A bird's eye of Prefabricated Construction based on bibliometric analysis from 2010 to 2019

Yunping Huang1, Jinjiang Yan1 and Lingling Chen1*

1Business school, Sichuan University, Chengdu, Sichuan, 610065, China
1*Corresponding author’s e-mail: 2014576069@qq.com

Abstract. Prefabricated construction (PC) is an effective way to solve the unsustainable issues caused by conventional construction methods. To analyze the status and frontier dynamics of PC, this paper provides a bibliometric analysis of 1162 papers on PC publications from the Web of Science (WoS) database for the 2010-2019 period. In the paper, we firstly investigate the publication and citation structure of PC, then co-authorship network of countries/regions and institutes are detected as well. Finally, cited sources and research topics are explored by conducting co-citation network and co-occurrence network, respectively. This paper provides useful and new insights to summarize the progress of PC in a bird’s eye and brings a reference to the future development of PC.

1. Introduction
Prefabricated construction (PC) is considered to be an innovative construction method that can improve sustainable benefits, such as reducing carbon emission [1], decreasing labor costs [2], and shortening construction schedules [1, 3]. Research shows that the construction industry annually generates approximately 33% of carbon emissions, and consumes roughly 40% of global energy usage [4]. This indicates that the construction industry has a great potential in realizing environmental protection and energy conservation [5]. Therefore, the study of PC could help us to transform some disadvantages of the traditional construction industry into more sustainable development. And it’s important to know the latest trend and circumstances of PC so that better understanding can be grasped, especially for those researchers who want to have a quick and fuller picture in this field.

Bibliometrics uses statistics and visualization methods to explore the structures and patterns of certain disciplines [6]. An very early definition of this term provided by Pritchard is “the application of mathematics and statistical methods to books and other media communications.” [7] A more comprehensive definition proposed by White and McCain is that “bibliometrics is the quantitative study of the literature as they are reflected in bibliographies.” [8] According to yet another definition delivered by Broadus [9], bibliometrics is “the quantitative study of physical published units, or of bibliographic units, or of surrogates of either.” The ability of bibliometrics to classify all aspects of publications and their reported results in an organized form makes bibliometrics a popular method. And a wide range of topic categories have been analysed with bibliometrics, such as green innovation [10], green supply chain management [11], and building information modeling [12]. Additionally, this methodology not only can be applied in all of the fields of science but also is possible to review the performance of different journals [13, 14].

The existing research results show that the bibliometric analysis can find out a lot of valuable information, and this kind of study is of great significance. However, up to now, there are few studies for PC review and it is even less to analyse PC with methods of bibliometric analysis. This paper aims
to carry out an analysis for PC studies in the perspective of bibliometrics. The remainder of this paper is organized as follows: Section 2 studies the general citation structure and co-authorship network in countries/regions and institutes of PC. Section 3 explores the co-citation network of cited sources and research topics of this field. The concluding remarks are presented in last Section.

2. General analysis of the PC publications

This study uses the Thomson Reuters Web of Science database (WoS) (formerly the ISI Web of Knowledge), which is an online scientific information supporter. The search term used is “prefabricated construction”, and the results are chosed from core collection of WoS. There are 1162 publications in total from 2010 until now (5 November 2019). After choosing the database, the second step is to select the indicators to evaluate the sample obtained. The study focuses on the number of publications, citations, and h-index to measure productivity and influence [15]. The contributions of authors and institutes can be reflected by the number of publications. The numbers of citations and average citations often are correlated with the quality and influence of scholars. The H-index takes the quantity and quality of academic output into account simultaneously [16]. We then use biblioshiny, which is one application of R language, and Excel to help us do some statistics. VOS viewer software is also adopted in this paper as a visualising analysis tool.

