Barriers to Adoption of Precast Concrete Construction in Buildings

Alan Verghese Ittyeipe*, Anu V. Thomas

Department of Civil Engineering, TKM College of Engineering, Kollam, Kerala, India

*Corresponding author: alanittyeipe@gmail.com

doi: https://doi.org/10.21467/proceedings.112.2

ABSTRACT

The increasing demands for housing the burgeoning urban population in developing countries like India has impelled the need to shift to mechanised construction practices like Precast Concrete Construction (*PCCon*) for faster supply of projects. *PCCon* has been successfully implemented in developed countries to meet the once prevalent housing shortages and is still being adopted extensively in high rise residential building projects in these countries. *PCCon* offers several benefits compared to cast in situ construction practices such as reduced construction time, time and cost certainty, improved quality control and improved health and safety. *PCCon* also promotes environment friendly construction, addresses shortage of skills and results in minimisation of life cycle costs. Despite these benefits, there is only limited uptake for *PCCon* in developing countries. An extensive literature review was carried out in this study and 39 preliminary barriers to adoption of *PCCon* were identified. These have been classified into 6 categories, namely, Cost issues, Project delivery and Supply chain, Design issues, Awareness and Knowledge, Policies and Regulation, Social climate and Market demand. The prospects and challenges to adoption of *PCCon*, particularly in the Indian construction sector, are also discussed. The results of study will create an awareness on the barriers to adoption of *PCCon* and thereby help policy makers, industrialists and various stakeholders associated with *PCCon* to plan their future actions.

Keywords: precast concrete construction (PCCon), developing countries, barriers

1 Introduction

Precast concrete construction (*PCCon*) is "a building technique where by the concrete components are cast either in a factory or at a fixed location on site, and completed elements are erected and assembled in situ to form complete building structure" (Chiang et al., 2006). *PCCon* is a time-tested alternative for the cast in situ construction, which have been successfully implemented in developed countries to meet the once prevalent housing shortages. *PCCon* was widely popularised after the World War II, in order to meet the pressing demands for the construction of large-scale public housing projects in the Eastern and Western Europe (Arditi et al., 2000). The mounting pressure to meet the housing demands at a faster rate has led to the substantial growth of precast industry in the European countries. For instance, in 1996, Denmark (43%), Sweden and Germany (31%) accounted the highest precast levels globally (Jaillon and Poon, 2009). Also, the precast concrete system in the European Union and northern European countries was reported to account to 20-25% and 40-45% of the construction industry, respectively (Polat et al., 2010). *PCCon* is still being adopted in developed countries for faster delivery of construction projects with reduced waste generation and improved productivity, owing to a sustainable construction practice. For instance, the use of precast systems for high rise housing in Singapore for the past 30 years (Sherfudeen et al., 2016). Other interchangeable terminologies associated with "precast concrete construction" (*PCCon*) used in the global construction industry are: offsite

Proceedings DOI: 10.21467/proceedings.112; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-3-3

production (OSP) in U. K. (Goodier & Gibb, 2005), offsite manufacture (OSM) in Australia (Blismas & Wakefield, 2009), offsite construction (OSC) in China (Mao et al., 2015), prefabrication in Hong Kong (Jaillon & Poon, 2009), industrialised building systems (IBS) in Malaysia (Nawi et al., 2011). Offsite is considered to be a type of Modern Methods of Construction (MMC) (Pan et al., 2007), whereas not all MMC can be regarded as offsite.

PCCon offers several benefits compared to cast in situ construction and these are described in Table 1. Despite these benefits, there is only limited promotion for *PCCon,* in developing countries like India. Hence the study focusses on identifying the various barriers to the promotion and growth of *PCCon* for buildings.

