective, the construction sector is one in which energy and natural resources are primarily consumed (UNEP 2013). Meanwhile, the construction sector in China continues to contribute a large percentage to the national gross domestic product. The focus of China's central government has been moved toward higher quality, innovative products, and established management processes (Wang and Yuan 2011). Prefabrication is identified as a promising solution to achieve this target. Compared to traditional construction methods, prefabrication entails benefits such as accelerated construction, improved quality, decreased material waste, and reduced hazards (Arif and Egbu 2010). Considering that prefabrication is nowadays mostly applied in the housing sector in China (Ji et al. 2017), this study specifically chose prefabricated housing (PH) as the research scope. PH generally refers to the practice of producing building components in a manufacturing factory, transporting complete components or semicomponents to construction sites, and assembling the components to create residential buildings (Tam et al. 2007). This study adopts the latest definition of PH by the China authority: "Residential buildings that are assembled on-site using prefabricated components" (MOHURD 2017). Based on the level of prefabrication, PH has been classified in the literature into four categories: (1) component manufacturing; (2) nonvolumetric subassemblies; (3) volumetric subassemblies; and (4) modular buildings (Goodier and Gibb 2007). Although the use of nonvolumetric subassemblies is quite prevalent (Pan and Xiong 2009), component manufacturing is still adopted as the mainstream in most projects in China.

PH has gained considerable attention and support from the Chinese government (Ji et al. 2017). Recently, the State Council of the People's Republic of China announced that the incentive policies for prefabrication would be enforced, such that prefabricated construction is expected to account for 30% of total construction within approximately 10 years (GOSC 2016). To achieve the expected diffusion of PH, numerous challenges need to be understood to be overcome, such as higher capital costs (Xue et al. 2018a), new technologies, low process efficiency (Zhai et al. 2014), the lack of regulations (Mao et al. 2015), and so forth. Cost spending to overcome challenges stemming from the attributes of the transactions in terms of asset specificity, frequency, and uncertainty are mostly transaction costs (TCs) (Williamson 1985).

TCs generally refer to costs of trade beyond the material cost of the product, such as the costs of project searches, negotiation, monitoring, regulatory approval, and any deviations from contract conditions (Antinori and Sathaye 2007; Li et al. 2015). With a contribution to analyze and optimize the governance organization, TCs have gained considerable importance in research into the aspects of project management (Walker and Kwong Wing 1999), institutional governance (Lai and Tang 2016), procurement management (Carbonara et al. 2016), and policy management (Fan et al. 2018).

The occurrence of TCs contributes to the increase in total construction costs, which can also lead to disputes, delays, abandonment, and low efficiency in the supply chain. TCs commonly

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Note. This manuscript was submitted on March 9, 2020; approved on July 11, 2020; published online on October 21, 2020. Discussion period open until March 21, 2021; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Construction Engineering and Management***, © ASCE, ISSN 0733-9364.

appear in the traditional construction industry (Li et al. 2015), while they are more noteworthy in the innovation industry because of the higher proportion. For instance, TCs of energy-efficient buildings have been estimated to be as high as 20% of the investment cost (Gooding and Gul 2016). As an innovative industry in the construction sector, the implementation of PH is faced with high uncertainties, risks, and challenges, and thus higher TCs. There are only a few studies available to understand the TCs of PH since TCs is a concept that has been newly applied in this context. According to Williamson (1985), the main founding father of TCs economic theory, actors involved in the transactions are one of the central determinants of TCs. Stakeholders are the main actors involved in the transactions, as well as the payers of TCs in most cases. High TCs do not only hinder the implementation of innovative technologies in the building sector but also prevent market stakeholders from entering the sustainable market (Qian et al. 2015). However, there have been very few attempts so far to investigate the TCs of PH. In response to this research gap, delivering a clear understanding of TCs for the stakeholders is of great necessity, which is also a key to implementing and promoting PH in China.

This study intends to articulate how key stakeholders perceive TCs in the practice of PH in China. The subresearch questions are as follows: (1) What are the important TCs in PH projects? (2) How do stakeholders perceive TCs from the perspective of their roles? and (3) What are the similarities and differences among key stakeholder groups about the perception of TCs in PH? It is so far unknown that the challenges in the PH process lie in the additional hidden costs, and these hidden costs have not been fully understood. The TCs theory can be provided with a unique lens to identify these hidden costs and how they relate to the stakeholders in the PH process. Once identified, it would help to investigate further the potentials to reduce the TCs.

Literature Review

Prefabricated Housing in China

PH was introduced to China in the 1950s to meet the massive housing demand (Wu et al. 2019a). In 1998, the Ministry of Housing Industrialization Promotion Centre was established to manage and implement the PH development in China (Ji et al. 2017). Recently, driven by sustainable development, a profound global challenge, there has been a growing interest from Chinese authorities to promote PH. PH was emphasized as one of the prominent themes by the Plan on Green Building (China State Council 2013) and the National Plan on New Urbanization 2014–2020 (GOSC 2014). However, even with strong motivation from the authorities, the production of PH in China is still lagging far behind the developed countries and the local market demands. As of 2015, the prefabricated productivity in China can supply only 2% of the annual construction scale (Chang et al. 2018).

According to the four prefabrication levels defined by Goodier and Gibb (2007), component manufacturing is still adopted as the mainstream in most projects in China. The most commonly adopted precast components in China's PH market include precast laminated floor slabs, precast stairs, precast balcony slabs, and precast air-conditioning boards. Consideration has been given to extend prefabrication to entire kitchen assemblies and washrooms, as well as water tanks (Pan and Xiong 2009). The structure of PH in China includes reinforced concrete (77.1% of the total gross floor area of PH) and steel structures, while wood construction is rarely applied (Ji et al. 2017). The development of a typical PH project in China mainly goes through five phases: (1) concept, (2) planning and design, (3) manufacturing, (4) construction, and (5) operation and maintenance (Wu et al. 2019b).

Considering the new market and intense implementation pressure, stakeholders in China's PH industry are facing severe challenges. The new network, new cooperation, risks (Zhai et al. 2014), mismatching between the existing governance system, and the new PH supply chain are all causing extra effort, time, and costs, resulting in higher TCs (Wu et al. 2019b). TCs contribute to the increase of the additional costs in PH. It was indicated that the cost of PH projects was 10%–20% higher compared to on-site construction in China (Mao et al. 2016).

Transaction Costs in PH

According to Winch (1989), in an emerging field where the environment is too complicated and uncertain, the ability to make rational decisions is limited or bounded, and TCs tend to be higher. TCs theory is helpful in that it provides a new lens to identify the hidden costs in the transaction process of PH.

In this study, TCs in the PH industry are defined explicitly as costs in terms of risks, time delay, information search, negotiation, contracting, organization setup, monitoring, and enforcement (Wu et al. 2019b). TCs in China's construction market are even higher during its transformational period from traditional methods toward prefabrication (Sha 2004). To understand the nature of TCs in PH, sources of TCs along the entire supply chain need to be thoroughly investigated. The current literature provides very little evidence on TCs in PH. Instead, knowledge of TCs in the general construction industry and challenges of PH served as a pool to extract TCs for PH. This study adopted the TCs framework developed by Wu et al. (2019b). Table 1 lists all sources of TCs in both traditional projects and PH projects, which shows the original 33 TCs along the entire process, split into the usual five phases of PH projects.

TCs that Appear Both in Traditional Projects and PH Projects

As shown in Table 1, some sources of TCs in PH are the same as what they are in traditional projects, for instance, "Land surveying," "Insurance," and "Contract signing." Some other TCs' resources are also common in traditional projects, such as the "Project proposal," "Feasibility study," "Decision-making," "Land-bidding," "Financing," etc. However, the content of these TCs may be somehow different from what is in the traditional projects, which is because of the adoption of prefabrication. For instance, a feasibility study of PH is more complicated than it is in traditional projects, which is due to the different performance of PH on the aspects of technical, economic, and social influence. Therefore, to conduct a comprehensive feasibility study, costs arise for extra professional consultation. Besides, the land-bidding of PH projects consumes extra efforts of local governments by putting the requirement of adopting prefabrication in the bidding documents; and corresponding efforts have to be paid by tendering firms on considering prefabrication. Costs for permission and approval occur for the development of every regular project. At the same time, they appear to be more of a burden in PH projects for both the firms and the authorities, because of the lengthy approval process and the professional requirements. Also, the detailed design of PH projects contains further considerations on components design, for example, incorporating different components together, in terms of lifting, transporting, placing on the foundation, and joining all parts together to form the building (O'Connor et al. 2015).

