Enablers and Inhibitors of Prefabrication Construction for Housing: An Overview

OLOTO, ENITAN; * ADEBAYO ,ANTHONY AND IWEKA ,ANTHONY
Department of Architecture, University of Lagos, Akoka, Nigeria
Author for correspondence*: enylegacy@yahoo.com

Prefabrication enablers and inhibitors in the housing construction sector differ over time and vary from country to country. To adopt this technology, awareness on current trends and the latest innovations should be increased by reviewing previous studies. The objective of this study is to conduct a revision of common enablers and inhibitors of prefabrication adoption, taking into consideration the experience gained and reported by several developing countries. The study captures common enablers and inhibitors of prefabrication in Nigeria, with 4 developing countries within the research, as very little literatures exists that identifies perceived factors that encourage the adoption of prefabrication, which are unique to the Nigeria housing construction industry. The study adopts a literature survey qualitative technique, with 24 current literature researches on prefabrication and its enabling and inhibiting factors towards implementation and adoption randomly selected and reviewed in order to capture, and analyse similar trends which cut across 4 identified developing countries located in Asia and Africa. Results showed that technical factors were predominantly the highest ranking factors that influenced the adoption or deterrent of prefabrication. Though other factors are important, further investigation on the technical factors and the development of strategies for eliminating inhibiting factors and improving on the enabling factors is required. Prefabrication enablers should be improved upon by continuously meeting clients' needs and respond to the global, social and environmental challenges, thereby preparing grounds for organizations to find out ways of reducing the inhibitors and ensuring a smooth transition to prefabrication construction based project delivery.

Keywords: Enablers, Inhibitors, Prefabrication, Housing Construction Industry

INTRODUCTION

There is an advocate for a radical change in housing delivery methods in several developed countries, including the UK, USA, Australia, and South Africa (Rahimiana, Goulding, Akintoye, & Kolo, 2017). This change suggests that a paradigm shift from the conventional construction approach to a more innovative housing production processes like prefabrication should be adopted (Dada, 2013). Distinct benefits of using offsite production like greater certainty of outcomes, deliveries and effective costs control, time compression of site activities, improved site logistics, quality benefits, reduction of snagging and rework , and health and safety benefits (Tezel, Koskela, Gosling, & Kumar, 2017), are some of the many reasons for this suggestive shift in innovative housing construction methodology. However, reviews made by this study on current research by various scholars (Elnaas, 2014; Blismas, Pasquire, & Gibb, 2006; Navaratnam, Ngo, Gunawardena, & Henderson, 2019) show the incentives for adopting prefabrication may differ in different regions (Xiahou, Yuan, Liu, Tang, & Li, 2018). El-Abidi and Ghazalia (2015) equally stated that based on previous studies, prefabricated building usage motivations in the construction sector differ over time and vary from country to country. While the promotion of prefabrication in developing countries is still at the initial stage (Adebayo & Dixon-Ogebchi, 2017), a systematical analysis of the enabling and inhibiting factors would help decision makers get a comprehensive understanding of prefabrication development and select proper strategies to promote this construction method. As cities evolve and exponentially expand, the need for space to live, work, and play remains the same. How the housing construction industry organizes, arranges, designs, and builds those spaces, however, inevitably needs to be revolutionized. With cities worldwide on the cusp of one of the largest building sprees in history, architects, engineers, and construction workers need to be ready for radical change. The 2018 Revision of World Urbanization Prospects produced by the Population Division of the UN Department of Economic and Social Affairs (UN DESA) notes that future increase in the size of the world's urban population are expected to be highly concentrated in just a few countries like India, China and Nigeria, who will account for 35% of the projected growth of the world's urban population between 2018 and 2050 (United Nations, 2018). Rapid population growth is

therefore leading to a major and inevitable demand for new urban infrastructure in many large developing cities in Africa, South America and Asia (Muggah & Hill, 2018). These developing cities are not void of housing shortage.

People need safer and more comfortable places to live, and prices need to be reasonable. Prefabrication construction is a cost-efficient, fast and sustainable building technology for large housing projects that don't compromise on quality and can solve housing shortage issues pertinent in developing countries. Recent calls have been launched worldwide for the "revival" of innovative approaches such as the prefabrication building system (Pan, Gibb, & Dainty, 2008), which is under numerous nomenclatures in different countries like the UK and Malaysia, who refer to this technology as an Offsite Modern Method of Construction (offsite-MMC) (Alonso-Zandari & Hashemi , 2016) and Industrialize Building Method (IBM) (Kamar, Azman, & Nawi, 2014) respectively, in order to improve construction within the housing industry, meet market demand; and furthermore, overcome the dependence on skilled labour. Despite the well documented benefits of prefabrication as a method for advancing housing construction output (Blismas & Wakefield, 2009; Alazzaz & Whyte, 2014; Pasquire, Gibb, & Blimass, 2004; Heinz & Wamelink, 2015), this method of housing construction witnesses factors that inhibit its adoption for sustainable housing development. This paper provides a review of academic work done in the area of prefabrication within four selected developing countries: India, China, Malaysia, and Nigeria. This is because these countries have on-going economic activities, current initiatives to import construction materials, increasing interest of researchers in understating the adoption of prefabrication so that lessons could be learned, and knowledge transfer between developing and developed countries within the area of new methods of construction including prefabrication. The literature reviewed from these countries, hope to give more insight into the similarity, difference and uniqueness of the factors that enable or inhibit prefabrication adoption.

Prefabrication Construction Method: Definition and Overview

Over the past few decades, the construction sector in several nations has experienced poor performance and low productivity (Nadim & Goulding, 2010). The labour intensive nature of the industry and shrinking levels of professional skills and craftsmanship has been key factors hampering productivity growth (Abdel-Wahab & Vogl, 2011). As a way forward in resolving the problem of productivity, limitations to traditional on-site construction has been the introduction of off-site construction methods such as prefabrication and modularization with a view to increase efficiency and standardize the management of quality (Alazzaz & Whyte, 2012). It is increasingly becoming a major alternative technique and strategic direction compared to the traditional in-situ method (Alazzaz & Whyte, 2014).