2.1. Publication and citation structure of PC

The change of literature quantity is a direct response to the scientific knowledge quantity in this field. From 2010 to 2019, there are 1162 publications under PC theme. The changes over the past 10 years are shown in Figure 1, which shows that the overall number of publications has increased year by year. Between 2010 and 2014, the number of publications was less than 80, and there was a slight decrease in 2014(74) compared with that in 2013(78). Since 2015, the number of publications has gained its growth significantly, with 184 and 220 papers published in 2017 and 2018, respectively. The fitting curve $y = 57.085e^{0.3226x}$ R²  = 0.9678 shows that the cumulative amount of research literature in the field of PC is close to exponential growth, which reflects that PC is attracting more attention from scholars.

![Figure 1. Total publications (accumulated) and total citations.](image)

Table 1 shows the number of papers published on PC and their total citations. Additionally, by defining some thresholds, Table 1 identifies the range of highly cited papers relative to those with one or five citations. There are 3 papers that have more than 100 citations. In addition, 0.95% of the papers have received more than 50 citations, 23.41% and 51.46% of the papers have received more than five and one citations, respectively, implying that most PC publications have been noticed by scholars. In
terms of the number of citations from 2010 to 2019, we can observe that there are ups and downturns during this period, with a peak value reached in 2016 of 807 citations. It is understandable that the impact of publications from 2010 to 2016, with time goes by, was almost increasing year by year. But new publications need more time to catch up with, so it is natural that the H-index should decrease after a few years.

Table 1. Annual citation structure of the PC publications.

| Year | TP  | TC  | ≥100 | ≥50 | ≥20 | ≥10 | ≥5  | ≥1  | H-index |
|------|-----|-----|------|-----|-----|-----|-----|-----|---------|
| 2010 | 54  | 280 | 0    | 0   | 6   | 6   | 10  | 25  | 7       |
| 2011 | 54  | 388 | 0    | 1   | 6   | 14  | 20  | 29  | 12      |
| 2012 | 67  | 535 | 1    | 2   | 6   | 15  | 20  | 39  | 13      |
| 2013 | 78  | 541 | 2    | 2   | 9   | 16  | 23  | 38  | 11      |
| 2014 | 74  | 633 | 0    | 3   | 8   | 18  | 29  | 54  | 15      |
| 2015 | 110 | 711 | 0    | 3   | 12  | 19  | 33  | 71  | 15      |
| 2016 | 143 | 807 | 0    | 0   | 11  | 33  | 54  | 85  | 16      |
| 2017 | 184 | 624 | 0    | 0   | 5   | 22  | 50  | 109 | 12      |
| 2018 | 220 | 497 | 0    | 0   | 4   | 13  | 26  | 111 | 12      |
| 2019 | 178 | 96  | 0    | 0   | 0   | 2   | 7   | 37  | 5       |
| Total| 1162| 5112| 3    | 11  | 67  | 158 | 272 | 598 | 118     |

| Percentage | 100% | 100% | 0.26% | 0.95% | 5.77% | 13.60% | 23.41% | 51.46% |

| aTotal publications.  |
| bTotal citations.    |

2.2. Co-authorship network of countries/regions, institutes

In this part, we discuss the influential countries/regions and institutes through co-authorship network of PC publications. At present, co-authorship has enjoyed its popularity as the most common way of cooperation, and international country/regions co-authorship is an essential form of co-authorship. It can be found which are active country/regions from the international country co-authorship network. Furthermore, international co-authored articles normally have a good performance both in numbers and citations [17].

To this end, this study uses VOSviewer software. In Figure 2, a node represents a country/region, and the size of the node represents the weight of the country/region. When two countries/regions have a cooperation relationship, a line is established, and the thickness of the line reflects the degree of cooperation between them. We set the threshold at 6, then there are 36 countries meeting the requirement. The VOSviewer software divides these 33 nodes into 8 clusters (3 items are not connected). One color means one cluster. As we can observe from Figure 1, China, the USA, Australia, and Germany are the biggest nodes. Denmark and Sweden belong to the green cluster. Spain and Portugal belong to yellow cluster. Therefore, geographical proximity is an important factor that determines international cooperation. In addition, China has thick belts with Australia and England. It indicates that increasing international exchanges have promoted academic communications nowadays. An increasing number of scholars in the field of PC choose to go abroad for further studies and academic visits, especially for China, Australia and England.
In Figure 3, we also show the co-authored network of the institutes. There are 1185 institutes with publications under the theme of PC. After setting the threshold of publications at 5, 44 related institutions are selected. Vosviewer software divides the 44 institutes into 10 clusters. Hong Kong Polytechnic University, Chongqing University, Shenzhen University and Melbourne University are the four largest nodes in Figure 3. Monash University, University of Trento and Royal Melbourne Institute of Technology University are in orange cluster. Beijing Jiaotong University and Tsinghua University are near to each other. It can be concluded that language and geographical proximity are essential factors affecting university cooperation.
3. Co-citation network of cited sources and research topics
To gain a picture which journals are more influential and what are hot topics in PC, we present the co-citation network of cited sources and keywords occurrence as follows.