Table 1. Sources of TCs in conventional projects and PH projects

Code	Sources of TCs	TCs in conventional projects	TCs in PH projects	References for identifying TCs
TC_1	Project proposal	Examine the project's financial, location, and environment reasonableness	Extra consideration for the adoption of the prefabrication	Antinori and Sathaye (2007) and Kiss (2016)
TC_2	Feasibility study	Time, labor, and effort spent on information collection and analysis	More complicated due to the different performance of PH on the aspects of technical, economic, and social influence	Antinori and Sathaye (2007)
TC_3	Identifying PH experienced partners	—	Looking for partners with experience in prefabrication	Larsson and Simonsson (2012) and Kamali and Hewage (2016)
TC_4	Consultation	Looking for supports from the professionals	Exploring special technical solutions for prefabrication	Mao et al. (2015)
TC_5	Learning	Time and efforts are devoted to collaboration with new partners, learning the new technology and digest new information	Extra investment for learning knowledge about prefabrication	Wu et al. (2019b)
TC_6	Decision-making	Market analysis, discussion, and negotiation in the form of meetings	Longer lead-in time for decision-making	Blismas et al. (2005)
TC_7	Land abidding	Publishing the announcement for the bidding; organizing the auction and the candidate evaluation	Extra requirements about adopting prefabrication in the bidding documents; corresponding efforts have to be paid by tendering firms on considering prefabrication	Buitelaar (2004)
TC_8	Permission and approval	Efforts to get the construction land-use planning permit and the land-use title certificate	Efforts to meet the special requirements for prefabrication	Antinori and Sathaye (2007) and Qian et al. (2015)
TC_9	Financing	Fill out loan applications, discuss the project with lenders, review alternative loan terms, and respond to financial due diligence questions	Evaluate the extra financial risk for the adoption of prefabrication	Antinori and Sathaye (2007)
TC_{10}	Land surveying	On-site surveying, information collecting, and analysis	Same as the TCs in the conventional projects	Buitelaar (2004)
TC_{11}	Architectural design	Labor and time spent on communication to conduct the design work	More intensive preproject planning and engineering are needed	Kamali and Hewage (2016)
TC_{12}	Detailed design	Time and effort on making the detailed construction scheme, including the optimization of the original design	The complexity of modules' design; further considerations for incorporating different components	O'Connor et al. (2015)
TC_{13}	Design consultation	Information searching and communication	Extra consultation about the prefabrication	Mao et al. (2015)
TC_{14}	Procurement of the general contractor	Calling for the bid, candidates evaluation, contract negotiating ,and signing	More effort on identifying the general contractors who are able to implement assembly	Mao et al. (2015)
TC_{15}	Procurement of subcontractors	Organizing the bidding, assessment of subcontractors, signing the contracts with subcontractors	Additional efforts on looking for subcontractors with the ability for prefabrication	Qian et al. (2015) and Kiss (2016)
TC_{16}	Special technical solutions for prefabrication	—	A particular technology scheme is needed when adopting prefabrication	Qian et al. (2015) and Kiss (2016)
TC_{17}	Setting up the project Organization	Organization of project management, including hiring new workers, setting new institutions, and new offices	Longer time is needed to set up when people are not familiar with prefabrication	Qian et al. (2015)
TC_{18}	Hiring skilled labour	Time to search and hire skilled laborers	Machine-oriented skills, both on-site and in the factory, increase when adopting prefabrication	Chiang et al. (2006)
TC_{19}	Frequent communication for component production	—	Communication and cooperation is needed from all involved stakeholders to ensure product consistency	Kamali and Hewage (2016)
TC_{20}	Production supervision	—	Monitor the manufacturing in the factory	Mundaca (2007)
TC_{21}	Component quality test	—	Invest time and labor to check the quality of prefab products	Mundaca (2007)
TC_{22}	Components transportation	—	Connect the off-site manufacture and on-site construction tasks, which need intensive coordination among stakeholders	Kamali and Hewage (2016)
TC_{23}	Risk of delivery early or delay	—	The early components' delivery causes extra costs from on-site protection. The delay of components causes the delay of the construction period	Larsson and Simonsson (2012)

Table 1. (*Continued*.)

Code	Sources of TCs	TCs in conventional projects	TCs in PH projects	References for identifying TCs
TC_{24}	Labour education	Training includes techniques skills, safety, management rules, etc.	Extra training about the techniques and management for prefabrication	Zhai et al. (2014)
TC_{25}	Insurance	Insurance associated with project risk, accident, and natural disaster	Same as the TCs in the conventional projects	Antinori and Sathaye (2007)
TC_{26}	Monitoring construction activities	Including safety supervision, time control, and quality supervision for construction	More attention needs to be paid on works about assembly in the whole construction	Li et al. (2013), Mundaca et al. (2013), and Kiss (2016)
TC_{27}	Design change	Workloads regarding redesign, negotiation, and the arrangement of new construction	Extra workloads may result from the reproduction of the components or molds	Tam et al. (2015)
TC_{28}	Dispute solution	Mainly communication and labor costs arising from the dispute	There are more chances that more stakeholders would be involved in the dispute in PH projects	Lu et al. (2015)
TC_{29}	Assembly	—	The assembly has higher requirements for the skills of on-site workers, which generates extra training costs and longer lead-in time	Wu et al. (2019b)
TC_{30}	Permission and approval	Efforts to get the housing sale permit or presale permit	It appears to be more burden in PH projects for both the firms and the authorities, because of the lengthy approval process and the professional requirements	Mundaca et al. (2013) and Kiss (2016)
TC_{31}	Advertising	Efforts for advertising the new projects to the public, the authorities, and potential partners	Advertising and promotion for prefabricated housings bring an additional burden on stakeholders	Wu et al. (2019b)
TC_{32}	Contract signing	Prepare the contract; negotiate on the terms	Same as the TCs in the conventional projects	Mundaca (2007)
TC_{33}	Taxation	Business tax, city maintenance and construction tax, educational surtax, land-added value tax, property tax, income tax, etc.	Sometimes taxation can be less if there are economic support policies for PH	Xue et al. (2018b)

Note: "—" = Task does not exist in conventional projects.

Special TCs for PH Projects

Some sources of TCs are specific for PH projects, including "Identifying partners with PH experience," "Prefabrication technical solutions," "Hiring skilled labor," "Frequent communication for prefabrication," "Components quality test," "Components transportation," etc. For example, the demand for machine-oriented skills, both on-site and in the factory, increases when adopting prefabrication. It will involve hiring skilled workers and local labor training (Chiang et al. 2006). Transportation of the prefabrication components is the task that connects the off-site manufacturer with the on-site construction, which is identified as a vital challenge that needs intensive coordination (Kamali and Hewage 2016).

Transaction Costs of Key Stakeholders in PH

Prefabrication introduces a new way of doing transactions for construction projects, which poses several challenges to the involved stakeholders. As a project-based industry, PH involves many stakeholders, with each party being an independent entity chasing its own interests and playing different functional roles in the innovative process (Xue et al. 2018c). However, not all stakeholders can significantly influence the process efficiency of PH (Mettepenningen et al. 2011). A valuable perspective from which to understand the process of PH is that of the key stakeholders. Wu et al. (2019b) identified six key stakeholders in PH projects: developer, general contractor, local government, supervisor, architect, and components supplier. The definitions of the key stakeholders in China's PH are given in Table 2.

Stakeholders are designated to perform different tasks throughout the PH supply chain. As such, they are facing particular challenges when they perform their tasks. In China, in which PH is still in its infancy, there are relatively more issues. After an analysis of the literature, Fig. 1 summarizes how the key stakeholders are related to TCs in the PH development process.

Table 2. Definition of stakeholders in China's PH

Stakeholder	Definition
Developer	Who initiates the project, explores the consumers' demands, and sets up the project organization; links with designers, contractors, government regulatory bodies, and the public. In the Chinese context, developers are sometimes taking the role of the clients.
General contractor	Who is responsible for arranging the project timeline, the assembly, construction, and working with other stakeholders, including providing the adjusted technology proposal for architects.
Local government	Who approves permits for new developments and monitors the production.
Architect	Who is responsible for preliminary design, final brief, and detailed design.
Supervision company	Who guarantees the schedule, quality, and cost of the project on behalf of the client.
Components supplier	Who produces prefabrication components or units according to the detailed design from the architect.

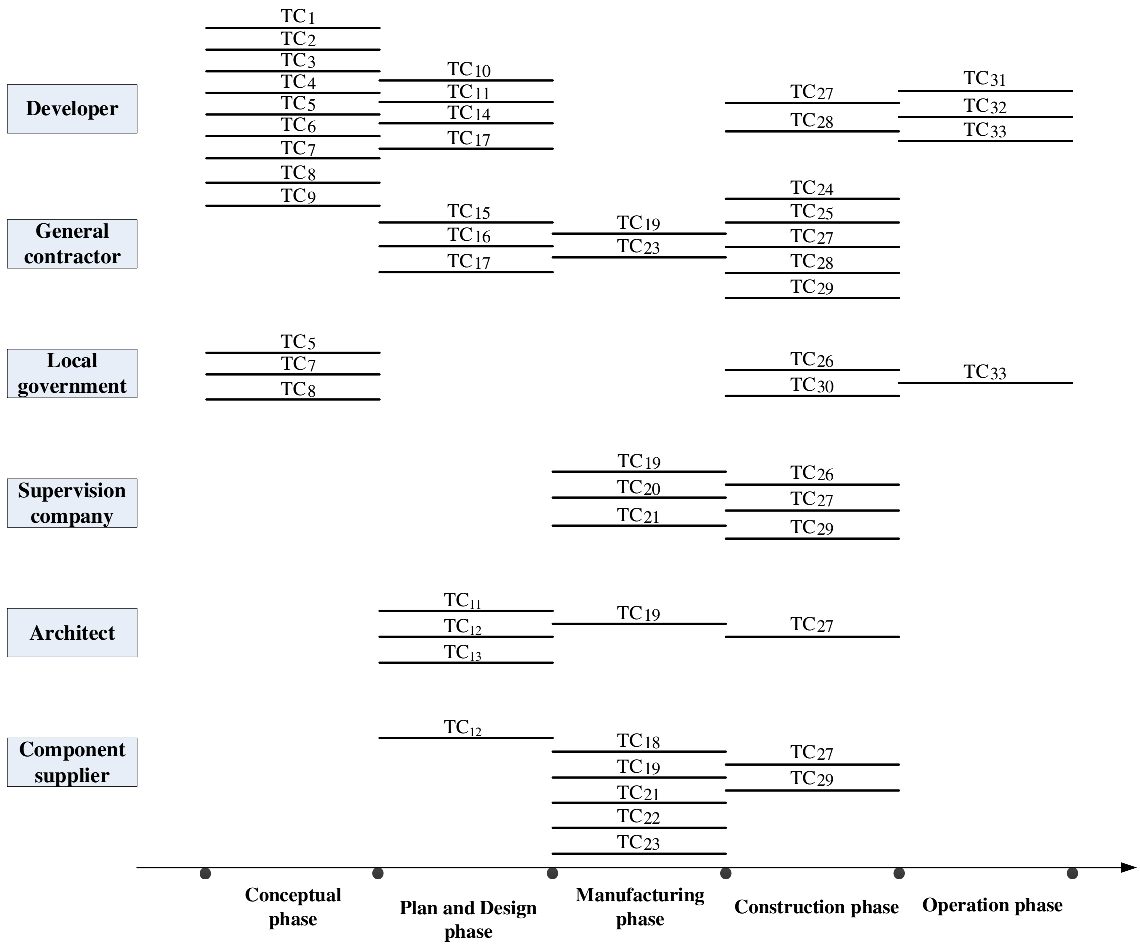

Fig. 1. TCs of key stakeholders in the supply chain of PH.