Prefabrication in housing construction is defined in different ways by different authors. However, some of the definitions are narrowed in explanations, yet in line with general definitions. On the one hand, Tatum (1986) defines prefabrication as the transferring stage of construction activities from field to an off-site production facility. A more detailed definition given by Björnfot and Sardén (2008) is that prefabrication is the making of construction components at a place different from the point of final assembly, and may lead to better control of the inherent complexity within the construction process. On the other, Chiang, Cahn, and Lok (2006) define prefabrication as manufacturing and pre-assembly process, generally taking place at a specialized facility, in which various materials are joined to form a component part of the final installation. It can also be defined as a manufacturing and pre-assembly process, whereby, construction components are made at a location different from the place of final assembly, under specialized facilities with different materials, may lead to better control of the inherent complexity within the construction process (Senaratne, Ekanayake, & Siriwardena,

2010). The Modular Building Institute defines "prefabrication" as the process of manufacturing and assembling the major building components at remote offsite locations for their subsequent installation on construction site (MBI, 2010). Operationally, prefabrication is a construction innovation, which aims to take away the construction activities (as much as possible) from the project site to the factory in order to ensure better quality and safer production under controlled working conditions (Shahzad, Mbachu, & Domingo, 2015). This construction approach is seen as being more environmentally friendly, safer and productive than the conventional stick-built approach (Arif & Egbu, 2010; Azman, Ahamad, Majid, & Hanafi, 2010). Prefabrication encompasses the construction of all building components that is a part of a larger final assembly (Gibb, 1999). Prefabrication is an offsite manufacturing process that takes place at a specialized facility in which various materials and building systems are joined to form a component or part of a larger final installation (Haas, O'Connor, Eickmann, & Fagerlund, 2000). Work is done at a remote location for increased construction speed and quality (Schoenborn, 2012).

"Prefabrication production" borrows key ideas from the manufacturing industry. In the latter, products are modularized and components are standardized. On-site labour is replaced with an off-site machine. Although scope is reduced, productivity, quality, and cost are improved by batch production in a controlled environment. In some sectors of the housing industry where the construction process is sufficiently repetitive, the concept of the prefabricated housing can be applied to achieve greater productivity, higher quality and lower cost for construction projects (Xu, 2010). Thus, the following definition of prefabrication can be put forward by this study and its scope on housing construction, while incorporating key attributes of afore-mentioned definitions, as 'a rapid production procedure, where building components are coupled off-site within a mechanized controlled environment with the sole aim of heightening productivity and providing mass housing considered for habitation as marketable end-products for targeted end users'. Prefabrication has some unique features such as centralization of production, mass production, standardization, specialization, effective organization, integration, repetition, lightweight components, factory production (Pheng & Chuan, 2001; Tam, V., Tam, Zeng, & Ng, 2007). These unique features facilitate effective construction techniques in terms of quality, time, cost, function, productivity, safety, waste minimization, and sustainability. Further, it offers benefits such as saving site space; on-site less labour intensive operations; and, opportunities for good architecture. Features of prefabrication on sustainable construction include: increase the potential of improved supply chain integration of green materials; safer working conditions; easier recycle of materials in an off-site environment; enhance flexibility and adaptability; reduced overall life cycle cost; reduced environment impact; and, reduced economic impact (Kim & Bae, 2010). These merits of prefabrication confirm its appropriateness, whilst identification of the associated demerits may lead to possible improvements to enhance the soundness of the prefabrication technique for building construction. A number of studies (Tam et al., 2007; Waskett, 2001; Adebayo & Dixon-Ogbechi, 2017; Kamar, Azman, & Nawi, 2014) identify key issues in prefabrication. These are: higher initial construction cost, time-consuming for design, construction planning, procurements and approval procedures, use of extensive mechanization and automation leads to significant waste; overproduction, waiting time, transportation, over processing, inventories, moving, making defective parts or products, lack of variety in design, high technology usage, required well-trained people, issues related to site, high-quality control techniques and more efficient testing. Furthermore, Waskett (2001) identified barriers to apply prefabrication in the construction industry such as a general image; perceived performance; customer expectations; perceived value; industry culture; and product awareness. These demerits and barriers should be reduced or eliminated to reap the optimal benefits from prefabrication. Since prefabrication is a manufacturing process found in construction,

techniques which are used to improve the manufacturing processes of factory productions in other industries could be applied to it.

Prefabrication is a radical innovation within the housing system because the dominant methods for completing a project are entirely restructured. According to Slaughter (1998), all previous linkages and interactions may be irrelevant for a radical innovation, not only with respect to the systems but also the ties among organizations. Prefabrication has been used extensively and widely for many years around the world. Pre-assembly, prefabrication, modularization, system building and industrialized buildings are the terms which have been frequently used to describe that the manufacture of building components are constructed either on-site or off-site in a factory covering manufactured, modular an pre-cut or pre-engineered systems (Wong, Hao, & Ho, 2003). The terms, however, are often interchangeably used and their precise definitions depend heavily on the users' experience and understanding, which differs from country to country. In this research, prefabrication is preferred with special emphasis on the building components made and assembled off-site in a factory. Off-site fabrication is a topic of international interest and provides an effective construction technique in terms of quality, time, cost, function, productivity, and safety. Prefabrication is adopted worldwide as the ideal means of producing an immense array of elements from structural members, cladding units, and bathrooms to fully-finished modular buildings. As many prefabrication technologies deliver a better product because the building is done in a quality controlled, sheltered environment, the move to more prefabrication in the housing industry is inevitable. It is seen as one of the tenets of improving construction in the 21st century (Egan, 1998; Yeung, Chan & Chan, 2002). This is also echoed by Raysford (2000), who states that a much greater emphasis on off-site assembly is one of the key ingredients to changing the construction culture to retain and recruit talent and at the same time deliver improvements in performance required by increasingly demanding clients. Though prefabrication production is arguably an application in manufacturing settings that can be applied as a potential way to improve and overcome the issue of housing shortage through rapid offsite production, there remain pertinent deterrents of this innovative approach to housing construction. The need to understand and appreciate the enablers and inhibitors of prefabrication from different perspectives across the globe captured by various scholars is paramount to assist in decision making amongst policymakers, end-users and manufacturers of such technologies.

Enablers and Inhibitors of Prefabrication Adoption: An Overview

To date, an impressive number of studies have been launched on the perceived perception of prefabrication construction (Alazzaz & Whyte, 2014). Over the past few decades, the construction sector in several nations has experienced poor performance and low productivity (Nadim & Goulding, 2010). The labour intensive natures of the industry and shrinking levels of professional skills and craftsmanship have been key factors hampering productivity growth (Abdel-Wahab & Vogl, 2011). As a way forward in resolving the problems of productivity limitations to traditional on-site construction has been the introduction of off-site construction methods such as prefabrication and (Alazzaz & Whyte, 2012). The main reason for industry's endorsement of off-site production methods has been a perceived improvement in productivity (Bernstein, Morton, Gudgle, & Russo, 2010). While there has been a substantial body of research which has focused on the perceived enablers of prefabrication construction, there has been relatively little research that has compared these perceived enablers across the board from the perspectives of various researches in different countries that have embraced this method of construction. Blismas. et al. (2006) has discussed the advantages of prefabrication techniques in terms of time, quality, cost, productivity, people/manpower, and process. Furthermore, they have documented major benefits as the speed of construction, higher quality, lower cost, increased certainty, less wastage, greater productivity, less

manpower, health and safety risks, environmental impact and simplified construction process. However, the implementation or adoption decision of prefabrication is influenced by factors such as location, land use, density, volume, user needs, labour and environmental conditions (Gibb & Isack, 2003). Though there are benefits of off-site construction, the trend of prefabrication take-up in construction is different in different countries (Arif, Bendi, Sawhney, & Iyer, 2012). Though prefabrication is not a new technology the application, drivers and consequences are to be explored from a perception of current expertise and management practice (Gibb, 2000).

