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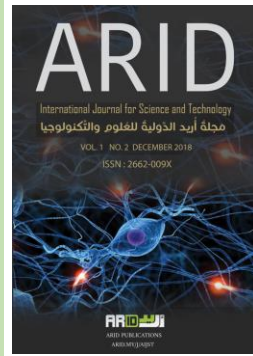


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INDUSTRIALIZED BUILDING SYSTEMS: A BIBLIOMETRIC ANALYSIS FROM 1980 TO 2017

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ABSTRACT

Industrialized building system (IBS) is an innovative building technology that provides faster, cleaner, neater, and more quality construction. Bibliometric quantification has been done to determine the amount of publications for this novel research area considering the scientific literature that are available from the Web of Science and to find the most common terms in this field to enable the researchers to study all the available terms. Bibliometric study is a new trend in scientific publication which statistically analyses the available published scientific paper and provide valuable information about changes in the trends in any field of study. As a result, the researchers have found that the number of publications in the field of industrialized building increased in the last decade. It is also found that the same system has different terms which represent industrialization of construction among the different countries. Industrialized building or industrialized building, Manufactured homes or Manufactured housing, Modern Methods of Construction (MMC), Modular building or Modular construction or Modular houses or modular homes, Offsite Manufacture/Manufacturing, Offsite Construction or Offsite Production or Offsite Fabrication, Prefabrication or Prefabricated and Relocatable homes/houses are different terms that used to refer to the same process that includes manufacturing all or some of buildings' elements and then transport and install them at construction site. The distribution of publications among the countries has been swung. The term of "Prefabrication" or "Prefabricated" is widely used in China and the U.S., whereas, about 70% of the publications that used the term of "Industrialized building" or "Industrialised building" are from Malaysia. Moreover, there is a noticeable increment in the number of countries that conducted researches in this field.

KEYWORDS: *industrialized building system, bibliometric study, prefabricated building system, modular buildings.*

1. Introduction:

The early attempt of applying industrialized construction was found in the previous century, when steel beams joined with precast slab panels and used for fast construction of high-rise buildings in the United States of America [1]. Moreover, in Europe, after the demolition that brought by the Second World War, there was a critical deficiency in housing units, skilled workers and construction materials. The need for using fast and economic construction system was very urgent. Therefore, the use of prefabricated system was adopted and turned to be more popular to solve housing problems [2].

In Malaysia, the Traditional Malay House (TMH) was a very common type of housing in the past. The components of these houses were prepared before construction, including the columns, beams, walls, floors and roofs. These houses provided the concept of modularity and repetitiveness that had helped in the development of construction industrialization.

The first official company that produced standard designs of traditional Malay houses in Malaysia was Kayu Sedia (KS) company, which was established in 1968. One of the products of this company was the readymade houses with affordable prices and variations in design. Kayu Sedia Company was considered as an IBS manufacturer because of standard design modules, applying standard dimensioning systems (Imperial foot and inch), mass-production based on standard design modules, and in factory and high-quality production [3].

With the development, prosperity and tremendous increase in population, demand for housing have been increased all over the world. The conventional construction method was not able to meet these demands due to the slow pace of construction and high costs [4]. Therefore, adopting novel

technology for construction has become the preferable plan for the developed and some developing countries.

The new innovative construction technology was proposed in several studies as the solution to meet the intensive demands for buildings and providing valuable advantages such as providing in-factory quality control, decreasing construction time, minimizing the dependency on foreign workers, increasing safety during work and increasing cleanness and neatness at the construction site [5, 6]. These advantages have encouraged the developers to use the new system in their projects [7]. In addition, it is proved that IBS has a better advantage in terms of sustainability issue by reducing embodied energy (MJ) and Global Warming Potential (GWP) towards a low carbon development [8].

However, some obstacles are still facing this technology. In view of Ariffin consider [9], it is proved that the industry is still in a confronting issue regarding the application of IBS through the use of classic method of procurement. As there is a development in the technology of construction through the utilization of new industrialized method, new and suitable project procurement is required to achieve successful projects effectively. As each task is one of a kind and dynamic in term of procedures, hazard presentation and obligations between all gatherings in this manner the need of having a standard type of agreement for IBS. Moreover, the study of Yunus and Yang [10] showed that there is a lack of incentives and regulatory procedures in IBS implementation, a fragmentation of authority and little concern on sustainability issues. In term of developing industrialized building system, the study of Mahbub [11] showed that the building that are built using such methods needs total integration of all subsystems and components into an overall process which include design considerations, industrialized components production in the factory, transportation, and assembly techniques.