For developers, most of their TCs arise at the early stage of the supply chain [(TC$_1$)–(TC$_9$)] according to their role of imitating projects. Specifically, the lack of availability of knowledgeable and experienced experts is a challenge, such as engineers and designers who have enough experience for prefabrication (TC$_3$) (Larsson and Simonsson 2012). The long lead-in time for decision-making (TC$_6$) is also recognized as a hindrance (Blismas et al. 2005; Goodier and Gibb 2007). In the plan and design phase, developers are responsible for TCs such as the land-bidding (TC$_7$), general contractor procurement (TC$_{14}$), permission application (TC$_8$), etc. (Wu et al. 2019b). TCs related to the developers also appear in the construction phase, arising from the design change (TC$_{27}$) (Tam et al. 2015) and dispute (TC$_{28}$) (Lu et al. 2015). In the operation phase, as the sponsor and owner in many cases in China, developers are responsible for TCs related to advertising (TC$_{31}$) (Wu et al. 2019b), contract signing (TC$_{32}$) (Mundaca 2007), and taxation (TC$_{33}$) (Xue et al. 2018b).

TCs related to general contractors typically occur in the construction phase. Qian et al. (2015) identified procuring professional subcontractors (TC$_{15}$) and setting up the project organization (TC$_{17}$) as the sources of TCs. Hong et al. (2018) pointed out that additional miscellaneous works such as hiring highly skilled workers (TC$_{24}$), design changes (TC$_{27}$), and logistic processes (TC$_{23}$) are significant contributors to the rising cost in PH. Besides, general contractors are the main stakeholders for executing the assembly (TC$_{29}$) (Wu et al. 2019b). Extra time and costs may arise from the disputes (TC$_{28}$) in the construction process (Lu et al. 2015).

The most common TCs for the local governments are the costs of permits and monitoring. In the concept phase, Buitelaar (2004) expounded that TCs from land-bidding (TC$_7$) are generated by publishing the announcement, organizing the auction, and evaluating the candidate. Kiss (2016) stated that some TCs are from monitoring and enforcement as the field of technology changes. In PH projects, the local governments are highly involved in the manufacturing and construction work (TC$_{26}$), while there are permits approvals (TC$_{30}$), production monitoring, quality assessment, etc. (Jiang et al. 2019).

Responsibilities of the supervision companies in PH projects mainly include factory supervision (TC$_{20}$) and site supervision (TC$_{26}$) (Wu et al. 2019b). To ensure strict quality control on prefabrication, they do quality detection for both the raw materials and prefabricated components (TC$_{21}$). Their responsibilities also include monitoring the assembly process (TC$_{29}$) and supervising the final building acceptance (Tam et al. 2007).

For the architects, intensive preproject planning and engineering are believed to be significant challenges for the architectural design [(TC$_{11}$)–(TC$_{13}$)] (Kamali and Hewage 2016). The detailed design (TC$_{12}$) of PH considers feasibility, which should be encouraging for work such as manufacturing, transportation, lift, and assembly. Additionally, architects can also be severely affected by the design change (TC$_{27}$). As stated by Tam et al. (2015), the inflexibility for design changes is one of the most severe hindrances in PH projects.

Component suppliers, in their new role in a construction project, mostly participate in the manufacturing phase. To enlarge the market scale, they put much effort into understanding the design plan (TC_{12}), training their labor (TC_{18}), and exploring technology for quality testing. Besides, there is intensive communication in the component manufacturing stage (TC_{19}) due to the high requirements for consistency in PH projects (Tam et al. 2015). Apart from this, transportation is also a vital challenge (TC_{22}). In addition to their knowledge of general transportation regulations, they also need to liaise for special traffic control for heavy and bulky modules, so that additional labor training for the components transportation is an extra burden (Chiang et al. 2006; Kamali and Hewage 2016).

Although the previous studies have tried to analyze the challenges of PH, none of them attempted to explore the perceptual consensus or differences of stakeholders about TCs. TCs are generated in the transaction process and originate from the behavior of stakeholders (Williamson 1985). Stakeholder perceptions of TCs, therefore, have a tremendous determinate effect on project efficiency. The use of perceptions is also theoretically consistent with the concept of bounded rationality in the TCs theory, which refers to human behavior that is intentionally rational but only to a limited extent (Simon 1978). Because of the importance of perceptions regarding TCs, some studies use this instead of real TCs measurements (e.g., Badstue 2004; Brockhoff 1992).

Methodology

To elicit the opinion of professionals about TCs in PH projects, both qualitative and quantitative approaches are used. Semistructured interviews are conducted to validate Fig. 1 for understanding how TCs appear at different phases and are related to different stakeholders. Professional opinions were obtained from different stakeholders on recognizing their critical TCs, which provides practical evidence to explain the results of the subsequent questionnaire survey. The questionnaire survey is then adopted to evaluate the importance level of TCs and to understand stakeholders' perceptions of TCs. The overview of the methodology is given in Fig. 2.

Chongqing was selected as the study area. Chongqing is a representative city to show the present situation of PH in most Chinese cities. First, Chongqing plays a vital economic and political role in China. As the newest of the four municipalities under the direct governance of China Central Government, Chongqing plays an essential and strategic role in Western China. The urbanization rate of Chongqing is expected to rise from 60.9% in 2015 to more than 75% by 2030, according to the Population Development Plan of Chongqing City (2016–2030) (Gan et al. 2019). Rapid urbanization and economic development have put Chongqing in a favorable situation to promote PH adoption. Second, there is a vast potential PH market in Chongqing. With over 33 million m^2 completed floor space of residential buildings in 2017, Chongqing plays a significant role in the housing construction market in China (Chongqing Statistics 2018). In a transforming stage from traditional on-site construction to off-site prefabrication, stakeholders in Chongqing will notice the problems and challenges to the construction market. Third, Chongqing reflects the average level of PH application in China cities. Dou et al. (2019) scored the development level of PH in 31 provinces in China; Chongqing was scored at 3.2, which is the closest to the average level (3.1). Therefore, studies about PH in Chongqing help to give a relatively objective understanding of PH practice in China.

Semistructured Interviews

Semistructured interviews were used to understand how TCs appear at different phases and relate to different stakeholders, while professionals' opinions from different stakeholders are given to recognize their critical TCs. The respondents selected have a management-level position and extensive practical experience with PH. Their senior profile ensures that they have a sophisticated understanding of the whole supply chain. In total, 25 respondents were interviewed as representatives of key stakeholders in PH. Profiles of the interviewees are shown in Table 3. The interview was conducted separately, to reflect on the respondents' perceptions of the TCs impact from their past experiences.

Questionnaire Survey

The purpose of the questionnaire survey was to determine the importance of TCs items and to find potential conflicts or areas of agreement among key stakeholder groups. The questionnaire survey was conducted in Chongqing, China, from September 28 to November 20, 2017. Accordingly, 400 questionnaires were distributed via hard copy, email, and through an online questionnaire tool (Sojump 2017). A process of *snowball* or referral sampling was used, which was particularly useful in surveying on-site managers who were generally more difficult to identify and contact.

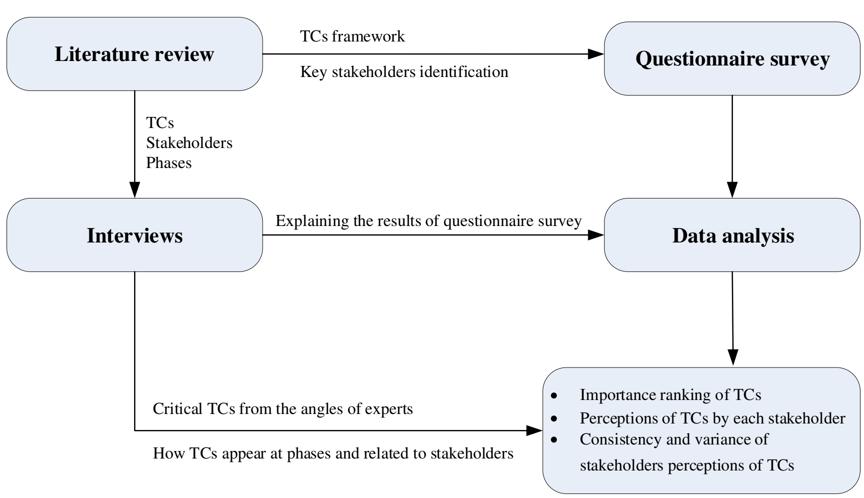

Fig. 2. Overview of the research process.

Table 3. Profiles of interviewees

Stakeholder	Position	Profile
Local government	Section director	Municipal Commission of Urban-Rural Development
	Director	Construction Technology Development Center
	Technical engineer	Construction Industry Modernization Department
	Section manager	Municipal Commission of Urban-Rural Development
Developer	Senior engineer	Real Estate Company
	Operation manager	Real Estate Company
	Manager	Department of investment and development, Real Estate Company
	Quantity surveyor	Real Estate Company
	Architect	Local District Development Group
	Quantity surveyor	Local District Development Group
	Quantity surveyor	Local District Development Group
	Engineer	Local District Development Group
General contractor	Construction engineer	Construction Engineering Company
	Project manager	Construction Engineering Company
	Project manager	Construction Engineering Company
	Quantity surveyor	Construction Engineering Company
Component supplier	Manufacturing manager	Precast concrete Components Company
	Senior manager	Precast concrete Components Company
	Architect	Construction High-tech Building Material Company
	Production manager	Construction High-tech Building Material Company
Architect	Design director	Design Company
	Researcher	Design Company
	Designer	Design and Research Institute of Construction Engineering Group
Supervisor	Chief supervision engineer	Engineering Supervision Company
	Supervision engineer	Engineering Construction Supervision Company

A valid response rate of 25% was determined from the 154 questionnaires returned. After data checking, 110 completed questionnaires were believed as valid and trustable to support the data analysis. Cronbach's Alpha was 0.895, indicating that the questionnaire adopted has a high level of internal consistency and was thus very reliable.