After a rigorous review of literature, some of the articles were identified that presented a range of issues under enablers and inhibitor. In order to investigate the enablers and inhibitor, studies like Pan, Gibb, and Dainty (2007) considered cost certainty, time certainty, on-site duration minimization, high quality achievement, health and safety risk reduction, reduction in environmental impact during construction, environmental performance maximization during life cycle, restricted site specifics, addressing skills shortages, government promotion, revisions to building regulations, implementing as part of company strategy and client's influences. In the context of a project, Badir, Kadir, and Hashim, (2007), examined the role of key players as enablers of prefabrication construction take-up. The key players identified are the client, designer, contractor, architect, supplier and statutory authorities.

Prefabrication construction also needs to consider a long-term perspective. Economic, environmental, social contexts and perspectives influence the stature of offsite construction (Arif & Egbu, 2010). According to Arif and Egbu (2010), barriers were examined against a range of factors including the nature of system and complexity, labor and skills, client's initiation, previous experience, legal influence and response to innovation. During this study the authors identified that skill shortage; client's influence and promotion were added to the list of factors influencing the adoption of offsite construction and were included in the survey presented to the participants. Edge, et al. (2002) found that house buyers are so strongly influenced by negative perceptions of the post-war 'prefab' that they will resist any innovations in-house construction which affect what a 'traditional' house looks like. The human perception barrier, grounded in the historical failure of offsite practices, also exists among architects and other designers (Pan, Dainty, & Gibb, 2004). This, coupled with technical difficulties (e.g. site specifics, logistics, interfacing problems), high costs (where economies of scale are not possible) and the fragmented structure of the supply chain inhibits designers' acceptance of off-site technologies (Pan et al., 2004). Theses inhibiting trends cut across different developed counties where prefabrication is already being practiced. A cultural shift is equally noticed as a challenge to orient people towards prefabrication construction in developing economies (Arif & Egbu, 2010). This can be further dealt with attitude, education, and motivation. The above-discussed factors were noticed in most of the past research. Arif and Egbu (2010) also stated that these factors can be contextualized for other countries. Hence the current paper considered the existing literature to investigate enablers and inhibitors to prefabrication construction in several countries well known for the building method.

Enablers and Inhibitors of Prefabrication Construction for Housing in Developing Countries

For the purpose of this study, four developing countries (India, China, Malaysia, and Nigeria) have been identified, and literatures regarding prefabrication in these regions have been reviewed, analyzed and documented, to shed more light on the similarities or difference in opinions on the enablers on inhibitors of prefabrication adoption.

In India, the rapid growth of the construction industry has influenced key players in the industry to adopt alternative technologies addressing time, cost and quality. Survey results revealed that there is significant offsite usage in Indian construction industry (Arif, Bendi, & Sawhney, 2012). Data gathered by Arif, Bendi, and Sawhney (2012), through a survey of 17 high-level managers from some of the largest

stakeholder organizations of the construction sector in India, suggested that the influence of time and cost were major enablers of the adoption of prefabrication construction. Majority of the respondents agreed to the assurance of time and cost certainty. This again proves that the construction industry is time and cost driven having a third-factor quality. The survey results further stress the need to address time, cost and quality while implementing alternative technologies in the construction industry. The documented results of Arif, Bendi and Sawhney, (2012), also pointed that absence of adequate building codes standards and practices and lack of sufficient information or knowledge of prefabrication were major inhibitors of prefabrication construction implementation in India. In the context, the respondents also highlighted that an ineffective building planning system in India was hindering the speed of prefabrication uptake. The belief that "prefabrication is more expensive than conventional systems" has a high occurrence in the literature review but surprisingly this factor was not highlighted by the present respondents. Reduced quality, longer lead-in times and reluctance to innovation were strongly disagreed as barriers which mirror the findings of previous researchers (Goodier & Gibb, 2007). Dinoj and Kokila (2018) also carried out a research with the clear objective of highlighting the major barriers that inhibit the adoption of prefabrication technique in India, by conducting a survey which yielded 65 valid responsive respondents out of the 155 questionnaires sent out. The main inhibitors obtained from the survey were improper transportation facilities, logistical limitations to design and the perception that prefabrication is more expensive than traditional construction method. (Dinoj & Kokila, 2018) explained that this was due to India's building industry's focus on cost-effective construction especially where times impact on overall cost of a project has little influence on the approach to construction in less developed areas. Since technology is not widely used there was a high dependency on factory sites which are far, as a result, transportation cost increases, logistical limitations for design, and simultaneously construction cost also increases (Dinoj & Kokila, 2018). While the results of Arif et. al., (2012) did not highlight respondents views of prefabrication as being more expensive than the conventional method of construction as an inhibitor to adoption, the results of Dinoj and Kokila (201 8), clearly indicated that respondents perceived prefabrication being expensive than conventional building methods as major inhibitors. This may be due to the characteristics of the sample population both researchers chose to investigate. While Dinoj and Kokila (2018) conducted research with respondents who were 17 senior level executives and influential key players in public and private sectors in India; Arif, Bendi, and Sawhney (2012), focused on stakeholders in the construction industry which included client, designers, contractors, offsite suppliers, and manufacturers. The biases on the expensive procedure of prefabrication as against the conventional method are opinions reflective of top management decision makers versus general stakeholders' within the building industry. Smith and Narayanamurthy (2008), however interestingly shared an entirely different view on the ethical dilemmas on technology transfer and its acceptance. The authors were of the opinion that technology transfer has the potential of influencing government, economy, and culture of both the transferring and the receiving nations, therefore opening too many ethical dilemmas, bordering culture and value. Prefabrication according to Smith and Narayanamurthy (2008) will continue to grow in India as the demand for fast affordable housing increases. However, technology transfer of the prefabrication process, including materials and digital tools, can affect the environment, economy, and culture of the receiving country negatively. Risks associated with the transfer of prefabrication technology such as; host country not having adequate infrastructure, manufacturing and/or professional prowess to accept it, were part of the views documented in the paper. These were strongly believed to be inhibitors on the adoption of prefabrication.