1.1 The definition of industrialization in construction

Several studies have written in the definition of prefabrication and industrialization in construction; however, Kamar [7] concluded that all the previous definitions did not cover all the characteristic of prefabrication process that are: “industrialization in production, transportation and assembly technique, onsite fabrication, mass production, structured planning and standardization, and process integration”. The author developed a new comprehensive definition for this type of building technology that is “a process of building construction using the concept of mass-production through industrialized systems, produced at the factory or onsite within controlled environments, including the logistics and assembly aspects of it, done in appropriate coordination with thorough planning and integration”.

1.2 Terminology of industrialization in construction

A study of Steinhardt, Manley [12] showed that there are different terms that all represent industrialization of construction among the different countries. With the context of Malaysia, industrialized building system (IBS) has become a common term that used widely by the researchers, the government and the construction industry [7, 13-15]. The same term has been used in literature that refers to Israel construction [16] and in Indonesia [17]. Moreover, industrialised housing and Industrialised building is prominently used in Sweden and other European countries since the early 2000’s to represent offsite manufacturing of materials, supplier coordination, and the systematization of build processes [18], and historically used in the 1970s and 80s in New

Zealand [19]. As similar term that is industrialised homebuilding is used in the United States to refer to both modular and manufactured housing [20].

Kit homes, Kitset homes and Flat-pack kit homes have been used for partially prefabricated materials in New Zealand, Australia and the United States [19, 21]. Manufactured homes/housing is another term that used in the U.S. to refer to relocatable, typically low-quality homes built in a factory including an integral chassis for transporting the structure on wheels [22,23]. The same term is also used in Australia to refer to houses built in a factory, inconsistently covering both temporary structures installed in caravan parks and villages [24].

Modern Methods of Construction (MMC) is used in the United Kingdom which refers to both offsite work and onsite efficiency improvements [25, 26]. Modular building, Modular construction and Modular houses/homes is used widely in the United Kingdom, Australia, Canada and the United States [27, 29].

Offsite Manufacture or Offsite Manufacturing (OSM) is used widely in the United Kingdom and Australia [27, 29-31]. The same term is also used in Germany [32]. Other terms like Offsite Construction (OSC), Offsite Production (OSP) and Offsite Fabrication (OSF) can be interchange with Offsite Manufacturing used in numerous contexts [27]. Prefabrication or Prefabricated is widely used term with varying interpretations [19, 27, 33]. Relocatable homes/houses and Transportable homes/houses terms are commonly used in Australia and New Zealand to refer to houses completely prefabricated offsite and delivered to site fully finished [19]. Preassembly is less commonly used term [27].

2. Methodology

The researchers used the Web of Science (<http://www.isiknowledge.com>) Core Collection to search for publications in industrialized building system. All the terms that mentioned by related previous studies which refer to the concept of off-site construction across the global construction industry and represent industrialization in construction have been used as keywords for the search. The terms of “industrialized build*” or “industrialised build*”, “manufactured home*” or “manufactured house*”, “modular build*” or “modular construction*” or “modular house*” or “modular home*”, “Prefabricate*”, “modern methods of construction”, “offsite manufacture*”, “offsite Construction”, “offsite Production”, “offsite fabrication” and “offsite building*”, “preassembly”, “relocatable home*” or “relocated house*”, “transportable home*” or “transportable house*”, “kit home*” or “kitset home*” and “flat-pack kit home*” have been used specifically.

Searching using these keywords were conducted on the title, abstract, and keyword sections of published studies. The search was done in all languages to cover the global publications in this field. The rationale of choosing Web of Science Core Collection because the peer-review process at this data base provides a judicious filter for accurate scientific work. There are large number of conference papers that are published frequently, however, these papers are less Scientifically accredited [34]. Additionally, large amount of review studies in the construction domain have conducted their research studies based solely on articles in top ranked journals [35].

On 31th of November 2017, a total of 759 journal articles were identified, for which all bibliometric data were extracted and downloaded from Web of Science, forming the dataset utilized in the recent study.

A large number of science mapping tools for bibliometric analysis are available [30] and each tool has its efficiency and strength. In this study, StatPlanet software will be used as it is a freely available tool that offers the basic functional needs for visualizing bibliometric analysis within a single friendly intuitive interface and can provide integrated interactive maps and graphs. Using this software, the researches can extract the total number of publications each year, the geographical locations of authors, and research areas directly from Web of Science.

The search has been done to looking for data in Science Citation Index Expanded (SCI-EXPANDED) --1980-2017, Social Sciences Citation Index (SSCI) --1980-2017, Arts & Humanities Citation Index (A&HCI) --1980-2017, Conference Proceedings Citation Index-Science (CPCI-S) --2004-2017, Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH) --2004-2017, Emerging Sources Citation Index (ESCI) --2015-2017.