Questionnaire Design

The questionnaire included two sections. In the first section, we asked the respondents to provide their professional backgrounds, including their education, position, years of working experience, and the enterprise type. The second section constituted the main body of the questionnaire. It required each respondent to choose his/her perceived importance ratings of the 33 variables, from 1 (extremely unimportant) to 5 (extremely important), based on their experience.

Data Descriptions

Table 4 provides details of the respondents who participated in this survey, including their gender, age, education, year of experience in construction, and PH. It also shows the sample distribution among the six stakeholder groups. Most of the respondents were male (85.45%), which is reasonable due to the unique characteristics of the construction industry. Besides, the respondents' ages, between 21 and 40 years old, account for 96.36% of the whole. Overall, 80.91% of the respondents had received a bachelor's degree or higher, which explains the credibility of the data. It is interesting to notice that 75.45% of the respondents had experience in the construction industry for more than three years, while 12.73% had experience longer than 10 years. However, at the same time, few of the respondents (3.64%) had experience in PH for longer than three years. This reflects that the PH market in Chongqing is still in an initial stage of development.

Results and Findings

Results from the Interviews

As shown in Fig. 1, the interviewees gave their opinions on the TCs and related stakeholders in the transaction process of PH. Generally, they agreed with the proposed mapping of TCs. The learning costs (TC_5) were confirmed mostly in the conceptual phase by the interviewees. Firms with less experience had high learning costs because they need to switch their work to adapt to the prefabrication mode. A director from the Local Municipal Commission of Urban-Rural Development pointed out that most all stakeholders have to pay for learning, while some of these costs are calculated in the projects, and some are invisible and ignored. In addition, *assembly* (TC_{29}) received great attention from the industry in the construction phase. TCs from the assembly were known by the interviewed stakeholders as needed high initial investments, extra training costs of workers, longer lead-in times, risks of mistakes and reworks, etc. The on-site assembly was a challenging task mainly to the general contractors, while the other key stakeholders all mentioned their extra effort in it as well.

The second purpose of the interviews was to collect opinions from the experienced experts about how they perceive high TCs from the role in their firms. In the interviews with developers, managers highlighted their extra efforts on learning and permission application. The quantity surveyors emphasized their learning costs in doing a feasibility study, for instance, costs related to professional training sessions and learning new regulations. General contractors expounded their challenges in the procurement of subcontractors, design change, and assembly. The architect complained about the invisible efforts on communication from cooperation and negotiation. It was not surprising that the participants from the local government emphasized the costs for monitoring and promotion,

Table 4. Sample characteristics

Characteristic	Group	De	GC	LG	Ar	SC	CS	Frequency	Percentage
Gender	Male	25	21	11	11	15	11	94	85.45
	Female	5	4	3	2	1	1	16	14.55
Age	21–30	21	15	10	8	10	4	68	61.82
	31–40	8	8	5	5	5	7	38	34.55
	41–50	1	2	0	0	0	1	4	3.64
Education	Junior college	3	7	0	0	8	3	21	19.09
	Bachelor	18	17	6	1	7	6	55	50.00
	Master	9	1	9	11	0	3	33	30.00
	Doctor	0	0	0	1	0	0	1	0.91
Year in construction	0–3	8	4	5	6	3	0	27	24.55
	3–5	12	9	7	2	5	6	39	35.45
	5–10	8	6	3	4	5	3	29	36.36
	>10	2	6	0	1	2	3	14	12.73
Year in PH	0–1	17	14	6	3	8	3	50	45.45
	1–3	13	11	9	10	7	5	56	50.91
	3–5	0	0	0	0	0	1	1	0.91
	>5	0	0	0	0	0	3	3	2.73
Total	—	30	25	15	13	15	12	110	—
	—	27.27%	22.73%	13.64%	11.81%	13.64%	10.91%	—	100

Note: De = developer; GC = general contractor; Su = supervisor; Ar = architect; CS = components supplier; and LG = local government.

while the supervision company mentioned extra costs on manufacturing supervision.

General Importance Ranking of TCs from the Questionnaire Survey

With the data acquired from the questionnaire, we performed a ranking analysis to identify the important TCs. Several descriptive statistical analyses were applied, such as average and standard deviation. The Statistical Package for Social Sciences (SPSS) version 24.0 was used to perform statistical analysis.

As presented in Table 5, "Assembly" (TC_{29}), "Detailed design" (TC_{12}), and "Design change" (TC_{27}) are the top three significant sources of TCs in PH. "Assembly" (TC_{29}) is a procedure that does not exist in traditional construction projects. Being identified as the second most important source of TCs, "Detailed design" (TC_{12}) for PH projects is more complicated than it is in traditional projects. In addition to the complexity of the component design itself, further considerations are needed when incorporating different components together, for example, when they are lifted, transported, placed on the foundation, and joined to form the building (O'Connor et al. 2015). Additionally, another primary source of TCs is "Design changes" (TC_{27}), which may lead to the redesign, reconstruction, or even the changing of molds for components. In most cases, design changes could bring damage to the interests of all parties (section manager of the Municipal Commission of Urban-Rural Development).

Perceptions of TCs for the Six Stakeholder Groups

We calculated the mean and standard deviation of each variable to represent its level of importance to each of the six different stakeholder groups. Table 6 shows the ranking results of the 33 variables.

As shown in Table 6, the developers scored highest on "Assembly" (TC_{29}) and "Design change" (TC_{27}). "Assembly" is identified as a significant cause of additional costs by developers; transforming from traditional work to manufacturing and assembly poses immense pressure on developers' initial investment. Besides, developers believe that "Design changes" (TC_{27}) give rise to hidden losses, which are mainly reflected in the decline in the reputation of developers and the reduced willingness of other stakeholders to cooperate with them subsequently. It was told that even in totally fixed price contracts, design changes sometimes might bring more losses to the contractors than to the developer. However, the reputation damage to developers is irreversible.

"Assembly" (TC_{29}), "Hiring skilled labor" (TC_{18}), and "Design change" (TC_{27}) are the top three crucial TCs to general contractors. Technically, the assembly of components has higher requirements for workers' skills than traditional on-site work. It, therefore, generates extra training costs for workers and lead-in times. "Hiring skilled labor" (TC_{18}) for manufacturing ranks second. It may be because general contractors are mostly responsible for supplying components in China. Besides, the impact of "Design changes" (TC_{27}) is more severe in PH projects than in traditional construction projects. Sometimes, the molds for components are even needed to be changed due to the changes in the original design.

From the perspective of the local governments, "Assembly" (TC_{29}), "Architectural design" (TC_{11}), and "Component transportation" (TC_{22}) are the top three critical sources of TCs. The local government does not directly participate in the "Assembly" (TC_{29}). They are responsible for monitoring the assembly, including the tower crane work, safety, quality inspection, and spot checks of environmental protection measures. Besides, the local governments perceive "Architectural design" (TC_{11}) as a difficult task based on the experience of approval for a PH design scheme. "Component transportation" (TC_{22}) is ranked in third place for the local government, whereas extra staff and time are devoted to regulation-making, application approval, and regulation enforcement.

For the architects, "Assembly" (TC_{29}), "Design change" (TC_{27}), and "Communication during component manufacturing" (TC_{19}) are the most important TCs. Following the opinions of the interviewees, architects are more involved in the production and construction process in PH, compared with traditional projects. However, their experience is usually in design, which explains why architects have great difficulty with the activities in the production phase rather than in the design phase.

Table 5. General importance ranking of TCs

Code	Sources of TCs	Mean	Standard deviation	Rank
TC_1	Project proposal	2.54	1.18	23
TC_2	Feasibility study	2.73	1.07	22
TC_3	Identifying experienced partners	3.13	1.03	13
TC_4	Consultation	2.83	1.15	19
TC_5	Learning	3.18	0.98	12
TC_6	Decision-making	2.79	0.95	20
TC_7	Land-bidding	2.49	1.21	26
TC_8	Permission and approval	2.53	1.18	25
TC_9	Finanacing	2.42	1.14	29
TC_{10}	Land surveying	1.83	0.89	33
TC_{11}	Architectural design	3.13	1.14	14
TC_{12}	Detailed design	3.51	0.94	3
TC_{13}	Design consultation	2.91	1.04	17
TC_{14}	Procurement of the general contractor	2.37	1.08	30
TC_{15}	Procurement of subcontractors	3.00	0.85	15
TC_{16}	Special technical solution for prefabrication	3.26	0.95	9
TC_{17}	Setting up the project organization	2.79	1.00	21
TC_{18}	Hiring skilled labour	3.38	0.87	5
TC_{19}	Frequent communication for component production	3.38	0.95	6
TC_{20}	Production supervision	3.28	0.90	8
TC_{21}	Component quality test	3.24	0.88	11
TC_{22}	Components transportation	3.44	1.05	4
TC_{23}	Risk of delivery early or delay	3.25	0.99	10
TC_{24}	Labour education	2.97	1.01	16
TC_{25}	Insurance	2.45	0.98	27
TC_{26}	Monitoring of construction activities	2.86	1.07	18
TC_{27}	Design change	3.54	0.91	2
TC_{28}	Dispute solution	3.30	1.02	7
TC_{29}	Assembly	3.74	0.97	1
TC_{30}	Permission and approval	2.54	0.97	24
TC_{31}	Advertising	2.24	1.02	31
TC_{32}	Contract signing	2.17	1.00	32
TC_{33}	Taxation	2.45	1.08	28

It is not surprising that supervision companies also rated the greatest concern on "Assembly" (TC_{29}), because it is a task within the process with which they are not familiar. "Components production supervision" (TC_{20}) and "Components quality test" (TC_{21}) are also perceived as the most massive, extra workloads by supervision companies.