The construction sector in China accounts for about 6.5 percent of the total GDP, employing about 42 million people in 71,863

construction-related enterprises (Zhai, Reed, & Mills, 2014; Egbu, 2016). Along with the growth of the construction sector, there has been reforms and arrival of international construction companies in China, resulting into the uptake of new construction techniques like prefabrication, but also recognized as OSM in the Chinese construction sector (Malik, Khalfan, & Tayyab, 2014). Jaillon, Poon, and Chiang (2009) have identified that, for Hong Kong, the waste reduction benefit from adopting OSM is 52%, which is a significant savings on the island struggling to find landfill sites. Tam et al. (2007) concluded that although there are many inhibitors to OSM in Hong Kong, skilled supervision could lead to achieving a better environment and quality of the final product. Jaillon and Poon (2008) and Jaillon et al. (2009) highlighted some of the inhibitors to the implementation of OSM in Hong Kong which include; conflict with traditional design and construction processes and practices, lack of incentives for adopting OSM, lack of support from client due to overall high cost and lack of skilled labour and other factors. Arif and Egbu (2010) also identified the challenge of cultural change within the construction industry where on-site construction has been practiced for many decades, as an inhibiting factor. This is also a similar factor earlier mentioned in this paper by Smith and Narayanamurthy (2008) within the India construction industry. Arif and Egbu (2010) suggested that, through education and motivation, one would be able to bring this change within the industry to move to prefabrication construction. This also would require strong leadership and government support in various countries (Malik et al., 2014). Zhai et al. (2014) conducted their research by identifying six factors inhibiting the adoption of the OSM within the Chinese context including "constructability implementation," "social climate and attitudes," "architectural performance," "costing," "supply chain," and "preparatory stage." Despite all these barriers, Hong (2007) points out that OSM has increasingly become a major alternative construction method in China. One of the major reasons for OSM adoption is to meet the demand for increased quantity and quality housing stock combined with achieving environmental sustainability (Zhai et. al., 2014). Another recent study by Zhang and Skitmore (2012) focuses especially on adoption of OSM in the residential housing sector. The research presents lists of the enablers and inhibitors of OSM implementation in China. They concluded (after the analysis of the survey and case studies) that there were two major hurdles for the adoption of OSM in China; OSM is not a cost-effective construction method in comparison to the traditional construction method; and there are insufficient manufacturers of prefabricated construction components for OSM to be viable on any scale throughout the country. They feared that insensitive design and planning decisions in order to exploit the potential of OSM to achieve the cheapest cost could put off the prospective buyers and residents of the housing stock (Malik et al., 2014). On the other hand, Xiahou, Yuan, Liu, Tang, and Li (2018) identified fifteen enablers of prefabrication or Construction Industrialization as is it preferably referred to in China.

Based on published international journal articles, the identified enabling factors were grouped into three categories, namely, external development, transformation and upgrade of the construction industry, and strategies selected by the government. These three categories represent three major driving forces that put forward the development of CI in China. That is, the development of CI is not only pushed by the macro-development or pulled by the government, but it is also a self-driven process. Among the 15 CI enabling factors, pilot programs set up by the government were considered to be the most important in CI promotion. It was greatly perceived that pilot programs directly demonstrate the merits of CI to the public, which would help to increase awareness and acceptance by the society. Within the construction industry, the improvement of productivity, quality, and management were also considered as the priority incentives to promote CI in China. Currently, with the rapid urbanization of China, a higher quality production is needed in major cities. To achieve such goals, the traditional extensive methods of management are no longer able to

meet the current requirements (Xiahou et al., 2018).

Industrialized Building System (IBS) is the term coined by the industry and government in Malaysia to represent the adoption of construction industrialization and the use of prefabrication of components in building construction (Fauzi, 2017). Fauzi, (2017) carried out an IBS survey report to measure the perception of contractors in Malaysia in the adoption of IBS in construction. The report was able to identify the most important drivers for contractors to use IBS as follows; for achieving high quality, gaining speed of construction, minimizing on-site duration, demands from the client, and addressing skill shortage. The research also reveals that the main attribute to the lack of contractors embracing IBS is rarely purely technical in origin which is more related to the organizational strategy and soft issues which underpin the capability of the organization to successfully implement IBS. In the study conducted by Kamar et al. (2014), the characteristics of the population sample were category G7 contractors because of their influence on the course of direction of the construction industry. In addition, G7 contractors comprised the largest group of CIDB's contractors' classification registered as IBS contractors. The objective of this contractors' survey was to identify the most popular IBS system and the drivers and barriers to the use of IBS. Based on the results, the most important drivers for contractors to use IBS were achieving high quality, gaining speed of construction, minimizing onsite duration, client demand and addressing skill shortage. In contrast, factors such as energy saving, building's regulation and dealing with adverse weather condition were less important to the contractors. The most significant barrier restricting the use of IBS for contractors was higher construction cost, followed by high capital investment, difficulties in achieving economies of scale, inability to freeze design early and complex interfacing and lack of knowledge in IBS. Other factors related to the level of IT, building regulation and code and standard were not considered relevant by the contractors. The survey reveals that the factors responsible for the contractors' lack of acceptance toward IBS are rarely purely technical in origin.

Enablers and Inhibitors of Prefabrication Construction for Housing in Nigeria

The current housing situation in Nigeria demands speed in the delivery of housing (Kolo, Leilabadi, & Goulding, 2014). Many scholars ascertained that there are several benefits associated with the use of prefabrication (e.g., Arif, Bendi, & Sawhney, 2012; Arif & Egbu, 2010; Goulding et al., 2014; Pan et al., 2004). Regardless of these benefits, yet, there are barriers that hinder its adoption such as high costs, negative image etc. (Arif, Bendi, & Sawhney, 2012). The factors currently driving the demand for prefabricated systems are the establishment of special economic zones where new corporate offices are coming up, the need for convenient alternatives to conventional construction techniques, fast-paced urbanization in emerging regions, and growing investor interest in the real estate sector worldwide.

The development of the real estate industry in developing countries and the burgeoning demand for prefabricated building systems will have a positive impact on the growth of this market (Rahimiana, Goulding, Akintoye, & Kolo, 2017; Olamilokun, 2015; Opara, 2012; Kolo, Rahimian, & Goulding, 2014; Adebayo & Dixon-Ogbechi, 2017), this research was able to capture some of these enablers with anticipation that future research will prioritize also on identifying drivers of the prefabrication construction method. It seems previous literature on prefabrication in Nigeria presents an underlying bias already of the method of construction, thus the focus on barriers than drivers. However, Adebayo and Dixon-Ogbechi (2017), identified factors that promote the adoption of the prefabricated methodology for housing delivery by developers in Lagos state. The characteristics of the population sample were private developers and the need to sample and analyze their views and perceived efficiency of the private sector in contrast to the corrupt and sluggish public sector was crucial in the adoption of prefabrication for rapid housing delivery. Adebayo and Dixon-Ogbechi (2017) identified from data collated, 6 top ranking enablers of

prefabrication, out of the 16 perceived enablers provided in the survey questionnaire. These were economies of scale derived from bulk purchase, mass production and standardization; faster project completion time; greater quality control due to production in a controlled environment; cost-effectiveness due to minimal wastage and materials maximization; cost-effectiveness due to reduced site labor; cost-effectiveness due to less site material.