Table 1 Benefits of Precast Concrete Construction (*PCCon)*

Benefits	Comments & References
Reduction in construction time	*PCCon* when compared to cast in situ construction offers reduction in construction time to about 20% in Hong Kong (Jaillon & Poon, 2007) and 20-35% in India (Nanyam et al., 2017).
Time and cost certainty	*PCCon* overrides time and cost overrun (Blismas et al., 2005, Pan et al., 2007, Arif et al., 2012).
Improved quality control	*PCCon* ensures precision (Razkenari et al., 2019); provides exquisite surface finishes and improved aesthetics (Jaillon & Poon, 2007); facilitates better supervision (Tam et al., 2007); allows easy defect identification (Goodier et al., 2005), and reduce waste arising from defects (Jaillon & Poon, 2008).
Address skill shortage	*PCCon* when compared to cast in situ construction offers reduction of labour to about 9.5% in Hong Kong (Jaillon & Poon, 2007).
Environment friendly	*PCCon* reduces construction waste in site; facilitates the waste from manufacturing plant to be reused and recycled with much ease (Jaillon & Poon, 2007), ensures material saving thereby reducing air pollution and energy use (Yee, 2001); and reduce use of timber formwork (Yee, 2001, Jaillon & Poon, 2008).
Improved health and safety	*PCCon* ensures improved working conditions (Blismas et al., 2005); decreased noise and dust pollution (Jaillon & Poon, 2008).
Minimize life cycle costs	High construction cost of *PCCon* could be offset with the other benefits (Jaillon & Poon, 2007). *PCCon* also reduces maintenance work and associated cost (Jaillon & Poon, 2008).

2 Barriers

Researchers have tried to examine the various factors influencing the adoption of *PCCon* worldwide, which could help policy makers, industrialists and various stakeholders in identifying the barriers so as to align in accordance with the changing demands of the respective region of study and time. An extensive literature review was carried out to understand the various barriers that existed from time to time for the growth of *PCCon* in building construction across the world, and these are listed in Table 2. The barriers identified have been classified into 6 categories namely, Cost issues, Project delivery and Supply chain, Design issues, Awareness and Knowledge, Policies and Regulation, Social climate and Market demand. Figure 1 depicts the classification of the barriers to adoption of *PCCon.*

Proceedings DOI: 10.21467/proceedings.112
ISBN: 978-81-947843-3-3

Series: AIJR Proceedings
ISSN: 2582-3922

Table 2 Barriers to Precast Concrete Construction (*PCCon*)

Code	Barrier	References
B1	High initial capital investment	[1], [2], [3], [4], [5], [6], [7], [8]
B2	Perceived higher cost	[6], [9], [10], [11], [12], [13]
B3	Inability to achieve economies of scale	[2], [6], [7], [11]
B4	Transportation cost	[6], [14], [15]
B5	Taxation issue	[7], [15], [16]
B6	Site constraints & logistics	[17], [18], [19], [20]
B7	Transportation restrictions	[8], [14], [15], [16], [21], [22]
B8	Poor contracting practices & documentation	[3], [4]
B9	Longer lead in time	[7], [9], [20]
B10	Lack of communication between stakeholders	[3], [4], [10], [14], [22]
B11	Lack of technology integration	[13], [23]
B12	Fragmentation in construction industry	[4], [5], [12]
B13	Inability to freeze the design and specifications early	[2], [19], [20], [24]
B14	Inflexibility for design changes	[8], [19], [20], [25], [26]
B15	Water leakage/seepage issues	[4], [7], [16]
B16	Uncertainty in the performance under earthquake	[10], [14], [15]
B17	Impaired aesthetics	[10], [14], [16], [19], [22]
B18	Lack of expertise and knowledge in the design	[1], [10], [14], [22]
B19	Lack of expertise and knowledge in the assembly and construction	[9], [10], [14], [22]
B20	Lack of courses in curriculum	[1], [14], [22]
B21	Lack of professional training	[3], [14]
B22	Lack of specialised skill force	[4], [5], [7], [10], [19]
B23	Lack of awareness among awarding authorities	[3], [23]
B24	Lack of awareness by the market and public	[3], [23]
B25	Lack of adequate standardization	[1], [7], [12], [13], [22]
B26	Lack of standards and codes	[5], [6], [16], [19]
B27	Lack of local R&D and services	[3], [4], [6]
B28	Lack of testing and certification facilities	[3], [4], [14], [22]
B29	Lack of mandatory policies	[13], [20]
B30	Lack of incentive policies	[4], [13], [27]
B31	Lack of government procurement	[13]
B32	Uncertainty of market demand	[6], [12], [14]
B33	Limited choice and manufacturing capacity	[12], [24]
B34	Negative perception	[1], [16], [23]
B35	Dominated traditional construction method	[8], [20], [23]
B36	Lack of support from private sector	[3]
B37	Lack of past experience and information	[3], [5], [26]
B38	Unemployment issues of workers	[6]
B39	Problems of worker union activities	[14], [15]