As a new stakeholder role in construction projects, component suppliers evaluate the difficulty of the activities without comparing with traditional projects, but based their views on their perceptions of production activities. Although "Detailed design" (TC_{12}) is initially the responsibility of the architects, component suppliers have to participate in it because the designs of components in China are not mature yet and so they need to complete this work together. Additionally, "Hiring skilled labor" (TC_{18}) and "Design changes" (TC_{27}) are also identified as high TCs sources by the component suppliers.

Consistency and Variance of Stakeholder Perceptions of TCs

Scores on TCs were treated as continuous data, and ANOVA was used to ascertain whether or not various respondent groups had consistent opinions. ANOVA is a collection of statistical models, pioneered by Fisher, which can be used to analyze the differences between group means and their associated procedures (Fisher 1992). If a probability value P from an ANOVA test is below 0.05, it suggests that there is a high degree of difference in the opinion among groups. ANOVA has been applied as an effective method to understand TCs. Adhikari and Lovett (2006) analyzed the variation of TCs for different income groups in natural resource management. Chomchaiya and Esichaikul (2016) developed a framework for government e-procurement performance measurement using ANOVA.

In this study, three-step prechecking was prepared before the ANOVA analysis. First, the data distribution was tested for each stakeholder group. ANOVA is valid to apply; although, within six groups, not all variables are normally distributed (Blanca et al. 2017). Second, we did the power check of the sample size. According to the widely used rule (Lan and Lian 2010), the required sample of each group should be above 10, which was met in this survey. Third, we checked the homogeneity of the data to consider the variables in one-way ANOVA.

Results of the homogeneity test revealed that there were three variables with p values below 0.05—TC_9, TC_{14}, and TC_{32}. They cannot be included in one-way ANOVA because the variances of these three items are unequal. Then, one-way ANOVA and the post hoc test for the remaining 30 sources of TCs were conducted, considering the stakeholders' group identity (Table 7).

The ANOVA test results indicated that there were statistically nonsignificant differences ($P \geq 0.05$) between stakeholder groups for 12 of the 33 TCs. Among them, the mean scores of "Propose special technical solutions for prefabrication" (TC_{16}), "Insurance" (TC_{25}), and "Production supervision" (TC_{20}) had the lowest F values. It means they received the most consistent opinions among all stakeholder groups. Besides, consistent perceptions appeared in six out of the nine stakeholders' crucial TCs ($P < 0.05$): "Architectural design" (TC_{11}), "Hiring skilled labor" (TC_{18}), "Components production supervision" (TC_{20}), "Components quality test" (TC_{21}), "Component transportation" (TC_{22}), and "Assembly" (TC_{29}). Generally, stakeholders all believe that new tasks bring challenges to them while they are all directly or indirectly involved with them. For instance, the perceptions of "Assembly" (TC_{29}) among stakeholders were rather consistent. Moreover, although "Architectural design" (TC_{11}) is performed by the architects, the other stakeholders also believe that the addition of innovative prefabrication technology brings extra difficulties to this task.

In addition to pointing to a consensus in the ranking of TCs in PH, there were differences between the mean perceptions of respondents from different stakeholder groups. The remaining 18 variables were analyzed by post hoc multiple comparisons. The Gabriel post hoc test was applied due to the unequal sample sizes of the six stakeholder groups in this study (Field 2018). Table 7 gives the results of the Gabriel post hoc test, showing that the 18 variables with at least one pair of stakeholder groups differed significantly from each other ($P < 0.05$). Three key TCs identified by stakeholders were on the list of these 18 variables

- Detailed Design (TC_{12}) component supplier (CS) > general contractor (GC)

  Results show that the perceptions of TCs from the detailed design stage are significantly different between the component supplier and the general contractor. Component suppliers remarked that it is the most critical source of TCs (mean = 4.17). Interviewees from the component suppliers pointed out that they have to be actively involved in the work of detailed design, not only because it could be a way to improve their reputation and to promote their business but also due to the lack of experienced architects.

Table 6. Mean Scores of TCs of stakeholder groups in PH

Code	Source of TCs	Developer		General contractor		Local government		Architect		Supervision company		Component supplier	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
TC_1	Project proposal	2.70	26	2.67	20	1.79	28	3.00	19	1.40	26	3.25	15
TC_2	Feasibility study	2.63	28	2.00	27	2.62	21	3.69	8	1.43	25	3.00	23
TC_3	Identifying experienced partners	3.48	6	3.00	6	3.00	15	3.46	14	1.71	22	2.88	29
TC_4	Consultation	2.78	23	2.33	24	2.46	24	3.62	13	1.60	23	3.25	15
TC_5	Learning	3.07	16	3.00	6	2.77	19	3.92	5	2.67	13	3.50	5
TC_6	Decision-making	2.85	20	2.00	27	2.77	19	3.38	16	1.50	24	3.00	23
TC_7	Land-bidding	2.85	20	3.00	6	1.93	27	2.54	28	1.00	29	2.75	32
TC_8	Permission and approval	2.85	20	2.67	20	1.71	29	2.77	23	1.00	29	3.38	10
TC_9	Financing	2.74	25	3.00	6	1.42	31	2.92	20	1.00	29	2.71	34
TC_{10}	Land surveying	2.03	34	1.67	31	1.36	34	1.62	34	1.00	29	2.75	32
TC_{11}	Architectural design	2.90	18	2.75	18	3.80	2	3.23	18	2.50	14	3.17	20
TC_{12}	Detailed design	3.31	10	3.11	5	3.67	4	3.92	5	3.00	7	4.17	1
TC_{13}	Design consultation	2.69	27	2.17	26	3.00	15	3.69	8	2.17	19	3.38	10
TC_{14}	Procurement of general contractor	2.48	31	2.00	27	2.00	26	2.62	27	1.00	29	3.13	21
TC_{15}	Procurement of subcontractors	3.24	12	3.17	4	3.00	15	2.38	31	2.50	14	3.38	10
TC_{16}	Special technical solution for prefabrication	3.17	14	3.00	6	3.13	14	3.69	8	3.14	6	3.50	5
TC_{17}	Setting up the project organization	2.97	17	2.90	14	2.43	25	2.77	23	2.00	21	3.25	15
TC_{18}	Hiring skilled labor	3.37	8	3.41	2	3.23	12	3.46	14	3.00	7	3.83	2
TC_{19}	Frequent communication for component production	3.53	4	3.00	6	3.57	5	4.08	3	2.69	12	3.33	13
TC_{20}	Production supervision	3.27	11	2.94	13	3.29	7	3.69	8	3.40	2	3.13	21
TC_{21}	Component quality test	3.43	7	2.78	17	3.21	13	3.69	8	3.27	3	3.00	23
TC_{22}	Components transportation	3.67	3	3.00	6	3.71	3	3.77	7	2.93	9	3.42	8
TC_{23}	Risk of delivery early or delay	3.50	5	2.82	16	3.57	5	3.38	17	2.86	11	3.33	13
TC_{24}	Labor education	3.20	13	2.83	15	3.25	10	2.69	25	2.27	18	3.58	4
TC_{25}	Insurance	2.57	29	2.18	25	2.56	22	2.23	33	2.45	16	3.00	23
TC_{26}	Monitoring construction activities	3.14	15	2.40	22	3.29	7	2.54	28	2.87	10	2.82	31
TC_{27}	Design change	3.69	2	3.22	3	3.25	10	4.23	2	3.20	4	3.75	3
TC_{28}	Dispute solution	3.34	9	2.71	19	3.27	9	4.00	4	3.20	4	3.50	5
TC_{29}	Assembly	3.72	1	3.48	1	4.00	1	4.38	1	3.67	1	3.42	8
TC_{30}	Permission and approval	2.86	19	2.00	27	2.55	23	2.85	21	2.15	20	2.88	29
TC_{31}	Advertising	2.37	33	1.60	32	1.44	30	2.46	30	1.25	27	3.25	15
TC_{32}	Contract signing	2.41	32	1.60	32	1.38	32	2.31	32	1.00	29	3.00	23
TC_{33}	Taxation	2.52	30	2.40	22	1.38	32	2.85	21	1.25	27	3.25	15

- Frequent Communication for Component Production (TC_{19}) architect (Ar) > general contractor (GC) Ar > supervision company (SC)

  TC_{19} received considerable attention from all key stakeholders (mean > 3.0). The pair comparison reflects that there are differences in the perceptions between the architects and general contractors, architects, and the supervision company. Compared to the general contractors and the supervision companies, more effort on communication and cooperation has been needed from the side of the architects. Interviewees also claimed that intensive meetings for the production of the components had become a burden to the architects.
- Design Change (TC_{27}) Ar > GCAr > SC

  Although it is commonly identified as a critical TCs resource, design change received greater attention from architects than general contractors and supervision companies. The design change is one of the most significant risks for architects, and it brings additional workload and costs. Prefabrication requires high technical consistency, for which high costs can occur on communication when there are design changes.

Discussion

The results of the data analysis show similarities as well as a diversity of stakeholders' perceptions of TCs, which stimulated a necessity to further explore the consistencies and differences of stakeholders' perceptions about TCs in PH projects. First, by analyzing the consistency of the TCs the stakeholders' were most concerned, this study can help to build a thorough understanding of TCs from their nature. Our goal was not only to identify the critical TCs from the eye of each stakeholder but eventually to investigate the hindrances along the supply chain that incur common TCs to the relevant stakeholders. Second, for private stakeholders, exploring the consistencies of stakeholders' perceptions about TCs can contribute to finding better strategies for the governance of the whole supply chain. Understanding the differences in stakeholders' perception is helpful to understand the differences in their roles and interests in the PH. Knowing the difficulties and interests of other stakeholders is beneficial for enterprises in the PH industry to adjust their measures and strategies. Moreover, exploring the consistencies and differences of perceptions of TCs among stakeholders provides the policy makers with a better understanding of needs from the market, which will contribute to making more effective policies.