According to Olamilokun (2015), a thorough review of the research by Olatunji (2008), found the following: top management support and commitment, education and skills development, client interest in the use of lean construction in their project, commitment and cooperation of professional bodies, attitudinal change, government policy and availability of trained professionals are among the facilitators to adopting lean construction principles across organizations. Ayodeji, Selekere, Joshua, Kukoyi and Omuh (2016) also carried out studies on 100 prefabricated homeowners and occupants, and 25 professionals with knowledge and skill in the construction of prefabricated buildings in Lagos state. The major enabling factor of influence identified amongst the professionals was the shorter duration of assembling than the conventional method. Despite the aforementioned enablers/drivers, seminal literature has also highlighted a myriad of inhibitor/barriers that can hinder the successful adoption of prefabrication in different countries (e.g., Goulding, Rahimian, Arif, & Sharp, 2014; Arif, Bendi & Sawhney, 2012; Jonsson & Rudberg, 2013; PrefabNZ, 2013).

Acknowledging these issues, this research purposefully investigated these barriers from secondary data evidence regarding their likelihood to shape/inform the research context of Nigeria. Though Pan, Dainty, and Gibb (2004) identified two barriers to the adoption of prefabrication, namely human barriers and technical barriers, Kolo, Leilabadi, and Goulding (2016) further identified a third barrier; the industrial barrier. One of the initial industrial barriers is that of perceived cost (Rahimiana, Goulding, Akintoye, & Kolo, 2017). Opara (2011) also identified high cost as a barrier to the adoption of prefabrication in Nigeria. Initial cost has been acknowledged as the main barrier to the adoption of prefabrication in many countries, for example, India (Arif, Bendi, & Sawhney, 2012); New Zealand (PrefabNZ, 2013); and Nigeria (Opara, 2011). Arif, Goulding, and Rahimian (2012) suggested that it is more important for the offsite industry to focus more on visualization and simulation technologies (pilot projects) as a means of increasing awareness of prefabrication. These could be government or private pilot initiations. Manufacturing capacity was another barrier to the adoption of prefabrication These issues are not as apparent in countries where prefabrication has already been established, (e.g. UK, US, Japan and Nordic countries) as these tend to have a robust supply chain including manufacturing factories to support the prefabrication market. However, in countries like Nigeria, there are only a few factories involved in the manufacturing of prefabrication components which certainly hinders the adoption of prefabrication (Rahimian et. al., 2017). This inhibition to adoption was also identified by Scofield, Wilkinson, Potangaroa, and Rotimi (2009). Scofield et al., (2009), stated that countries that are more established in the use of prefabrication, for instance, UK, US, Japan etc. have a good number of factories that are into the manufacturing of prefabrication components.

In Nigeria, there are quite a number of factories involved in the manufacture of prefabrication components but very few produce on a large scale enough to carter for the enormous housing demands in Nigeria. Examples are: HFP Engineering Limited; Nigerite Limited; Tempo-housing Nigeria Limited; and Nigeria Portable Cabins, to mention a few. Certainly, Nigeria needs to have more factories manufacturing prefabrication components to meet increasing and future demands. Another reason for inhibition to adopting this form of building technology according to Rahimian et. al., (2017) is that prefabricated housing was used during periods of high demand (e.g. First and Second World Wars with various types of housing system based on pre-cast/in-situ concrete, timber, steel/iron variants); and the resultant product was relatively "low quality", with a short lifespan.

Although prefabrication has advanced significantly from this era, Opara (2011) confirmed that similar negative perception still is a real human barrier for the adoption of prefabrication in Nigeria. Ayodeji (2016) also identified in his research that the two highest ranking inhibitors to the adoption of prefabrication perceived by professionals in the building industry were the initial high cost of machinery setup and the lack of awareness by the public regarding the prefabricated method of construction.

Other barriers that are technical and associated with the adoption of prefabrication are the lack of suitable building codes and standards (Goulding et al., 2014). This also poses a major problem in Nigeria, where no official codes or standards exist to guide the use of prefabrication (Rahimian et. al., 2017). Arif, Bendi, & Sawhney (2012) also identified the negative perception and inadequate building codes/standards. In the opinion of Arif, Bendi, and Sawhney (2012), prefabricated housing was used in the U.K during periods of high demand, that is after the world wars and most of these buildings were of low quality and standard. As a result, there was a general notion that factory manufactured buildings are of low quality but current research shows otherwise. Arif, Bendi, & Sawhney (2012) identified improved quality as one of the major drivers of the adoption of prefabrication. This is compounded when factoring in the shortage of skilled workers and labor-specific requirements for prefabrication deployment (Goulding et al., 2014). This problem is expounded in countries like Nigeria where the prefabrication industry is relatively small and reliant on expatriate skills (Opara, 2012). The construction sector needs to train construction professionals in the area of prefabrication. This training will create more awareness among professionals and also potential clients (Kolo et al., 2014).

RESEARCH METHOD

The study adopted a systematic review of literature using qualitative technique. An electronic search was carried out using Google search with the search terms: prefabrication; developing countries; adoption of prefabrication etc. The literature search was focused on recent (less than 6 years) and relevant publications in prefabrication amongst the four selected countries. Other literature provided more in-depth understanding of the phenomenon. A total of twenty-four (24) current and relevant literature researches on prefabrication and its enabling and inhibiting factors towards implementation and adoption were randomly selected and reviewed in order to capture, and analysis similar trends which cut across four (4) identified developing countries located in Asia and Africa. 6 papers from each selected countries, that research on prefabrication and factors that either inhibited or enabled its adoption were reviewed. At least ten studies are needed for a review as recommended by Cochrane handbook (2011).

DISCUSSION

A total of twenty-four (24) current literature researches on prefabrication and its enabling and inhibiting factors towards implementation and adoption were reviewed in order to capture, and analysis the similar trends which cut across four (4) identified developing countries located in Asia and Africa, so as to provide future directions on ways to further encourage the widespread adoption of prefabrication. Several types of research have been conducted in various countries to investigate factors that could affect the successful adoption of prefabrication Olamilokun (2015). Abubakar et al. (2010) classified these barriers into six categories namely; financial, educational, governmental, attitudinal, managerial and technical issues, which were based on a thorough and critical review of international literature. This research, however, argued that these six (6) categories could either be enablers or inhibitors and not necessarily inhibitors alone, therefore categorizing the enabling and inhibiting factors respectively under each identified issue. In summary, the research observed after identifying the enabling and inhibiting factors within the selected literature that technical factors were predominantly the highest ranking factors that influenced the adoption or deterrent of prefabrication as seen in Table 1. This was determined by the number of times it was indicated in the literature reviewed. Though other factors are important, there is a need to

investigate further on the technical factors and develop strategies of eliminating the inhibiting factors and improving on the enabling factors if prefabrication must be adopted. Educational factors were the least represented in the literature selected and reviewed. This shows that a lot of stakeholders in the housing construction industry are knowledgeable of this construction method but not necessarily implementing the technique. Table 1 shows a summary of the identified factors which cut across the four selected countries.