[1] Rahman & Omar (2006); [2] Pan et al. (2007); [3] Kamar et al. (2009); [4] Nawi et al. (2011); [5] Arif et al. (2012); [6] Mao et al. (2015); [7] Nanyam et al. (2017); [8] Razkenari et al. (2020); [9] Goodier & Gibb (2005); [10] Polat (2010); [11] Cheng et al. (2017); [12] Gan et al. (2018); [13] Wu et al. (2019);[14] Arditi et al. (2000); [15] ICI Handbook (2016); [16] Sherfudeen et al. (2016); [17] Pheng &Chuan (2001); [18] Jaillon & Poon (2008); [19] Zhai et al. (2013); [20] Zhang et al. (2018); [21] Chiang et al. (2006); [22] Polat (2008); [23] Nadim & Goulding (2011); [24] Blismas et al. (2005); [25] Jaillon & Poon (2007); [26] Tam et al. (2007); [27] Jaillon & Poon (2009)

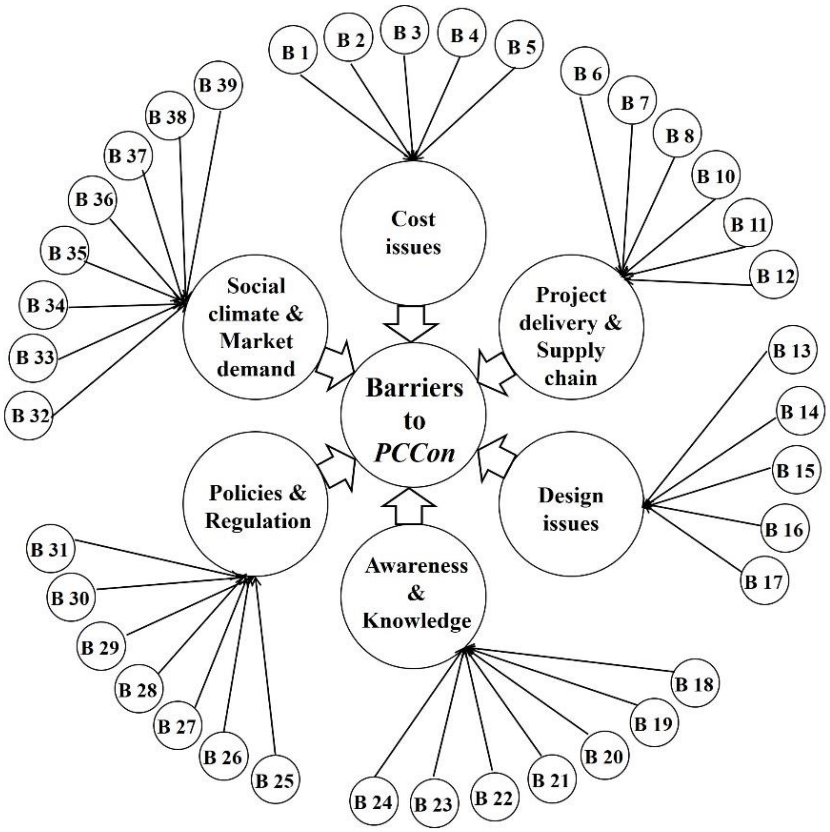

Figure 1 Classification of barriers to Precast Concrete Construction (*PCCon*)

2.1 Cost issues

High initial capital investment (B1) is considered to be a major barrier in the implementation of the *PCCon*. Investing in heavy equipment and machinery requires high capital investment by contractors (Rahman & Omar, 2006) and is considered to be a hindrance for small contractors especially with no financial backup in adopting Industrialised Building Systems (IBS) (Kamar et al., 2009). For setting up manufacturing plants, huge investment is required for purchasing new machinery, mould and importing foreign technology (Kamar et al., 2009, Nawi et al., 2011, Mao et al., 2015).