Consistency of the Perceptions of TCs between Stakeholders

According to data analysis results of TCs ranking for each stakeholder group, nine items were commonly recognized by six key stakeholders groups as significant sources of TCs in PH:

Table 7. Analysis result of ANOVA and Post Hoc test

Code	Source of TCs	Between groups: Sum of squares	Between groups: Degree of freedom	Within groups: Sum of squares	Within groups: Degree of freedom	F	Significance	Post hoc Gabriel test: $P < 0.05$
TC_1	Project proposal	22.018	5	73.353	64	3.842	0.004	CS > LG; CS > SC
TC_2	Feasibility study	26.664	5	55.857	67	6.397	0.000	Ar > De; Ar > SC; GC > Ar; CS > SC
TC_3	Identifying experienced partners	19.584	5	54.275	65	4.691	0.001	De > SC; Ar > SC; LG > SC
TC_4	Consultation	19.572	5	70.341	63	3.506	0.007	Ar > SC
TC_5	Learning	12.204	5	54.416	65	2.915	0.020	Ar > LG
TC_6	Decision-making	17.539	5	46.292	65	4.925	0.001	De > SC; Ar > SC; LG > SC; CS > SC
TC_7	Land-bidding	18.180	5	81.067	63	2.826	0.023	De > SC
TC_8	Permission and approval	30.329	5	65.114	64	5.962	0.000	De > LG; De > SC ; CS > LG; Ar > CS CS > SC
TC_{10}	Land surveying	14.548	5	41.423	65	4.566	0.001	CS > LG; CS > Ar; CS > SC
TC_{11}	Architectural design	11.420	5	89.314	73	1.867	0.111*	—
TC_{12}	Detailed design	13.340	5	69.908	87	3.320	0.009	CS > GC
TC_{13}	Design consultation	17.837	5	62.518	70	3.994	0.003	Ar > De; Ar > LG; Ar > SC
TC_{15}	Procurement of subcontractors	9.404	5	44.596	70	2.952	0.018	De > Ar
TC_{16}	Special technical solution for prefabrication	4.124	5	69.498	76	0.902	0.484*	—
TC_{17}	Setting up the project organization	8.286	5	71.102	74	1.725	0.139*	—
TC_{18}	Hiring skilled labor	4.741	5	68.289	92	1.277	0.280*	—
TC_{19}	Frequent communication for component production	16.449	5	73.254	95	4.266	0.002	Ar > GC; Ar > SC
TC_{20}	Production supervision	4.501	5	72.906	90	1.111	0.360*	—
TC_{21}	Component quality test	8.349	5	70.004	96	2.290	0.052*	—
TC_{22}	Components transportation	10.963	5	97.677	94	2.110	0.071*	—
TC_{23}	Risk of delivery early or delay	9.903	5	91.659	99	2.139	0.067*	—
TC_{24}	Labor education	15.941	5	90.974	99	3.469	0.006	De > SC; CS > SC
TC_{25}	Insurance	5.136	5	83.897	87	1.065	0.385*	—
TC_{26}	Monitoring construction activities	10.373	5	105.706	96	1.884	0.104*	—
TC_{27}	Design change	12.519	5	73.328	98	3.346	0.008	Ar > GC; Ar > SC
TC_{28}	Dispute solution	14.137	5	88.953	95	3.020	0.014	Ar > GC
TC_{29}	Assembly	9.244	5	89.360	100	2.069	0.076*	—
TC_{30}	Permission and approval	12.895	5	74.435	88	3.049	0.014	De > GC
TC_{31}	Advertising	20.922	5	47.199	60	5.319	0.000	CS > GC; CS > LG; CS > SC
TC_{33}	Taxation	22.303	5	51.758	59	5.085	0.001	De > LG; Ar > LG; Ar > SC; CS > LG; CS > SC

Note: $^*p > 0.05$; and "—" = statistical nonsignificant.

"Architectural design" (TC_{11}), "Detailed design" (TC_{12}), "Hiring skilled labor" (TC_{18}), "Communication during component manufacturing" (TC_{19}), "Components production supervision" (TC_{20}) and "Components quality test" (TC_{21}), "Component transportation" (TC_{22}), "Design changes" (TC_{27}), and "Assembly" (TC_{29}). From the nature of TCs, it was observed that stakeholders in the PH industry in China are putting more of their attention on TCs related to the asset specificity of PH. Asset specificity refers to the specific investment for a particular transaction (Williamson 1981). It is observed that the three most important TCs—"Assembly," "Detailed design," and "Design change"—are highly related to the specificity of prefabrication. For instance, "Assembly" requires new construction techniques for the workers, more intensive coordination among stakeholders, as well as extra supervision and monitoring work for the authorities.

Another common point on stakeholder perceptions of TCs is that they emphasized activities involving innovation works where high uncertainties and risks may arise (Mettepenningen et al. 2011). For example, being more complicated than found in the traditional construction projects, design changes in PH projects not only cause remanufacturing or reassembly but could even lead to changing the molds for producing components. In most cases, design changes may damage the interests of all related stakeholders.

Differences between the Perceptions of TCs from Public Stakeholders and Private Stakeholders

Playing different roles in PH projects, stakeholders have various interests. Due to their different interests, stakeholders could encounter different impediments leading to divergent perceptions on the TCs (Gan et al. 2019). The phases that stakeholders participate in and the activities involved in the different roles determined that the stakeholders experience different TCs. Based on the data analysis findings, further discussions about the differences in the perceptions of TCs between public and private stakeholders were carried out

1. Private stakeholders tend to emphasize TCs from their production, while the authorities have an overview of all sources of TCs in the whole supply chain. For example, the interviews with general contractors and supervision companies reflected that they prefer to highlight the challenges that come from the innovation of PH compared with traditional projects. Four of the five private key stakeholders identified the "Assembly" as the task where high TCs occur, which is due to the changes in their regular production activities. However, different from private stakeholders, the goal of the local government is not to make profits but to promote PH in China (Zhai et al. 2014). The view of the government is more objective and comprehensive compared with the private stakeholders. It is interesting to note that the

most important TCs evaluated by the local government are "Assembly," "Architectural design," and "Component transportation," which are not directly carried out by the local governments. In addition, during the interviews, government experts expressed a clear understanding of TCs by explaining academic and economic meaning.

2. The burden of TCs from PH is allocated diversely to private and public stakeholders, which leads to different intentions to reduce TCs. It is known from the interviews that private stakeholders are bearing most of the TCs in a PH project because of their direct involvement in the development process. Specifically, developers pay for most of the TCs in the concept and design phase, whereas general contractors are bearing most TCs in the construction phase (Wu et al. 2019b). The interviewees delivered a firm intention from the perspective of private stakeholders to lower their TCs. On the contrary, the interviewees showed that public stakeholders believe that the existence of TCs is inevitable. To the governments, maximizing social benefits, rather than minimizing TCs, is the goal. Some additional TCs are favorable for the projects and the industry as a whole, for example, the formulation of industry norms (Lu et al. 2015). The questionnaire survey results did not show that approval and monitoring costs as the most critical TCs from the perspective of local government. It somehow implies that they believe the TCs spending on promotion of PH would contribute to the improvement of the social benefits in the long run.

Strategic Implications to Stakeholders in PH Projects

It is assumed that the fewer the TCs, the more smooth and efficient the development process is (Webster 1998). From a perspective of cost efficiency, some of the TCs are deadweight losses that have to be minimized.

Suggestions for Private Stakeholders

First, by identifying the commonly emphasized nine TCs sources by key stakeholders, there are some general suggestions to the private stakeholders according to their perceptions' consistency. (1) Partner cooperation is a solution to eliminate redundant TCs and improve the efficiency of the organization's operation. Ensuring the efficiency of projects is not a single party's affair, but it is instead a collective effort from all interested parties in the partnership arrangement (Osei-Kyei and Chan 2017). (2) This study has made it clear that communication and coordination are among the most concerned sources of TCs in PH by key stakeholders. Therefore, developing long-term cooperative relationships between stakeholders (e.g., between architect companies and developers) is one of the solutions to smooth the coordination and to save costs from information searching. (3) Furthermore, private stakeholders could reduce their internal TCs on the firm level by upgrading the firm organization. As shown from the survey results, the "Detailed design" is partly taken by the architects, while there was no team available in their initial organization. Then, extra costs have to be paid for hiring new staff or adjusting the task distribution among staff. To reduce TCs arising from the internal organization, they must adjust the structure of their organization to adapt to the new transaction and administration process (Ketokivi and Mahoney 2016).

Second, considering the differences in stakeholders' roles and perceptions of TCs, implications of specific measures are also given to each private stakeholder. For the developers, learning costs (e.g., in the form of meetings, project investigations) are worth paying to reduce the TCs from the mistakes and low efficiency in the "Assembly" (Kiss 2016). For the general contractors, reducing uncertainty in the early phases is a solution to decrease TCs from "Assembly" and "Design change." A practical solution is to use mature design technologies for assembly simulations, such as having pipeline interferences by using building information model (BIM), which results in very few design changes. The architects perceived TCs from "Communication during component manufacturing" as a great challenge. Corresponding management measures, such as ensuring the completeness of plans and specifications, can decrease the number of disagreements and disputes in the manufacturing, therefore reducing the TCs in the manufacturing stage (Li et al. 2013). The supervision companies have recognized their massive, extra workloads on the "Components production supervision" and "Components quality test." Possible measures to minimize TCs could be experience-learning. Supervision lessons learned from completed PH projects should be kept in the organizational memory and be used in future projects (Mettepenningen et al. 2011). Additionally, as reflected in the interview, component suppliers believe that their early involvement in the "Detailed design" can benefit the efficiency of their manufacturing activities. Therefore, the TCs from the "Detailed design" are not necessary to be reduced from the side of the component supplier even though it is recognized as a vital source of TCs by them.