Table 1
A Summary of Identified Enabling and Inhibiting Factors

DEVELOPING COUNTRIES	FACTORS											
	Management		Financial		Educational		Governmental		Technical		Human Attitudinal	
	E	*I*	*E*	*I*	*E*	*I*	*E*	*I*	*E*	*I*	*E*	*I*
INDIA N (4)	•	••	•						•	•••••		••
CHINA N(8)	••	•••		•			••		•	••••		•••
									•			
									•			
									•			
MALAYSIA N(2)									•			
		•		•••		•			•	••••		
									•			
NIGERIA									•			
									•			
	•	•	••	•	•	•	••		•	•••	•	•
N(10)									•		•	
									•			
									•			
									•			
									•			
									•			

Note: **E**-Enablers, **I**-Inhibitors, **N**-Number of reviewed literature, •- identified factors in the literature

CONCLUSION AND FURTHER STUDIES

In pursuance of this, the ultimate goal of this research will be in future researches, to develop a roadmap that will facilitate the effective adoption of prefabrication in Nigeria. This paper presented a series of underpinning steps based on the views of various researchers on the enabling and inhibiting factors to prefabrication adoption. Whilst prefabrication inhibitors have been highlighted within the Nigerian context, there is an exigent need to investigate these issues further, as it is important to proffer solutions to this environment e.g. infrastructure and local suitable materials for prefabrication. This paper has been constructed using the existing literature related to prefabrication in the context of developing countries. The proposed prefabrication adoption strategies could be formed by developing a framework for further research relating to prefabrication in developing countries. As such, it may be useful for housing policy makers, construction executives, managers, designers, developers, and scholars to rethink about housing issues by conducting future empirical research within and beyond the domain of construction. The study has established findings on the potential enablers and inhibitors of the prefabrication construction in four selected developing countries. It is recommended that the enablers be tremendously improved upon. This would be achieved by continuously meeting clients' needs and respond to the global, social and environmental challenges. This should prepare grounds for organizations to find out

ways of reducing the inhibitors and ensuring a smooth transition from the traditional construction approach to prefabrication construction based project delivery ultimately in the Nigerian construction industry. Government, housing construction agencies and organizations, should increase involvement of pilot projects at private and government levels as strategies for increased acceptance and not necessarily awareness, as the study shows that knowledge of prefabrication was the least indicator in Table 1. It is critical to conduct a systematic analysis of the driving and inhibiting factors for the decision makers to understand the incentives of prefabrication development and help them to select proper strategies. For the comprehensive realization of prefabrication benefits to developing countries, more research that is rooted in understanding the theory of manufacturing and construction is strongly recommended and will be useful in developing a suitable roadmap for the successful adoption of prefabrication in Nigeria.

REFERENCES

Abubakar, M. B., Subashini, S., David G. P., & Rod, G. (2010). *Barriers towards the sustainable implementation of lean construction in the United Kingdom construction organizations*. Paper presented at the ARCOM Doctoral Workshop, Construction and Infrastructure School of Engineering and the Built Environment, University of Wolverhampton, UK.

Abdel-Wahab, M., & Vogl, B. (2011). Trends of productivity growth in the construction industry across Europe, US and Japan, *Construction Management and Economics, 29*, 635-644.

Adebayo, A.K., & Dixon-Ogbech,i B.N. (2017). Urban mass housing in Lagos metropolis Nigeria-The potentials and marketability of prefabricated housing system. *Journal of Strategies and International Studies*, *12*(1), 25-30.

Alazzaz, F., & Whyte, A. (2012). *Towards Assessing Productivity in Off-Site Building Methods for Engineering and Construction Projects*. Paper presented at the 1st Australia and South East Asia Conference in Structural Engineering and Construction (ASEA-SEC-1), Research Publishing Services, Perth, Western Australia, 915-920.

Alazzaz, F., & Whyte, A. (2014). Uptake of off-site construction: Benefit and future application. *Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 8*(12), 1150-1152. https://doi=10.1.1.660.2528.

Alonso-Zandari, S., & Hashemi, A. (2016, December) *Prefabrication in the UK housing construction industry*. Paper presented at the 5th International Conference on Zero Energy Mass Customized Housing (ZEMCH), Kuala Lumpur, Malaysia. Retrieved from https://mafiadoc.com/prefabrication-in-the-uk-housing-construction-industry_5adcc12d7f8b9aac048b46ff.html

Arif, M., Bendi, D., Sawhney, A., & Iyer, K. C. (2012). State of offsite construction in India-Drivers and barriers. *Journal of Physics:Conference Series*, *364*(1), 12-19.

Arif, M., & Egbu, C. (2010). Making a case for offsite construction in China. *Engineering, Construction and Architectural Management, 17*(6), 536 - 548.https://doi: 10.1108/09699981011090170

Arif, M., Goulding, J., & Rahimian, F. (2012). Promoting off-site construction: Future challenges and opportunities. *Journal of Architectural Engineering*, *18*(2), 75-78. https://doi:10.1061/(ASCE)AE.1943-5568.0000081

Ayodeji, O., Selekere, T. E., Joshua, O., Kukoyi, P. O., & Omuh, I. O. (2016) Prefabrication method of building construction in Lagos state, Nigeria: Prospects and challenges. *International Journal of Engineering Technology and Computer Research (IJETCR) 4*(1), 88-100. Retrieved from https://www.ijetcr.org

Azman, M.N.A., Majid, T.A., Ahamad, M.S.S., & Hanafi, M. H. (2011). A study on the trend of the use of IBS components and the setting up of IBS manufacturing factories in the Malaysian construction industry. *Malaysian Construction Research Journal*, 9(2),18-30. Retrieved fromhttps://www.researchgate.net/publication/260202480_A_study_on_the_trend_of_the_use_of_IBS_components_and_the_setting_UP_of_IBS_manufacturing_factories_in_the_malaysian_construction_industry

Badir, Y., Kadir, M., & Hashim, A. H. (2007). Industrialized building systems construction in Malaysia. *Journal of Architectural Engineering, 8*(1), 119-23.

Blismas, N.G., Pasquire, C.L. & Gibb, A.G.F., 2006. Benefit evaluation for off-site production in construction. *Construction Management and Economics*, *24*(2), 121-130. Retrieved from https://dspace.lboro.ac.uk/2134/9224

Björnfot, A. & Sardén, Y. (2006). *Prefabrication: A lean strategy for value generation in construction.* Paper presented at the14th Annual Conference of the International Group for Lean.

Blismas, N., & Wakefield, R. (2009). Drivers, constraints and the future of offsite manufacture in Australia. *Construction Innovation, 9*(1), 72-83. Retrieved from https://doi:10.1108/14714170910931552.