The perceived higher cost (B2) for offsite construction (OSC) was found to be a significant barrier among contractors and clients in UK, in a survey conducted by Goodier et al. (2007). In China, the cost for OSC was 20% higher than the total cost involved in the traditional construction (Mao et al., 2015). Polat (2010) has stated that the perceived higher costs in developing countries is mainly due to lack of competition and promotion by limited number of qualified precast concrete manufacturers in the industry and also the low cost associated with the labour-intensive industry. The requirement for skilled labour in the mechanised construction necessitates the need for additional education and training for employees which could incur cost (Chiang et al., 2006, Zhai et al., 2013).

The inability in achieving the economies of scale (B3) by the developers is stated as a hindrance to the development of precast concrete construction (Pan et al., 2007, Mao et al., 2015, Nanyam et al., 2017). Arditi et al. (2000) reported that more than half of the contractors responded that no significant cost savings was observed when they had used precast concrete systems. Economies of scale can be achieved when the unit

Proceedings DOI: 10.21467/proceedings.112
ISBN: 978-81-947843-3-3

Series: AIJR Proceedings
ISSN: 2582-3922

costs decrease with increased production. Thus, the limited production due to the wide swing in the market demand could result in higher costs and subsequently in diseconomies of scale (Mao et al., 2015).

Transportation cost (B4) is directly proportional to the distance between the plant and the site. Arditi et al. (2000) stated that transportation cost was a decision factor for manufacturers to initiate a project. The cost of transportation increases the total cost of producing precast components by 15 to 20% (Mao et al., 2015, ICI Handbook, 2016).

The additional burden of taxes (B5) such as excise duty and Value Added Tax (VAT), before the introduction of Goods and Services Tax (GST) was described as a significant challenge posed in the Indian precast industry (Sherfudeen et al., 2016, Nanyam et al., 2017).

2.2 Project delivery and supply chain

The space constraint and on-site storage conditions (B6) pose a major problem for the bulky precast components delivered to the construction sites (Pheng & Chuan, 2001, Zhai et al., 2013). Limited access to site (Jaillon & Poon, 2008, Sherfudeen et al., 2016) and lack of storage space on site (Zhang et al., 2018) have been reported as a major constraint in Hong Kong, due it its dense environment.

The restrictions in the transportation (B7) of the precast concrete components such as the load carrying capacity of the bridges and pavements and the horizontal and vertical clearances in tunnels and underpasses lead to inevitable design limitations related to the size and weight (Arditi et al., 2000, Polat, 2008, Razkenari et al., 2019). The prefabrication yards are usually set up far away from the city limits for its cheaper labour and land costs by the precast suppliers (Chiang et al., 2006, ICI Handbook, 2016). Thus, the precast components need to be transported longer distances. The unavailability of suitably sized heavy vehicles and the restrictions on the window time for the transportation of precast components is described as a major problem in India (Sherfudeen et al., 2016).

Adoption of better contracting practices and its documentation (B8) could ensure proper integration of different stakeholders which could result in the successful implementation of *PCCon*. Zhang et al. (2018) proposed that design and build contracts could prove effective as contractor would undertake the entire design, management and construction works. Also, special conditions of contract can be brought with regard to *PCCon* (ICI Handbook, 2016).

The longer lead in time (B9) might be attributed to the extension of time required to the manufacture the precast components, so as to ensure accurate detailing of design which sometimes could lead to revision of all the assembly details (Goodier & Gibb, 2005, Nanyam et al. 2017, Zhang et al., 2018). The inexperience and lack of communication of the stakeholders also contributes to the longer lead in time.

The need for improved communication and integration (B10) of the various stakeholders is significant in the successful adoption of *PCCon* (Arditi et al., 2000). Lack of proper communication and information transfer among the stakeholders from the design to construction stages could lead to severe delays in production and erection schedules, cost overruns, and constructability problems (Polat, 2008, Polat, 2010).