3.1. Co-citation network of cited sources of PC
Co-citation analysis was first introduced by Small [18]. A co-citation relationship is established when two journals appear in the references of one publication simultaneously. In general, if two journals have a co-citation relationship, they are similar to some extent. We show the co-citation network of cited sources in Figure 4. We set the threshold at 20, and 125 journals are selected for inclusion in Figure 4. Different colors represent different clusters as mentioned above. VOSviewer software divides these 125 sources into 5 clusters. It is noteworthy that Construction and Building Materials, Automation in Construction, Energy and Buildings, Engineering Structures are the main sources of PC publications. To gain a deeper view into the graph, We provide the top 10 highly cited sources in Table 2. Link strength is the frequency with which two journals appear in one publication simultaneously. As can be seen. Automation in Construction is the leading journal on this list, with 727 citations. It is followed by Energy and Buildings, Construction and Building Materials whose citations are 509 and 467, respectively. It’s interesting to point that not all of those sources with higher citations have better performance in total link strength, such as the fourth and fifth one in Table 2, indicating that numbers of co-citations and citations are just relevant at some levels.

Figure 4. Co-citation network of cited sources of PC.

Table 2. Top 10 highly cited sources of PC publications.

| Rank | Source                                      | Citations | Total Link Strength |
|------|---------------------------------------------|-----------|---------------------|
| 1    | Automation in Construction                  | 727       | 17208               |
| 2    | Energy and Buildings                        | 509       | 10262               |
| 3    | Construction and Building Materials         | 467       | 8505                |
| 4    | Engineering Structures                      | 454       | 10301               |
| 5    | Journal of Cleaner Production               | 451       | 14172               |
| 6    | Thesis                                      | 406       | 5814                |
| 7    | Building and Environment                    | 396       | 9437                |
| 8    | Journal of Constructional Steel Research    | 276       | 5080                |
| 9    | PCI Journal                                 | 249       | 6762                |
| 10   | Journal of Construction Engineering and Management-Asce | 245 | 7092 |
3.2. Keywords occurrence network of PC
The keywords occurrence network summarizes the main purpose of the literature, thus hotspots and research trends can be captured to a certain extent [19]. We investigate the frequently used keywords so as to identify the main research topics of PC. It should be pointed out that here we only analyze the keywords provided by the author. According to the results from VOSviewer, there are 3366 key words, and we set the minimum number of co-occurrences of a word at 5, then 81 items meet the threshold. And VOSviewer software divides these 81 key words into 14 clusters. The biggest node is “prefabrication”, Some other keywords are energy efficiency, sustainability, bim, life cycle assessment, accelerated bridge construction, seismic performance and so on. The above keywords represent the main topics of PC. In addition, there are some thick lines in the network, for example, the connections between sustainability and prefabrication, sustainability and energy efficiency, prefabricated construction and bim, indicating that these key words appear frequently in the same publication.