Chiang, Y.H., Cahn, E.H.W., & Lok, L.K.L. (2006). Prefabrication and barriers to entry: A case study of public housing and institutional buildings in Hong Kong. *Habitat International*, *30*, 482-499.

Cochrane handbook for systematic reviews of interventions (2011). London, UK: Cochrane Collaboration. Retrieved from https://community.cochrane.org/book_pdf/764

Dada, A. (2013,). Housing deficit: Experts canvass new construction system, Newspaper, *The Punch*. Retrieved from http://www.punchng.com/business/homes-property/housing-deficit-experts-canvass-new-construction-system/

Dinoj, K. T., & Kokila, R. (2018). Study on prefabrication technique in construction and its barriers. *The Asian Review of Civil Engineering, 7* (1), 40-43.

Edge, M., Craig, A., Laing, R., Abbott, L., Hargreaves, A., Scott, J., & Scott, S. (2002). *Overcoming Client and Market Resistance to Prefabrication and Standardization in Housing*. Retrieved from https://www.rgu.ac.uk/file/contents

Egan, J. (1998) *Rethinking construction: The report of the construction task force*,
Department of the Environments, Transport and the Regions, London. Retrieved from https://www.academia.edu/35422338/Egan_Report_Rethinking_Construction

Egbu, C., (2016). Technology and knowledge transfer in China. *Journal of Technology Management in China, 1* (3), 304–321.

El-Abidi, K.M.A., & Ghazalia, F.E. M. (2015). Motivations and limitations of prefabricated building: An overview. *Applied Mechanics and Materials*, *802,* 668-675doi:10.4028/www.scientific.net/AMM.802.668 https://www.researchgate.net/publication/282503636

Elnaas, E. (2014). *The Decision to Use Off-Site Manufacturing (OSM) Systems for House Building Projects in the UK*. (Doctoral dissertation) https://pdfs.semanticscholar.org/ce5d/f3eb910b3ea1106609f9eedb23d2065abe55.pdf

Gibb, A. (1999). *Off-Site Fabrication: Prefabrication, Preassembly, and Modularization.* Scotland: Whittles Publishing. Retrieved from https://www.thenbs.com/PublicationIndex/documents/details?Pub=WHITTLES&DocID=304112.

Gibb, A. G. F., & Isack, F. (2003). Re- engineering through pre-assembly: Client expectations and drivers. *Building Research & Information, 31*(2), 146-160.

Gibb, A. G. F., (2000). Standardization and pre-assembly- distinguishing myth from reality using case study research. *Construction Management and Economics, 19,* 307-315.

Goodier, C., & Gibb, A. (2007). Future opportunities for offsite in the UK. *Construction Management and Economics 25*, 585-595.

Goulding, J.S., Pour Rahimian, F. P., Arif, M., & Sharp, M.D. (2014). New offsite production and business models in construction: Priorities for the future research agenda. *Architectural Engineering and Design Management, 11*(3), 163-184.

Hass, C., O'Connor, J.T., Eickmann, J.A., & Fagerlund, W.R. (2000). *Prefabrication and preassembly trends and effects on the construction workforce*. Austin, U.S.A: Centre for Construction Industry Studies, the University of Texas at Austin.

Hong, P. (2007). *Application of industrialized housing system in major cities in China—A case study of Chongquing* (Doctoral dissertation).The Hong Kong Polytechnic University, Hong Kong. Retrieved from http://ira.lib.polyu.edu.hk/handle/10397/3402

Jaillon, L., Poon, C., & Chiang, Y. (2009). Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong. *Waste Management, 29* (1), 309-320.

Jaillon, L., & Poonm, C. (2008). Sustainable construction aspects of using prefabrication in dense urban environment: A Hong Kong case study. *Construction Management and Economics, 26*(9), 953–966.

Jonsson, H., & Rudberg, M. (2013). Classification of production systems for industrialized building: A production strategy perspective. *Construction Management and Economics*, 1-17.

Kamar, K.A.M., Azman,M.N.A, &Nawi, M.N.M. (2010). IBS survey 2010: Drivers, barriers and critical success factors in adopting industrialized building system (IBS) construction by G7contractors in Malaysia. *Journal of Engineering Science and Technology*, *9*(4), 490-501.Retrieved from https://www.researchgate.net/publication/ 2651662

Kim, Y.W., & Bae, J. (2010). Assessing the environmental impacts of a lean supply system: Case study of high-rise condominium construction in Korea. *Journal of Architectural Engineering, 16*, 144–150.

Kolo, S.J., Pour Rahimian,F., & Goulding, J.S. (2014, June) . *Housing delivery in Nigeria and the opportunity for offsite manufacturing*. Paper presented at the Creative Construction Conference. Prague, Czech Republic. Retrieved from http://2015.creative-construction-conference.com/wp-content/uploads/2015/01/CCC2014_F_Pour-

Kolo, S. J., Leilabadi, F. P. R., & Goulding, J. S. (2016, May). *Offsite manufacturing in Nigeria: Feasibility research and future directions*. Paper presented at

CIB World Building Congress. ,Tampere, Finland. Retrieved from https://www.modular.org/marketing/documents/Whitepaper_ImprovingConstructionEfficiency.pdf

Malik, M., Khalfan, A., & Tayyab, M. (2014). Current state of off-site manufacturing in Australian and Chinese residential construction. *Journal of Construction Engineering*, 1-5. Retrieved from https://doi.org/10.1155/2014/164863.

MBI. (2010). *Improving Construction Efficiency & Productivity with Modular Construction*. Charlottesville, Virginia, USA: Modular Building Institute. Retrieved from https://www.modular.org/marketing/documents/Whitepaper_ImprovingConstructionEfficiency.pdf

McGraw-Hill Construction Report. (2011). *Prefabrication and Modularization Increase Productivity*. Bernstein, H., Morton, B., Gudgle, J., & Russo, M.

Mohd, A. F., Sulaiman, H., Anizah, A., Ahmad, R. M. R., & Juzailah N.Y. (2017).Supply chain management on IBS implementation in Klang Valley construction industry: Challenges and issues. *IOP Conference Series: Materials Science and Engineering*, *291*, 012-015.

Muggah, R. & Hill, K. (2018, June) World Economic Forum. Retrieved from https://www.weforum.org/agenda/2018/06/Africa-urbanization-cities-double-population-2050-4%20ways-thrive/

Nadim, W., & Goulding, J. (2010). Offsite production in the UK: The way forward? A UK construction industry perspective. *Construction innovation*, *10*, 181-202.