Suggestions for Public Stakeholders

Public stakeholders have a function and ability to take actions that can reduce TCs for both the public and private stakeholders. (1) On the one hand, they can reduce TCs for private stakeholders by improving the knowledge level of the public. In our survey, many stakeholders mentioned the costs of hiring skilled labor and educating staff. The shortage of skilled and competent labor in the PH industry has become an obstacle to stakeholders in China. Improving the economic awareness of the TCs among private stakeholders is one of the essential points to reduce TCs practically. Therefore, it is suggested that, apart from training for the employed person, it would be more efficient to start with putting prefabrication in the education system in college. (2) On the other hand, developing a straightforward legal environment could play a significant role in decreasing the TCs burden (McCann 2013). The results of the interview reveal that, for public stakeholders, TCs are more likely to arise from permission approval, monitoring, and publicity. The unclear regulations brought additional TCs to the private stakeholders; for instance, the supervision companies identified components quality test as a difficulty when the official quality standards were absent. Therefore, the local government action is the key point of TCs related to the policy environment. Providing clear regulations, in terms of component design, assembly, and quality assessment, would significantly reduce TCs for both the public and private stakeholders.

Conclusions

The low-efficiency problem of PH is a commonly identified reality. TCs are identified to help reduce dead-loss costs through the construction process of prefabrication. This study explores the major stakeholder perceptions toward TCs in the transaction process of PH in China and finds the potentials to lower TCs for stakeholders.

The findings of the questionnaire survey show that assembly, detailed design, and design change are the most critical sources of TCs in PH in China. In particular, the component suppliers complained of TCs from the detailed design and hiring skilled labor. For the architects, assembly is the most critical TCs, although they do not participate on a practical level. The local government emphasized TCs on monitoring and enforcement in assembly, architectural design, and component transportation. In addition, in exploring the consistent perceptions of TCs between stakeholders, 12 of 33 TCs received consistent agreement between key stakeholder groups. It is observed that the commonly highlighted TCs in PH are highly related to the asset specificity and uncertainties from innovation. Besides, the analysis results also revealed perception differences of TCs between stakeholders due to their different roles and interests. Generally, private stakeholders tend to emphasize TCs from their production, while the authorities have an overview of all TCs in the supply chain. The most critical TCs evaluated by the local government are "Assembly," "Architectural design," and "Component transportation," which are not directly carried out by the local governments. Moreover, the information from the interviews and the survey delivered a firm intention from the perspective of private stakeholders to lower their TCs, whereas the public stakeholders believe that the existence of TCs is inevitable. It can be explained by the fact the private stakeholders are essentially profit-driven; the goal of the government is to promote the development of PH.

The practical implications from the findings of this study suggest that building strong cooperative relationships between partners is a long-term strategy for private enterprises to minimize their TCs. Educating the public can improve the knowledge level on PH and would further reduce the investment from private stakeholders for labor education. Moreover, public stakeholders are suggested to develop a straightforward legal environment for decreasing the TCs burden to both the public and private stakeholders. For instance, making clear regulations, in terms of component design, assembly, and quality assessment, can significantly reduce TCs for private stakeholders, which would also lower the monitoring TCs for the local governments.

The findings of this study are very impactful to both academia and practice for construction engineering and management. This study contributes to the theory by uncovering the TCs of PH projects from the perspectives of stakeholders. Compared with previous TCs-related researches in other fields that only focused on TCs of a single stakeholder (Kiss 2016; Mundaca et al. 2013; Qian et al. 2015), this study provides a broader scope by investigating the perceptions of key stakeholders on TCs. In practice, this research has allowed stakeholders to look beyond difficulties in production and have a complete view of the TCs. It guides a direction for the private stakeholders to strategically lower TCs at specific phases of the process and improve the project efficiency. Furthermore, the findings inspire policy makers to reduce TCs for both the private and public stakeholders, which will contribute to smooth transactions for future China's PH market. For cities and countries where the development of PH is in the early stage, findings from this study can provide implications on the aspect of TCs control in the development process of PH projects. Chongqing reflects the average level of PH application in China cities. Studies about PH in Chongqing give a relatively objective understanding of PH practice in China. It also provides a base for studies in other regions of China to investigate TCs in the local market by having Chongqing as a comparison case. Moreover, this study provides inspiration for understanding the states of TCs and investigating stakeholders' perceptions of TCs in other countries where the development of PH is in different stages. A limitation associated with this study is the comparatively small size of the sample. Perhaps future research can focus on the exploration of stakeholders' attitudes toward TCs in China with a broader research region and a more significant number of responses, according to the type of PH project and procurement methods.

Data Availability Statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments

This study is supported by the China Scholarship Council (No. 201606050102) and Faculty of Architecture and the Built Environment, Delft University of Technology. The second author is grateful for the Delft Technology Fellowship (2014–2020) generous funding support. The authors would also like to acknowledge the editing by Dr. Paul W. Fox of an earlier draft of this paper.

References

Adhikari, B., and J. C. Lovett. 2006. "Transaction costs and community-based natural resource management in Nepal." *J. Environ. Manage.* 78 (1): 5–15. https://doi.org/10.1016/j.jenvman.2005.04.005.

Antinori, C., and J. Sathaye. 2007. *Assessing transaction costs of project-based greenhouse gas emissions trading*. Berkeley, CA: Lawrence Berkeley National Laboratory.

Arif, M., and C. Egbu. 2010. "Making a case for offsite construction in China." *Eng. Constr. Archit. Manage.* 17 (6): 536–548. https://doi.org/10.1108/09699981011090170.

Badstue, L. B. 2004. *Identifying the factors that influence small-scale farmers' transaction costs in relation to seed acquisition*. ESA Working Papers 23800. Rome: Food and Agriculture Organization.

Blanca, M. J., R. Alarcon, J. Arnau, R. Bono, and R. Bendayan. 2017. "Non-normal data: Is ANOVA still a valid option?" *Psicothema* 29 (4): 552–557. https://doi.org/10.7334/psicothema2016.383.

Blismas, N. G., M. Pendlebury, A. Gibb, and C. Pasquire. 2005. "Constraints to the use of off-site production on construction projects." *Archit. Eng. Des. Manage.* 1 (3): 153–162. https://doi.org/10.1080/17452007.2005.9684590.

Brockhoff, K. 1992. "R&D cooperation between firms—A perceived transaction cost perspective." *Manage. Sci.* 38 (4): 514–524. https://doi.org/10.1287/mnsc.38.4.514.

Buitelaar, E. 2004. "A transaction-cost analysis of the land development process." *Urban Stud.* 41 (13): 2539–2553. https://doi.org/10.1080/0042098042000294556.

Carbonara, N., N. Costantino, and R. Pellegrino. 2016. "A transaction costs-based model to choose PPP procurement procedures." *Eng. Constr. Archit. Manage.* 23 (4): 491–510. https://doi.org/10.1108/ECAM-07-2014-0099.

Chang, Y., X. D. Li, E. Masanet, L. X. Zhang, Z. Y. Huang, and R. Ries. 2018. "Unlocking the green opportunity for prefabricated buildings and construction in China." *Resour. Conserv. Recycl.* 139 (Dec): 259–261. https://doi.org/10.1016/j.resconrec.2018.08.025.

Chiang, Y.-H., E. H. Chan, and L. K. Lok. 2006. "Prefabrication and barriers to entry—A case study of public housing and institutional buildings in Hong Kong." *Habitat Int.* 30 (3): 482–499. https://doi.org/10.1016/j.habitatint.2004.12.004.

China State Council. 2013. "Green building action plan." Accessed September 27, 2020. http://www.gov.cn/zwgk/2013-01/06/content_2305793.htm.

Chomchaiya, S., and V. Esichaikul. 2016. "Consolidated performance measurement framework for government e-procurement focusing on internal stakeholders." *Inf. Technol. People* 29 (2): 354–380. https://doi.org/10.1108/ITP-12-2013-0210.

Chongqing Statistics. 2018. *Chongqing statistical yearbook 2018*. Chongqing, China: Chongqing Statistics.

Dou, Y., X. Xue, Y. Wang, X. Luo, and S. Shang. 2019. "New media data-driven measurement for the development level of prefabricated construction in China." *J. Cleaner Prod.* 241 (Dec): 118353. https://doi.org/10.1016/j.jclepro.2019.118353.

Fan, K., E. H. W. Chan, and Q. K. Qian. 2018. "Transaction costs (TCs) in green building (GB) incentive schemes: Gross floor area (GFA) concession scheme in Hong Kong." *Energy Policy* 119 (Aug): 563–573. https://doi.org/10.1016/j.enpol.2018.04.054.

Field, A. 2018. *Discovering statistics using IBM SPSS statistics*. London: SAGE Publications.

Fisher, R. A. 1992. "Statistical methods for research workers." In *Breakthroughs in statistics*, 66–70. New York: Springer.

J. Constr. Eng. Manage., 2021, 147(1): 04020145

Gan, X. L., R. D. Chang, C. Langston, and T. Wen. 2019. "Exploring the interactions among factors impeding the diffusion of prefabricated building technologies: Fuzzy cognitive maps." *Eng. Constr. Archit. Manage.* 26 (3): 535–553. https://doi.org/10.1108/ECAM-05-2018-0198.

Goodier, C., and A. Gibb. 2007. "Future opportunities for offsite in the UK." *Constr. Manage. Econ.* 25 (6): 585–595. https://doi.org/10.1080/01446190601071821.

Gooding, L., and M. S. Gul. 2016. "Energy efficiency retrofitting services supply chains: A review of evolving demands from housing policy." *Energy Strategy Rev.* 11 (Jun): 29–40. https://doi.org/10.1016/j.esr.2016.06.003.

GOSC (General Office of the State Council of the People's Republic of China). 2014. *National plan on new urbanisation 2014–2020*. Beijing: GOSC.

