The hindrances of using modular constructions in Sichuan Province of China: A comprehensive literature review

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Abstract. In global construction markets, environmental sustainability plays a significant role in the sustainable development goals (SDGs) presented by the United Nations. To improve building sustainability, an increasing number of investigations have indicated the effectiveness of replacing the cast-in-place building method with modular constructions. However, the practical promotion of modular constructions has been facing various obstacles, especially for those developing countries. This article aims to explore the main hindrances of using modular constructions in the Sichuan Province of China, where the construction conditions are more complicated than other Chinese regions. Through a comprehensive literature review, dozens of previous studies on the barriers of promoting modular constructions outline the critical hindrances in Sichuan’s construction industries. The top five interdependent factors are related to the higher initial costs, insufficient working experiences, high degree of dependency on cast-in-place methods, complexity of stakeholder management, and defective policy support. The research findings can assist in promoting the local modular constructions more smoothly, which can efficiently improve the environmental sustainability of Sichuan under SDGs. To consolidate the research findings and supplement other potential barriers, a formal questionnaire on cultural resistance of ethnic minority groups in Sichuan is required for further investigation.

1. Introduction

On a global scale, human beings are now facing the significant challenges of climate change which may cause systematic risks and destructions on the earth. Lachimpadi et al. (2012) point out that the construction industry has taken up over half of raw material consumption, producing a great many pollutants and construction wastes annually [1]. United Nations (2016) presents the scheme of SDGs for requiring the sustainable development of human being's activities, such as the construction and urbanisation [2]. It is essential to adjust construction methods for development projects to achieve this objective. Chiang et al. (2006) agree that the change in building methods can be regarded as an effective way of improving constriction sustainability performance [3].

In modular building projects, many building components are produced in the off-site factories, and the prefabricated panels will be transported for the on-site assembling and constitution (Gorse, Johnston & Pritchard 2020) [4]. The prefabricated and assembling process is the major difference from cast-in-place approach because this traditional way undertakes and completes most construction tasks on site. Lawson, Ogden and Bergin (2012) also demonstrate that the prefabricated construction can be used for both low-rise and high-rise buildings safely [5]. Figure 1 lists three reputable building
projects located in European, which proves the feasibility of using modular construction even on high-rise buildings.

As shown in Figure 2, Jiang et al. (2018) conduct a SWOT analysis of the modular construction, trying to figure out its main advantages and disadvantages [6]. Compared with the cast-in-situ method, the off-site constructions are more advantageous on the environmental performance and ecological sustainability, safety of on-site constructions, and reductions on the construction lifecycle and labour resources. Similarly, Cao et al. (2015) claim that modular construction can greatly improve building sustainability compared with the conventional cast-in-situ approach [7]. For example, this sustainable building method can efficiently decrease the use of raw materials, energy consumptions, and construction pollutants as well. Based on its significant advantages on the sustainable development, the wide application of modular construction ought to be the first choice for construction industries in many developing countries, such as China, India, and other industrialised countries.

This research aims to identify the barriers of adopting off-site constructions in the Sichuan Province of China. Jiang et al. (2018) claim that the wide adoption of prefabricated buildings in China still has faced the dilemma that most constructions would prefer to use traditional cast-in-place way of delivering projects [8]. Besides this, some studies are focusing on the barriers of promoting modular constructions in China, but these investigations do not specify the researched regions. Sichuan Province has the most complicated construction conditions and requirements compared with many other regions in China, so Sichuan is one of the most typical Chinese regions. The National Bureau of Statistics (2016) identifies the major reasons for causing its complexity, including the huge population and rapid growth rate, the most active seismic regions in China, and multiple ethnic minority groups and their diversity of cultural background [9]. Accordingly, this research is to evaluate and select the
typical hindrances of using modular constructions in Sichuan based on a critical literature review. The research findings can facilitate the transformation process of building methods in Sichuan from cast-in-place methods to sustainable prefabricated approach. In other words, the environment condition in Sichuan can be improved efficiently, such as the local air quality, emission of construction pollutants and energy consumptions. This research can also be used as a case study for other Chinese regions to promote modular construction more smoothly.

2. Materials and Methods
This research mainly uses the method of critical literature review. This qualitative approach can collect useful data from the online library via the University of Adelaide. Precisely, it mainly explores and organises the possible barriers of using modular buildings from previous studies focusing on similar research areas whatever for China or other foreign regions. In order to ensure the quality and authority of research findings, the secondary data are all collated from reputable journals, such as Journal of Cleaner Production and special issues of the International Journal of Building. If the factor has a higher frequency of occurrence during the comprehensive literature review, it will be ranked as influential high-level factors. Additionally, whether the safety concerns to the seismic conditions, which is the main feature in Sichuan, is also explored by assessing peer-reviewed articles and technical reports.

3. Results & Discussion
By reviewing 30 accredited journal articles and conference papers, the most frequent factors are selected, and the top ten most common hindrances are collated in Table 1. The defective policy support, insufficient working experiences, high degree of dependency on cast-in-place methods, complexity of stakeholder management, and higher initial costs are the top five reasons for causing the barriers of using modular construction in Sichuan of China.

Table 1. Typical hindrances while promoting the use of modular constructions in China

| No. | Impeding factors of using modular constructions in China               | Frequency |
|-----|-----------------------------------------------------------------------|-----------|
| 1   | Defective policy support                                              | 15        |
| 2   | Insufficient working experiences on off-site constructions             | 12        |
| 3   | The high degree of dependency on cast-in-place methods                | 10        |
| 4   | The complexity of stakeholder management                              | 8         |
| 5   | Higher initial costs                                                  | 7         |
| 6   | Supply chain management                                               | 6         |
| 7   | Social resistance from the enterprise perception                       | 4         |
| 8   | Underdeveloped technology for prefabrication                          | 4         |
| 9   | Local market mature                                                   | 3         |
| 10  | Inflexible changes during the building phases                          | 2         |

Additionally, the safety concerns to the structures are also excluded from the possible barriers of adopting modular construction. Deng et al. (2020) conduct a first-hand experiment on whether the high-rise modular buildings can present satisfying anti-earthquake performance during the multiple seismic activities [10]. The experimental results prove the eligible safety and feasibility of modular constructions on seismic regions. Thus, in Sichuan, the safety concerns to the seismic performance of modular building ought to be excluded from further studies as well.

4. Conclusion
Through the critical literature review on the dozens of accredited research articles, the five most influential factors of impeding the use of modular construction in Sichuan are identified as the defective policy support, insufficient working experiences on off-site constructions, a high degree of dependency on cast-in-place methods, the complexity of stakeholder management, and higher initial costs. Besides this, previous studies also prove the safety of seismic performance while using modular constructions in earthquake areas. Thus, the safety concerns related to the anti-earthquake performance
of modular constructions can be excluded from the possible hindrances in Sichuan. These research findings can help construction practitioners to promote the local modular constructions more efficiently, which is following the governmental requirements on the sustainable development of local construction industries. Meanwhile, the environmental sustainability of Sichuan could be improved following the government's requirements and SDGs. Besides, the concluded hindrances can also be cited by other Chinese provinces that they may have similar geology conditions and policymaking. To consolidate the research findings and supplement other potential barriers, a formal questionnaire on cultural resistance of ethnic minority groups in Sichuan is required for further investigation.

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