All the related categories are refined to exclude studies that are not linked to the topic. The related categories are: civil engineering, engineering environmental, architecture, construction building technology, engineering multidisciplinary, green sustainable science technology, environmental studies, urban studies, planning development, engineering industrial, material science, engineering manufacturing.

3. Results and Discussions

One of the objectives of this study is to find the most popular terms that is used to represent industrialization in construction, so the researchers in this field can study all the available terms. Table (1) shows the number of the studies for each term of industrialization in construction.

Table 1: Number of the studies for each term that represent industrialization in construction

Terms	Number of studies	Highest publication countries
Prefabrication or Prefabricated	508	China (145 study)
Modular building, Modular construction and Modular houses/homes	118	The U.S. (25 study)
Industrialized building or industrialised building	68	Malaysia (46 study)
Manufactured homes/housing	44	The U.S. (31 study)
Modern Methods of Construction	12	Slovakia (8 studies)
Offsite Manufacture or Offsite Manufacturing (OSM), Offsite Construction (OSC), Offsite Production (OSP), Offsite Fabrication (OSF) and Offsite Building	6	England (4 studies)
Preassembly	2	The U.S.
Relocatable homes/houses	1	Australia
Transportable homes/houses	0	
Kit homes, Kitset homes and Flat-pack kit homes	0	
Total	759	

The results showed that the term of prefabricated or prefabrication is the most popular term as it has the highest publication around the world (508 studies). The country that has the most publication is China which has 145 studies. Figure (1) shows the distribution of publications that used prefabricated or prefabrication term around the world (from 1980 to 2017).

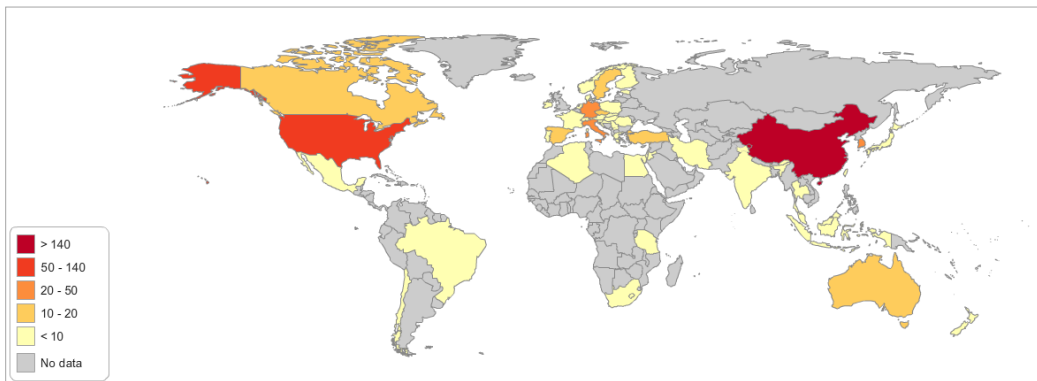


Figure 1: Number of publications that used prefabricated or prefabrication term per country (from 1980 to 2017)

According to this study, the publications that used the term of prefabricated or prefabrication were meager during the eighties and nineties, then started to increase after the year of 2005. The year of 2016 has the highest publication in this field as shown in Figure (2).