4. Concluding remarks
This study conducts a bibliometric overview of publications on PC from 2010 to 2019. And the WoS core collection database was used to analyse publications in the period mentioned above. The work includes four analyses: publication and citation structures, co-authorship network of countries/regions and institutes, co-citation network of cited sources, and keywords occurrence analysis. Several counterpart points can be concluded from the results:
• The field of PC has experienced substantial growth in past 10 years, especially after 2014, which reflects a noteworthy influence in this domain. The citations of PC publications in the recent 2 years still need time to catch up with that in earlier years.
• China, the USA, Australia, and Germany are the most active countries in PC publications. Hong Kong Polytechnic University, Chongqing University, Shenzhen University and Melbourne University are the most influential institutes. Language and geographical proximity are essential factors affecting cooperation.
• Energy efficiency, sustainability, bim, life cycle assessment, accelerated bridge construction, seismic performance are the most frequently key words in PC publications.

This paper aims to present the data of PC publications from different perspectives, so readers can understand PC field better according to his or her interests and priorities. Nevertheless, limitations exist due to a few issues surveyed in this work. Such as the database, this research is based on a sample of documents published in the WoS. However, there are many studies related to PC which are published
in non-indexed journals that are not accessible through the WoS database. And the results giving a picture of the current situation may change over time, especially for the publications in the past two years.

**References**

[1] Jeong, J., et al. (2017) An integrated evaluation of productivity, cost and CO2 emission between prefabricated and conventional columns. Journal of Cleaner Production., **142**: 2393-2406.

[2] Hong, J., et al. (2018) Barriers to promoting prefabricated construction in China: A cost-benefit analysis. Journal of Cleaner Production., **172**: 649-660.

[3] Ahmad, S. and R.M. Tahar. (2014) Selection of renewable energy sources for sustainable development of electricity generation system using analytic hierarchy process: A case of Malaysia. Renewable Energy., **63**: 458-466.

[4] Pan, W. and H. Garmston. (2012) Compliance with building energy regulations for new-build dwellings. Energy., **48**(1): 11-22.

[5] Liu, G., et al. (2019) A production line-based carbon emission assessment model for prefabricated components in China. Journal of Cleaner Production., **209**: 30-39.

[6] Moed, H.F., R.E. Debruin, and T.N. Vanleeuwen. (1995) New bibliometric tools for the assessment of national research performance - database description, overview of indicators and first applications. Scientometrics., **33**(3): 381-422.

[7] Pritchard, A. (1969) Statistical bibliography or bibliometrics. Journal of Documentation., **25**(4): 348-+.

[8] White, H.D. and K.W. McCain. (1989) Bibliometrics. Annual Review of Information Science and Technology., **24**: 119-186.

[9] Broadus, R.N. (1987) Toward a definition of bibliometrics. Scientometrics., **12**(5-6): 373-379.

[10] Albert-Morant, G., et al. (2017) Mapping the field: A bibliometric analysis of green innovation. Sustainability., **9**(6).

[11] Taticchi, P., et al. (2015) A review of decision-support tools and performance measurement and sustainable supply chain management. International Journal of Production Research., **53**(21): 6473-6494.

[12] Li, X., et al. (2017) Mapping the knowledge domains of Building Information Modeling (BIM): A bibliometric approach. Automation in Construction., **84**: 195-206.

[13] Tang, M., et al. (2018) Ten years of sustainability (2009 to 2018): A bibliometric overview. Sustainability., **10**(5).

[14] Yu, D., Z. Xu, and J. Antucheviciene. (2019) Bibliometric analysis of the journal of civil engineering and management between 2008 and 2018. Journal of Civil Engineering and Management., **25**(5): 402-410.

[15] Blanco-Mesa, F., J.M. Merigo, and A.M. Gil-Lafuente. (2017) Fuzzy decision making: A bibliometric-based review. Journal of Intelligent & Fuzzy Systems., **32**(3): 2033-2050.

[16] Hirsch, J.E. (2005) An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America., **102**(46): 16569-16572.

[17] Fornell, C. and D.F. Larcker. (1981) Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research., **18**(1): 39-50.

[18] Small, H. (1973) Cocitation in scientific literature - new measure of relationship between 2 documents. Journal of the American Society for Information Science., **24**(4): 265-269.

[19] Li, H., et al. (2016) Evolutionary features of academic articles co-keyword network and keywords co-occurrence network: Based on two-mode affiliation network. Physica a-Statistical Mechanics and Its Applications., **450**: 657-669.