Wu et al. (2019) mentioned that the integration of *PCCon* with other technologies (B11) such as Building Information Modelling (BIM) and Radio-Frequency Identification (RFID) could prove to be a significant factor for the development of *PCCon*.

The fragmented nature of the construction industry (B12) is a hindrance to effective communication and coordination of stakeholders in *PCCon* (Arif et al., 2012, Nawi et al., 2014, Gan et al., 2018). Thus, combined

and simultaneous involvement of various stakeholders are necessary to obtain the most optimum and efficient solution for precast building projects (ICI Handbook, 2016).

2.3 Design issues

Inability to freeze the design and specifications early (B13) in order to accommodate the varying requirements of the client is a barrier for *PCCon* (Blismas et al., 2005, Pan et al., 2007, Zhai et al., 2013). Zhang et al. (2018) commented that clients have more preference to a flexible construction method as they can incorporate their new ideas even after design stages and accommodate design changes in case of any unforeseen incidents during the construction period. Hence, inflexibility to design changes (B14) poses a barrier to *PCCon*.

Water leakage/ seepage problems (B15) could arise due to the errors caused by the cumbersome connections and jointing methods in precast concrete buildings (Nawi et al., 2011, Sherfudeen et al., 2016, Nanyam et al., 2017).

The ambiguity and unpredictability in the structural performance of precast structures during earthquake (B16) is cited as a hindrance to *PCCon* (Arditi et al., 2000, Polat, 2010).

The impaired aesthetics and versatility (B17) in using precast components has been stated as a reason for its lower popularity among designers and architects (Arditi et al., 2000, Polat, 2010, Zhai et al., 2013, Sherfudeen et al., 2016). The excessive tendency toward repetitiveness of precast components might cause monotony (Arditi et al., 2000). However, Polat (2008) reported that precast concrete systems encourage the use of flexible designs and complex patterns which otherwise would be difficult to produce by conventional construction practices. But the cost for producing large variety of precast components in order to meet the aesthetics demands might be much larger than for its production in situ (Polat, 2008).

2.4 Awareness & Knowledge

Lack of expertise and knowledge in the design (B18) and implementation (B19) is considered as a major barrier to the adoption of precast concrete construction (Arditi et al., 2000, Blismas et al., 2005, Rahman & Omar, 2006, Goodier et al., 2007, Polat et al., 2008, Polat et al., 2010, Razkenari et al., 2020). The common issues pertaining due to lack of knowledge and expertise in *PCCon* are: improper connection system due to the poor design and construction details, inaccuracy in levelling and alignment of bases, and also improper assembly of precast components especially connections, which could lead to delays in erection (Rahman & Omar, 2006).

Researchers pointed out that the curriculum does not address the subjects related to precast construction (B20) in the undergraduate and postgraduate courses, especially in the developing countries (Arditi et al., 2000, Rahman & Omar, 2006).

Lack of professional training (B21) limits adoption of *PCCon*. Arditi et al. (2000) commented that inadequate training of engineers and architects in the design issues of precast systems may cause problems in the production stage due to ambiguities in design which in turn may lead to inefficiencies during erection. The need for highly skilled labours (B22) is also a challenge for *PCCon* (Polat, 2010, Nawi et al., 2011, Arif et al., 2012, Zhai et al., 2013, Nanyam et al., 2017).

Kamar et al. (2009) stated that the lack of knowledge and awareness about precast design among authorities (B23) results in more time than usual for obtaining design approval. Nadim & Goulding (2011) reported that the awarding authorities need to be aware of the new process and contractual models.

Proceedings DOI: 10.21467/proceedings.112
ISBN: 978-81-947843-3-3

Series: AIJR Proceedings
ISSN: 2582-3922

Kamar et al. (2009) reported that lack of awareness on *PCCon* in the market and among public (B24) is a significant challenge and hence programs must be initiated to encourage two-way communications and best practice sharing between promoters, clients and contractors.