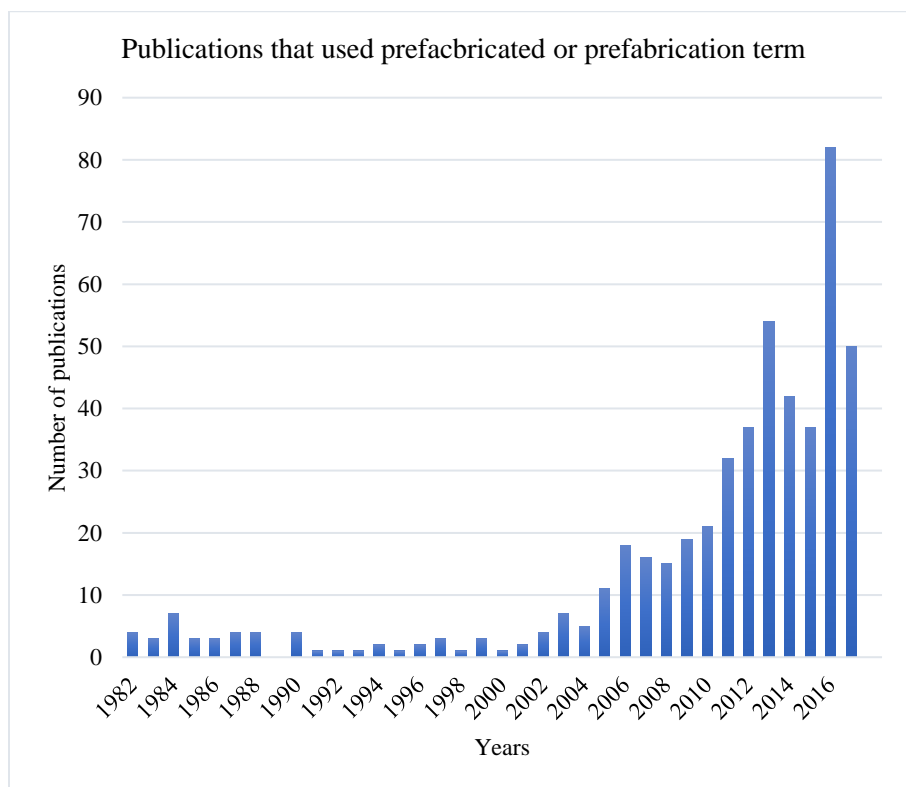


Figure 2: Number of publications that used prefabricated or prefabrication terms from 1980 to 2017

The second common terms are Modular building, Modular construction and Modular houses/homes that has 118 publications which are commonly used in the United States of America. Figure (3) shows the distribution of the publications around the world that used Modular terms from 1980 to 2017.

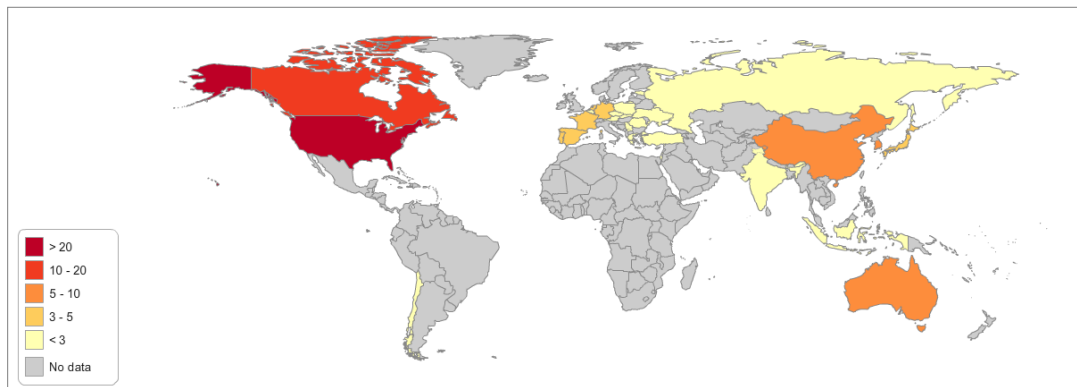


Figure 3: Number of publications that used Modular terms per country (from 1980 to 2017)

The publications that used these terms were oscillatory during the studied period. The year that has the highest publication in this field is 2016, as shown in Figure (4).

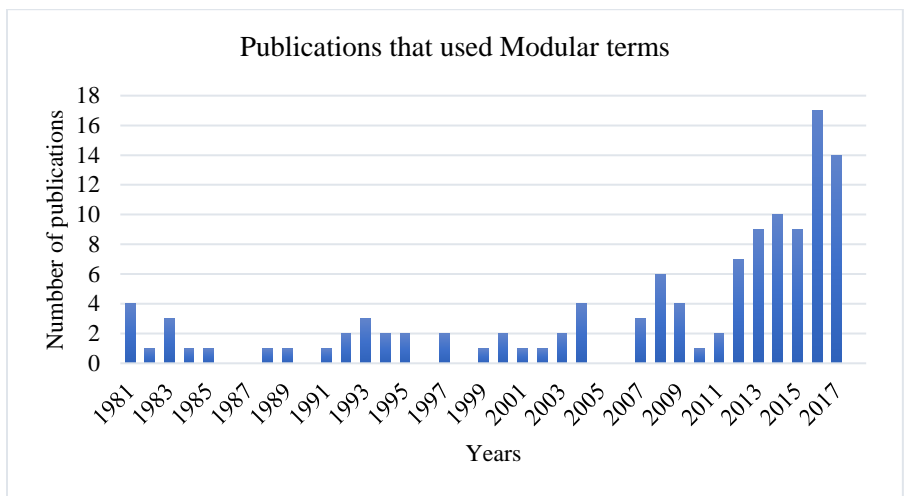


Figure (4) Number of publications that used Modular terms from 1980 to 2017

Next is the term of ‘Industrialized (or industrialised) building’ that has 68 studies. This term is widely used in Malaysia (46 studies). Figure (5) shows the distribution of the publications that used this term around the world from 1980 to 2017.