GOSC (General Office of the State Council of the People's Republic of China). 2016. "Guiding opinions on vigorously developing prefabricated buildings." Accessed September 27, 2020. http://www.gov.cn/zhengce/ content/2016-09/30/content_5114118.htm.

Hong, J., G. Q. Shen, Z. Li, B. Zhang, and W. Zhang. 2018. "Barriers to promoting prefabricated construction in China: A cost-benefit analysis." *J. Cleaner Prod.* 172 (Jan): 649–660. https://doi.org/10.1016/j.jclepro.2017.10.171.

Ji, Y. B., F. D. Zhu, H. X. Li, and M. Al-Hussein. 2017. "Construction industrialization in China: Current profile and the prediction." *Appl. Sci.* 7 (2): 180. https://doi.org/10.3390/app7020180.

Jiang, W., L. Luo, Z. Wu, J. Fei, M. F. Antwi-Afari, and T. Yu. 2019. "An investigation of the effectiveness of prefabrication incentive policies in China." *Sustainability* 11 (19): 5149. https://doi.org/10.3390/su11195149.

Kamali, M., and K. Hewage. 2016. "Life cycle performance of modular buildings: A critical review." *Renewable Sustainable Energy Rev.* 62 (Sep): 1171–1183. https://doi.org/10.1016/j.rser.2016.05.031.

Ketokivi, M., and J. T. Mahoney. 2016. "Transaction cost economics as a constructive stakeholder theory." *Acad. Manage. Learn. Educ.* 15 (1): 123–138. https://doi.org/10.5465/amle.2015.0133.

Kiss, B. 2016. "Exploring transaction costs in passive house-oriented retrofitting." *J. Cleaner Prod.* 123 (Jun): 65–76. https://doi.org/10.1016/j.jclepro.2015.09.035.

Lai, Y., and B. Tang. 2016. "Institutional barriers to redevelopment of urban villages in China: A transaction cost perspective." *Land Use Policy* 58 (Dec): 482–490. https://doi.org/10.1016/j.landusepol.2016.08.009.

Lan, L., and Z. Lian. 2010. "Application of statistical power analysis—How to determine the right sample size in human health, comfort and productivity research." *Build. Environ.* 45 (5): 1202–1213. https://doi.org/10.1016/j.buildenv.2009.11.002.

Larsson, J., and P. Simonsson. 2012. "Barriers and drivers for increased use of off-site bridge construction in Sweden." In *Proc., 28th Annual ARCOM Conf.*, 3–5. Glasgow, UK: Association of Researchers in Construction Management.

Li, H., D. Arditi, and Z. Wang. 2013. "Factors that affect transaction costs in construction projects." *J. Constr. Eng. Manage.* 139 (1): 60–68. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000573.

Li, H., D. Arditi, and Z. Wang. 2015. "Determinants of transaction costs in construction projects." *J. Civ. Eng. Manage.* 21 (5): 548–558. https://doi.org/10.3846/13923730.2014.897973.

Lu, W. X., L. H. Zhang, and J. Pan. 2015. "Identification and analyses of hidden transaction costs in project dispute resolutions." *Int. J. Project Manage.* 33 (3): 711–718. https://doi.org/10.1016/j.ijproman.2014.08.009.

Mao, C., Q. Shen, W. Pan, and K. Ye. 2015. "Major barriers to off-site construction: The developer's perspective in China." *J. Manage. Eng.* 31 (3): 04014043. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000246.

Mao, C., F. Xie, L. Hou, P. Wu, J. Wang, and X. Wang. 2016. "Cost analysis for sustainable off-site construction based on a multiple-case study in China." *Habitat Int.* 57 (Oct): 215–222. https://doi.org/10.1016/j.habitatint.2016.08.002.

McCann, L. 2013. "Transaction costs and environmental policy design." *Ecol. Econ.* 88 (Apr): 253–262. https://doi.org/10.1016/j.ecolecon.2012.12.012.

Mettepenningen, E., V. Beckmann, and J. Eggers. 2011. "Public transaction costs of agri-environmental schemes and their determinants—Analysing stakeholders' involvement and perceptions." *Ecol. Econ.* 70 (4): 641–650. https://doi.org/10.1016/j.ecolecon.2010.10.007.

MOHURD (Ministry of Housing and Urban-Rural Development of the People's Republic of China). 2017. "Standard for the assessment of prefabricated building." Accessed September 27, 2020. http://www.mohurd.gov.cn/wjfb/201801/t20180122_234899.html.

Mundaca, L. 2007. "Transaction costs of tradable white certificate schemes: The energy efficiency commitment as case study." *Energy Policy* 35 (8): 4340–4354. https://doi.org/10.1016/j.enpol.2007.02.029.

Mundaca, T. L., M. Mansoz, L. Neij, and G. R. Timilsina. 2013. "Transaction costs analysis of low-carbon technologies." *Clim. Policy* 13 (4): 490–513. https://doi.org/10.1080/14693062.2013.781452.

O'Connor, J. T., W. J. O'Brien, and J. O. Choi. 2015. "Industrial project execution planning: Modularization versus stick-built." *Pract. Period. Struct. Des. Constr.* 21 (1): 04015014. https://doi.org/10.1061/(ASCE)SC.1943-5576.0000270.

Osei-Kyei, R., and A. P. C. Chan. 2017. "Perceptions of stakeholders on the critical success factors for operational management of public-private partnership projects." *Facilities* 35 (1–2): 21–38. https://doi.org/10.1108/F-10-2015-0072.

Pan, Y. H., and J. Xiong. 2009. "Housing industrialization in Chongqing: Considerations for alternative design." In *Proc., 2009 Int. Conf. on Information Management, Innovation Management and Industrial Engineering*, 117–120. New York: IEEE.

Qian, Q. K., E. H. W. Chan, and A. Khalid. 2015. "Challenges in delivering green building projects: Unearthing the transaction costs (TCs)." *Sustainability* 7 (4): 3615–3636. https://doi.org/10.3390/su7043615.

Sha, K. X. 2004. "Construction business system in China: An institutional transformation perspective." *Build. Res. Inf.* 32 (6): 529–537. https://doi.org/10.1080/0961321042000280778.

Simon, H. A. 1978. "Rationality as process and as product of thought." *Am. Econ. Rev.* 68 (2): 1–16.

Sojump. 2017. "Online questionnaire tool." Accessed September 2, 2017. http://www.sojump.com.

Tam, V. W., C. M. Tam, S. Zeng, and W. C. Ng. 2007. "Towards adoption of prefabrication in construction." *Build. Environ.* 42 (10): 3642–3654. https://doi.org/10.1016/j.buildenv.2006.10.003.

Tam, V. W. Y., I. W. H. Fung, M. C. P. Sing, and S. O. Ogunlana. 2015. "Best practice of prefabrication implementation in the Hong Kong public and private sectors." *J. Cleaner Prod.* 109 (Dec): 216–231. https://doi.org/10.1016/j.jclepro.2014.09.045.

UNEP (United Nations Environment Programme). 2013. *Afghanistan: Post-conflict environmental assessment*. Geneva: UNEP.

Walker, A., and C. Kwong Wing. 1999. "The relationship between construction project management theory and transaction cost economics." *Eng. Constr. Archit. Manage.* 6 (2): 166–176. https://doi.org/10.1108/eb021109.

Wang, J., and H. Yuan. 2011. "Factors affecting contractors' risk attitudes in construction projects: Case study from China." *Int. J. Project Manage.* 29 (2): 209–219. https://doi.org/10.1016/j.ijproman.2010.02.006.

Webster, C. J. 1998. "Public choice, Pigouvian and Coasian planning theory." *Urban Stud.* 35 (1): 53–75. https://doi.org/10.1080/0042098985078.

Williamson, O. E. 1981. "The modern corporation: Origins, evolution, attributes." *J. Econ. Lit.* 19 (4): 1537–1568.

Williamson, O. E. 1985. *The economic institutions of capitalism*. New York: Free Press.

Winch, G. 1989. "The construction firm and the construction project: A transaction cost approach." *Constr. Manage. Econ.* 7 (4): 331–345. https://doi.org/10.1080/01446198900000032.

Wu, G. B., R. Yang, L. Li, X. Bi, B. S. Liu, S. Y. Li, and S. X. Zhou. 2019a. "Factors influencing the application of prefabricated construction in China: From perspectives of technology promotion and cleaner production." *J. Cleaner Prod.* 219 (May): 753–762. https://doi.org/10.1016/j.jclepro.2019.02.110.

Wu, H. J., Q. K. Qian, A. Straub, and H. Visscher. 2019b. "Exploring transaction costs in the prefabricated housing supply chain in China." *J. Cleaner Prod.* 226 (Jul): 550–563. https://doi.org/10.1016/j.jclepro.2019.04.066.

Xue, H., S. Zhang, Y. Su, and Z. Wu. 2018a. "Capital cost optimization for prefabrication: A factor analysis evaluation model." *Sustainability* 10 (2): 159. https://doi.org/10.1016/j.jclepro.2018.08.190.

Xue, H., S. Zhang, Y. Su, Z. Wu, and R. J. Yang. 2018b. "Effect of stakeholder collaborative management on off-site construction cost performance." *J. Cleaner Prod.* 184 (May): 490–502. https://doi.org/10.1016/j.jclepro.2018.02.258.

Xue, X., X. Zhang, L. Wang, M. Skitmore, and Q. Wang. 2018c. "Analyzing collaborative relationships among industrialized construction technology innovation organizations: A combined SNA and SEM approach." *J. Cleaner Prod.* 173 (Feb): 265–277. https://doi.org/10.1016/j.jclepro.2017.01.009.

Zhai, X. L., R. Reed, and A. Mills. 2014. "Factors impeding the offsite production of housing construction in China: An investigation of current practice." *Constr. Manage. Econ.* 32 (1–2): 40–52. https://doi.org/10.1080/01446193.2013.787491.