2.5 Policies & Regulations

Lack of standardization (B25) can result in severe compatibility issues which may arise when several precast manufacturers get involved in a project (Polat, 2008) and increase design difficulties (Wu et al., 2019). Standardization can improve the quality, enhance the ease of manufacturing and decrease variability (Rahman & Omar, 2006). Hence a nationwide standardization is a significant factor in the development of precast concrete construction in any country, which could implement set of policies for modularization and quality control (Arditi et al., 2000, Mao et al., 2015). Also, standardization of component sizes and specifications could aid in the production and construction practices which could further result in economies of scale and lower costs (Wu et al., 2019).

The lack of standardization and availability of codes and standards (B26) have been reported as a significant challenge for *PCCon* in developing countries like China (Zhai et al., 2013, Mao et al., 2015, Gan et al., 2018, Wu et al., 2019) and India (Arif et al., 2012, Sherfudeen et al., 2016, Nanyam et al., 2017).

Lack of local R&D institutes and services (B27), technologies and testing institutes, and related professionals is a significant challenge in ensuring the quality of precast components (Kamar et al., 2009, Nawi et al., 2011, Mao et al., 2015). The local contractors may have to depend very much on foreign expertise and technology due to lack of local R&D facilities, which could invite much reluctance in adopting precast construction that may involve higher costs (Nawi et al., 2011).

Nawi et al. (2011) emphasised the need for a dedicated assessment and certification system (B28) for precast products, manufacturers and installers to identify the current performance and to promote further improvement of precast concrete construction. Arditi et al. (2000) and Polat (2008) reported that there is stronger preference to precast products from PCI certified manufacturers among the contractors in US.

Lack of mandatory policies (B29) to adopt prefabrication in building is a significant factor that hinders the growth of *PCCon*. For example, in Singapore, after the introduction of buildability score regulation in 1999, prefabrication achieved an average level of 20% adoption by 2010 (Zhang et al., 2018). Wu et al. (2019) reported that the local authority of Tianjin City in China has launched mandatory policies to adopt prefabricated buildings in construction projects involving commodity housing projects, government funded projects and public buildings, with a goal of attaining prefabrication in 30% of new buildings in city by 2020.

In Hong Kong, incentive schemes were introduced from 2001, through Joint Practice Notes 1 and 2 (JPN 1 & 2), to promote the application of green building technologies and prefabrication, where Gross Floor Area exemption is granted for buildings adapting green features such as prefabricated non structural external walls (Jaillon & Poon, 2009). Similarly, in Beijing and Shanghai, China, government provides subsidy for prefabricated residential project with total construction area of more than 30000m^2 and an assembly rate of 40% or more, at a rate of 100 RMB per square meter (Wu et al., 2019). Lack of incentive policies (B30) such as financial support and tax incentives affects the promotion of *PCCon*.

Wu et al. (2019) commented that lack of government procurement (B31) is a significant factor to the growth of *PCCon* and government should initiate projects with prefabrication technology, which could publicise the advantages of the technology.

2.6 Social climate and Market demand

The uncertainty in the market demand (B32) for the precast components is a challenge for the developer with longer capital payback period (Mao et al., 2015, Gan et al., 2018).

In developing countries, the majority of manufacturers are either small or medium sized without adequate financial resources for quality control procedures or standards, there by leading to poor product quality (Polat 2010) and limited choice in the market (Blismas et al., 2005). Thus, limited choice and manufacturing capacity (B33) is a barrier to *PCCon.*

Several negative perceptions (B34) exist about early prefabricated buildings such as they have been considered as of poor quality, poor aesthetics and associated with past failures in UK, whereas in Sweden, they are considered as part of million homes programme (Nadim & Goulding, 2011). In Malaysia they were associated with mass production of low cost accommodation for lower income people (Rahman & Omar, 2006). In India the negative perception might be because of the consideration of 'Vastu Shastra' in the building construction in India which require custom design (Sherfudeen et al., 2016).