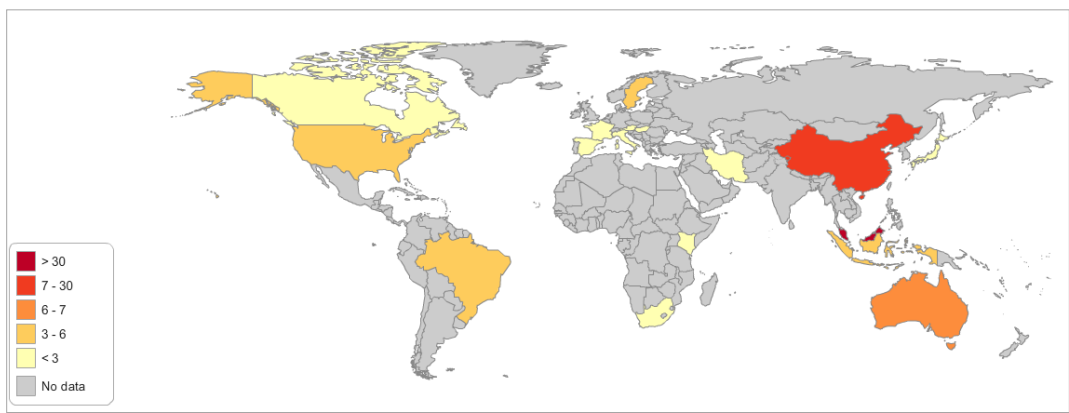


Figure 5: Number of publications that used industrialized or industrialised building terms per country (from 1980 to 2017)

The publication that used industrialized or industrialised building terms were in small number during the eighties. Then, the publications in this field were rarely used in the nineties and early 2000. Thereafter, the publications started to increase after 2005. The highest years of publications in this field were 2014 and 2016 as shown in Figure (6).



Figure 6: Number of publications that used industrialized or industrialised building terms from 1980 to 2017

According to table (1), Manufactured homes or housing term has 44 publications (used mostly in the U.S.), whereas Modern Methods of Construction term is used by 12 studies only. Other terms including Offsite Manufacture or Offsite Manufacturing (OSM), Offsite Construction (OSC), Offsite Production (OSP), Offsite Fabrication (OSF) and Offsite Building have been used by 6 studies. 2 and 1 studies have used the terms Preassembly and Relocatable homes or houses respectively. Transportable homes or houses and Kit homes, Kitset homes and Flat-pack kit homes have no publication in the web of science, however, these terms were mentioned in the previous studies [19, 21]

It is noticed that the research in this area is getting more attention as the publications are increasing in recent years. This conclusion is in line with the study of Kamar [7] who mentioned that upgrading the construction process through industrialization is a worldwide plan to enhance construction accomplishment and improvement. Moreover, this indicates that there is a governments' guidance to increase the implementation of industrialized building system. A good example of that is the announcement of Malaysian government in 2015 to accelerate the adoption of modern technologies for construction including the use of industrialized building system [36].

4. Conclusion:

The researches in Industrialized building field has received an increasing attention in the last decade as it is new building technology that offers numerous advantages. Bibliometric study has been conducted to search for all the terms that represent industrialization in construction. During the recent years, it is obvious that the publications in this area of research are increasing noticeably in all the terms that refer to this type of construction technology. The most common term around the world is Prefabricated or Prefabrication, followed by Modular building, Modular construction and Modular houses/homes. Industrialized or industrialized building term is most popular term in Malaysia. Some terms have been mentioned in previous studies, however, no related study was found in our search.

List of Abbreviations

IBS	Industrialized building system
MMC	Modern Methods of Construction
TMH	Traditional Malay House
KS	Kayu Sedia
MJ	embodied energy
GWP	Global Warming Potential
OSM	Offsite Manufacture or Offsite Manufacturing
SCI-EXPANDED	Science Citation Index Expanded
SSCI	Social Sciences Citation Index
A&HCI	Arts & Humanities Citation Index
CPCI-S	Conference Proceedings Citation Index-Science
CPCI-SSH	Conference Proceedings Citation Index-Social Science & Humanities
ESCI	Emerging Sources Citation Index
OSM	Offsite Manufacture or Offsite Manufacturing
OSC	Offsite Construction
OSP	Offsite Production
OSF	Offsite Fabrication
U.S.	United States of America

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