Navaratnam , S., Ngo, T., Gunawardena, T., & Henderson,D. (2018) Performance Review of Prefabricated Building Systems and Future Research in Australia *Buildings*, *9*(38). https://doi:10.3390/buildings9020038 Retrieved from www.mdpi.com/journal/buildings

Ogunde, A., Selekere, T. E., Joshua, O., Kukoyi, P. O., & Omuh, I. O. (2016). Prefabrication method of building construction in Lagos state, Nigeria: Prospects and challenges. *International Journal of Engineering Technology and Computer Research (IJETCR), 4* (1), 88-100. Retrieved from http://www.ijetcr.org

Olajide, O., (2015). Investigating facilitators and barriers for adopting lean Construction principles in the Nigerian building consulting firms. *International Journal of Innovative Research & Development, 4*(12), 234-239. Retrieved from www.ijird.com

Olatunji, J. (2008, July). Lean-in-Nigerian construction: State, barriers, strategies and "goto-gemba" approach. Pare presented at the 16th Annual Conference of the International Group for Lean Construction, Manchester, UK. Retrieved from https://www.semanticscholar.org/paper/lean-%e2%80%93-in-nigerian-construction-%3a-state-%2c-barriers-olatunji/d220827f6092c87ec84f0b450470820a547889a2

Opara, S., (2011, April) Modular Housing System GainingPopularity despite Huge Costs. Nigerian Best Forum (NBF) . Retrieved from http://www.nigerianbestforum.com/generaltopics/modular-housing-system-gaining-popularity-despite-huge-costs/

Pan, W., Dainty, A. R. J. & Gibb, A. G. F. (2004). Encouraging Appropriate Use of Off-site Production (OSP): Perspectives of Designers, *In 2nd CIB Student Chapter International Symposium*, 30-31 Oct 2004, Beijing, China. The Hong Kong Polytechnic University, 125-36.

Pan, W., Gibb, A. G. F. & Dainty, A. R. J., (2007). Perspectives of UK housebuilders on the use of offsite modern methods of construction. *Construction Management and Economics, 25,* 183-194.

Pan, W., Gibb, A.G.F. & Dainty, A.R.J. (2008) Leading UK housebuilders' utilization of offsite construction methods. *Building Research & Information*, *36*(1), 56-67.

Pan, W., Dainty, A. R. J., & Gibb, A. G. F., (2004). Managing innovation: a focus on off-site production (OSP) in the UK housebuilding industry. Paper presented at the 20th Annual ARCOM Conference, Heriot Watt University, Edinburgh, Scotland.

Pasquire, C., Gibb, A., & Blimass, N. (2004). Offsite production: Evaluating the Drivers and Constraints. Retrieved from https://iglcstorage.blob.core.windows.net/papers/iglc-c74d04b0-8e8a-4825-af45-2261f4924578.pdf

Pheng, L.S., & Chuan, C.J. (2001). Just-in-time management of precast concrete components. *Journal of Construction Engineering and Management*, *127*, 494–501.

. (2013). *Prefab Roadmap: A Way Forward for Prefabrication in New Zealand*.

Prefabricated Building System Market (2016) *Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2016-2024*.Retrieved from https://www.transparencymarketresearch.com/prefabricated-building-system-market.html.

Rahimiana, F.P., Goulding, J., Akintoye, A., & Kolo, S. (2017) Review of Motivations, Success Factors and Barriers to the Adoption of Offsite Manufacturing in Nigeria. *Procedia Engineering 196,* 512- 519. Retrieved from https://doi:10.1016/j.proeng.2017.07.232

Raynsford, N. (2000, April). *Rethinking construction – Profiting from innovation*, Paper presented at the Movement for Innovation Conference, Birmingham NEC, Retrieved from www.m4i.org.uk/conference/conf_speech.html

Senaratne, S., Ekanayake, S. D., & Siriwardena, M. (2010, May). Lean prefabrication: A sustainable approach. A paper presented at the *Building a Better World Conference: CIB 2010 World Congress*, Salford Quays, England. Retrieved from http://www.disaster-resilience.net/cib2010/index.php

Schoenborn, J. (2012). *A Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction*. (Doctoral dissertation). (Publication no. etd-05082012-010848).

Scofield, R., Wilkinson, S., Potangaroa, R., & Rotimi, F. (2009). *Driving Innovative Offsite Construction Techniques in New Zealand*. Paper presented at the Global Innovation in Construction Conference. Loughborough University, UK.

Shahzad, W., Mbachu, J., & Domingo, N. (2015). Marginal Productivity Gained Through Prefabrication: Case Studies of Building Projects in Auckland. *Buildings, 5*, 196-208. https://doi:10.3390/buildings5010196 Retrieved from: https://www.researchgate.net/publication/273494519_Marginal_Productivity_Gained_Through_Prefabrication_Case_Studies_of_Building_Projects_in_Auckland

Slaughter, S. (1998) Models of construction innovation. *Journal of Construction Engineering and Management*, *124*(3), 226 –231.

Smith, R., & Narayanamurthy, S. (2008). *Prefabrication in developing countries: A case study of India*. University of Utah press.

Tam, V., Tam, C., Zeng, C., & Ng, W. (2007). Towards adoption of prefabrication in construction. *Building and Environment, 42(*10), 3642–3654.

Tatum, C. B. (1986). Potential mechanisms for construction innovation. *Journal of Construction Engineering and Management, ASCE, 112*(2), 178-191.

Tezel, A., Koskela,L., Gosling, J., & Kumar, M. (2017) *From construction to production: Enablers, barriers and opportunities for the highways supply chain*. Technical Report. Retrieved from http://eprints.hud.ac.uk/id/eprint/34122/

United Nations, (2018). *Revision of the World Urbanization Prospects* Retrieved from https://population.un.org/wup/

Waskett, P. (2001) *DTI construction industry directorate project report: Current practice and potential uses of prefabrication*, BRE, (Report No. 203032). Watford.

Wong, R., Hao, J. L. & Ho, C. M. F. (2003). *Prefabricated building construction systems adopted in Hong Kong.* Paper presented at the International Association for Housing Science at World Congress of Housing: Process and Product, Montreal, Canada.

Xiahou, X., Yuan, J., Liu, Y., Tang, Y., & Li, Q. (2018). Exploring the driving factors of construction industrialization development in China. *International Journal of Environmental Research and Public Health*, *15*(3), 442. Retrieved from http://doi.org/10.3390/ijerph15030442

X. Xu, Y. Zhao. (2010). *Some Economic Facts of the Prefabricated Housing.* Industry Report, Rutgers Business School, Newark, NJ.

Yeung, N. S. Y., Chan, P.C., & Chan, D. W. M. (2002). Application of prefabrication in construction – a new research agenda for reform by CII-HK. Paper presented at the Conference on Precast. Concrete Building System. Hong Kong.

Zhai, X., Reed, R., & Mills, A. (2014). Factors impeding the offsite production of housing construction in China: An investigation of current practice. *Construction Management and Economics, 32(*1-2*)*, 40–52.

Zhang, X., & Skitmore, M. (2012). Industrialized housing in China: A coin with two sides. *International Journal of Strategic Property Management, 16,* (2), 143–157