The 'conservative approach' and 'resistance to change' (B35) attitude of the stakeholders makes the traditional construction method dominate over *PCCon* (Nadim & Goulding, 2011, Zhang et al., 2018, Razkenari et al., 2020). The entry of private sector is important in the promotion and continuation of *PCCon* industry. Hence lack of support from private sector (B36) is a challenge to *PCCon.* Lack of past experience (Kamar et al. 2009) and insufficient information (Tam et al. 2007) is a hindrance for adoption of *PCCon* (B37). Mao et al. (2015) had added the unemployment issues of workers (B38) in the list of preliminary factors for his study, after in depth interview with the developers in China. *PCCon* could result in the reduction of labourers on site. Arditi et al. (2000) had included union politics as a factor in his survey, to study the problems of worker union activities (B39) in the *PCCon* industry in US.

3 Challenges of Indian Construction Sector & Opportunities for PCCon

The overwhelming requirements for housing of the rapidly growing and urbanising population is a significant factor in the growth of construction industry in developing countries like India. India is expected to become the fastest growing and the world's third largest construction market by 2030 (Global Construction Perspectives & Oxford Economics, 2015). The urban population in India is likely to become 50% of the total population by 2050 (Make in India). The Indian construction sector is confronted by numerous issues such as the pressing housing demands (Global Construction Perspectives & Oxford Economics, 2015), poor standard of living (Nanyam et al., 2017), skill shortages (Venkatesh et al., 2012), time and cost overruns (PMI & KPMG, 2019), lack of lean principles, poor quality, inadequate sustainability and safety standards (Sawhney et al., 2014). *PCCon* proves to be a viable solution to overcome the above challenges with its benefits. However, the promotion of *PCCon* in India is slow. Hence a systematic and structured study which could yield a reliable consensus to prioritize the barriers inhibiting the growth of precast industry in Indian construction sector is necessary. The present study focusses only on identifying the various barriers to *PCCon.* The study can be further extended by understanding the significance of provisional list of 39 barriers identified in the context of Indian construction sector and thereby help in devising amicable solutions.

4 Conclusion

The study attempts to identify the various barriers to the growth of Precast Concrete Construction *(PCCon)* in developing countries. An extensive literature review was carried out in this study and 39 preliminary barriers to

adoption of *PCCon* were identified. These have been classified into 6 categories, namely, Cost issues, Project delivery and Supply chain, Design issues, Awareness and Knowledge, Policies and Regulation, Social climate and Market demand. The significance of these barriers in the Indian construction sector needs to be studied, and ascertaining the critical barriers to adoption of *PCCon* can help the policy makers to develop appropriate solutions. Thus, implementation of appropriate measures to overcome the barriers with the integration of various stakeholders could facilitate the growth of *PCCon* in India.

How to Cite this Article:

Ittyeipe, A. V., & Thomas, A. V. (2021). Barriers to Adoption of Precast Concrete Construction in Buildings. *AIJR Proceedings*, 9-18.

References

Arditi, D., Ergin, U., and Gunhan, S. (2000). "Factors affecting the use of precast concrete system." Journal of Architectural Engineering, 6(3), 79-86.

Arif, M., Bendi, D., Sawhney, A., and Iyer, K. C. (2012). "State of offsite construction in India-Drivers and barriers." Journal of Physics: Conference Series, 364, 012109.

Blismas, N. G., Pendlebury, M., Gibb, A., & Pasquire, C. (2005). "Constraints to the Use of Off-site Production on Construction Projects." Architectural Engineering and Design Management, 1(3), 153–162.

Cheng, C., Shen, K., Li, X., and Zhang, Z. (2017). "Major Barriers to Different Kinds of Prefabricated Public Housing in China: The Developers' Perspective." ICCREM 2017.

Chiang, Y.-H., Hon-Wan Chan, E., and Ka-Leung Lok, L. (2006). "Prefabrication and barriers to entry—a case study of public housing and institutional buildings in Hong Kong." Habitat International, 30(3), 482–499.

Gan, X., Chang, R., Zuo, J., Wen, T., & Zillante, G. (2018). "Barriers to the transition towards off-site construction in China: An Interpretive structural modelling approach." Journal of Cleaner Production, 197, 8–18.

Global Construction Perspectives & Oxford Economics. (2015). "Global Construction 2030: A global forecast for the construction industry to 2030," London.

Goodier, C., & Gibb, A. (2007). "Future opportunities for offsite in the UK." Construction Management and Economics, 25(6), 585–595.

ICI (2016). "Handbook on Precast Concrete for Buildings." Indian Concrete Institute Technical Committee (ICI-TC/02), Chennai.

Jaillon, L., & Poon, C. S. (2007). "Advantages and Limitations of Precast Concrete Construction in High-rise Buildings: Hong Kong Case Studies." Proceedings of the CIB World Building Congress.

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

Jaillon, L., & Poon, C. S. (2009). "The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector." Automation in Construction, 18(3), 239–248.

Kamar, K. A. M., Alshawi, M., and Hamid, Z. A. (2009). "Barriers to Industrialised Building System (IBS): The Case of Malaysia." BuHu 9th International Postgraduate Research Conference (IPGRC) (Eds., Alshawi, M., Ahmed, V., Egbu, C. and Sutrisna, M.), Salford, UK.

Make in India, Construction, Reasons to invest, Available at: https://www.makeinindia.com/sector/construction (accessed 10 May 2020).

Mao, C., Shen, Q., Pan, W., & Ye, K. (2015). "Major Barriers to Off-Site Construction: The Developer's Perspective in China." Journal of Management in Engineering, 31(3), 04014043.

Nadim, W., & Goulding, J. S. (2011). "Offsite production: a model for building down barriers. Engineering." Construction and Architectural Management, 18(1), 82–101.

Nanyam, V. P. S. N., Basu, R., Sawhney, A., Vikram, H., & Lodha, G. (2017). "Implementation of Precast Technology in India–Opportunities and Challenges." Procedia Engineering, 196, 144–151.

Nawi, M. N. M., Lee, A., and Nor, K. M. (2011). "Barriers to the implementation of industrialised building system in Malaysia." The Built & Human Environment Review, 4.

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(2), 183–194.

Pheng, L. S., & Chuan, C. J. (2001). "Just-in-Time Management of Precast Concrete Components." Journal of Construction Engineering and Management, 127(6), 494–501.

PMI and KPMG (2019). "Revamping Project Management : Assessment of infrastructure projects and corrective recommendations for performance improvement."

Polat, G., (2008) "Factors affecting the use of precast concrete systems in United States." Journal of Construction Engineering and Management, 134(3), 169 -178.

Polat, G., (2010) "Precast concrete systems in developing vs. industrialized countries." Journal of Civil Engineering and Management, 16(1), 85 -94.

Rahman, A.B.A., and Omar, W. (2006) "Issues and Challenge in the Implementation of IBS in Malaysia", Proceeding of the 6th Asia Pacific Structural Engineering and Construction Conference (ASPEC), C 45-53.

Razkenari, M., Fenner, A., Shojaei, A., Hakim, H., & Kibert, C. (2019). "Perceptions of offsite construction in the United States: An investigation of current practices." Journal of Building Engineering, 101138.

Sawhney, A., Agnihotri, R., and Paul, V. K. (2014). "Grand challenges for the Indian construction industry." Built Environment Project and Asset Management, 4(4), 317-334.

Sherfudeen, A. P., Kumar, N., Pillai, R. G., and Kalidindi, S. N. (2016). "Promoting precast concrete for affordable housing An overview on promotional policies worldwide and challenges and possibilities in India." Indian Concrete Journal, 90 (5), 13-24.

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

Venkatesh, M. P., Umarani, C., Renuga, S. M., and Malathi, B. (2012). "Analysis and identification of critical factors of delay in construction projects." NICMAR Journal of Construction Management, 27, 83-91.

Wu, G., Yang, R., Li, L., Bi, X., Liu, B., Li, S., & Zhou, S. (2019). "Factors influencing the application of prefabricated construction in China: From perspectives of technology promotion and cleaner production." Journal of Cleaner Production, 219, 753-762.

Yee, A. A. (2001). "Social and Environmental Benefits of Precast Concrete Technology." PCI Journal, May-June, 14-20.

Zhai, X., Reed, R., & Mills, A. (2013). "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, W., Lee, M. W., Jaillon, L., & Poon, C.-S. (2018). "The hindrance to using prefabrication in Hong Kong's building industry". Journal of Cleaner Production. doi:10.1016/j.jclepro.2018.08.190