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Industrialized Building Systems for the Kingdom of Saudi Arabia

Try P.Santoso[1], Bambang Trigunarsyah[1*], Mohammad A. Hassanain[2], Firas Tuffaha[1]

[1] *Construction Engineering & Management Department, King Fahd University of Petroleum and Minerals , Dhahran 31261, Kingdom of Saudi Arabia*
[2] *Architectural Engineering Department, King Fahd University of Petroleum and Minerals , Dhahran 31261, Kingdom of Saudi Arabia*
E-mail address: bambangts@kfupm.edu.sa

Abstract: Rapidly expanding population in the Kingdom of Saudi Arabia has a massive impact to put pressure on the shortage of housing and existing infrastructure. With average population growth rate of 1,9% yearly, the population in Saudi Arabia is projected to increase from 31 million in 2015 to 37 million in 2025. According to the housing ministry, Saudi Arabia needs to provide 3.3 million units to meet the demand in 2025, which is about 300,000 unit a year. In the past 40 years, using the conventional construction method, the Saudi construction industry was only able to build about 150,000 units per year. To meet the demand gap for the housing shortage, a new approach and innovation in construction methods are needed. Industrialized construction as an approach in construction methods has been studied and implemented in some countries that experienced similar corncerns. Industrialized construction can be defined as the implementation of manufacturing methods to construction-related activities to improve quality, reduce cost and project duration. Compared to the conventional construction method, prefabrication as industrialized construction methods has reduced construction labor on-site by 9.5%, construction project duration by 20%, and construction waste by 56%. It improves the quality, durability and cost saving not only for construction project owners, but also construction contractors. This paper discusses the possibility of 'industrialization' of building system in the Kingdom of Saudi Arabia as a solution for the housing shortage. It is an initial part of a study aims to develop a framework to develop industrialized building system in the Kingdom of Saudi Arabia. The is paper based on extensive literature review and case studies.

Key words: industrial building system, Kingdom of Saudi Arabia, prefabrication

1. INTRODUCTION

The world urban population growth has been reported to grow rapidly. In 2014, 54% of world's population resides in urban areas. By 2050, this percentage is projected to increase to 66% [1]. This expanding population leads to a rapid increase in demand for housing, which many countries could not meet. This condition leads to housing shortages. Housing shortage is not a new issue, as many countries have been facing this problem over the past few decades. Japan, for example, was strugling with housing shortage from mid-1940s until the 1970s [2]. Sweden also facing low supply of housing during 1960s [3]. Recently, Malaysia needed to develop 800,000 housing units in 1996 to meet the demand of housing for urban population expanding [4].

Beside the population growth, the rapid expanding population in the Kingdom of Saudi Arabia (KSA) is also caused by large movements of migrants, with a net inflow of more than 100 thousand migrants per year in 2010-2015 [5]. The escalation of urban population in the KSA puts pressures on the shortage of housing and the existing infrastructure [6]. With average annual population growth 1,9%,

the population in Saudi Arabia is projected to increase from 31 million in 2015 to 37 million in 2025. According to the Ministry of Housing, Saudi Arabia needs to provide 3.3 million units to meet the demand in 2025, which is about 300,000 units per year [7]. In the past 40 years, using the conventional construction methods, the Saudi construction industry was only able to provide 150,000 units per year [7]. To meet the demand gap for the housing shortage, an innovative approach in construction methodsis needed.

Industrialized construction or building system as an approach in construction methods has been studied and implemented in some countries that experienced similar corncerns [2, 4]. This system can be defined as the implementation of manufacturing methods to construction-related activities to improve quality, while reducing project cost and duration [4, 8-10]. According to Jaillon and Poon [11], compared to conventional construction method, prefabrication as an industrialized construction methods has been proven to reduce construction labor on-site by 9.5%, construction project duration by 20%, and construction waste by 56%. It also improves construction quality and durability as well as cost saving for both project owners and construction contractors. This paper discusses the possibility of 'industrialization' of building system in the KSA as a solution for the housing shortage. The paper begins with a discussion on the concept of industrialized building systems (IBS), which is then followed by its implementation. The paper concludes with the argument to adopt IBS as an approach to meet the housing shortage.

2. INDUSTRIAL BUILDING SYSTEMS

Industrialized Building Systems (IBS) is an innovative approach of construction methods by implementing manufacturing methods in activities related to construction. This approach could improve project time and construction quality, as well as reduce construction cost and wastes. This approach is growing in the construction industry under the name of Modern Method of Construction (MMC) in the US; Off-Site construction in the UK, Australia and China; Pre-Fabrication in Singapore and Hongkong, and Industrial Building System in Sweden, Japan and Malaysia [2, 4, 8, 12-15]. The Malaysian Construction Industry Development Board CIDB [16] defines Industrialized Building System (IBS) as "*a construction technique in which components are manufactured in a controlled environment on-site or off-site, transported, positioned, and assembled into a structure with minimal additional site work.*". Industrialized Building System starts in a factory as off-site production, which build a prefabricated or precast component either in modules or units. It continue to the delivery process from a factory to a construction site, and it finish with the installation of moduls or units to complete building construction as shown in Fig.1 [14, 17].

Historically, the development of IBS in standardization and pre-assembly started in the industrial revolution, as used by H.Manning in 1833 for the first prefabricated house the Colonial Cottage for Emigrants. Then, in 1851, theCrystal Palace projectin London by Joseph Paxton,who utilized advances in the manufacturing processes for cast iron and glass, and put together a modular design that could be prefabricated off site, then assembled and erected on site [9, 18]. Since then, the development of IBS was continued following the impact of the two world wars (1918 and 1945), where many countries, especially European countries (e.g U.K, Germany, Netherland, Sweden) and also Japan, faced a problem of urgent needs for housing. To solve this problem, in mid-1940s the government of Japan created a program to fullfil the need of 4.2 million housing units, [2]. In more recent examples, Sweden needed to develop one million apartment units during 1965-1975 [3], and Malaysia needed to develop 800,000 housing units in 1996 to keep up with population explotion it faced [4]. With the limitation of time and cost, as well as the need to meet the required project quality and quantity, Industrialized Building Systems was an effective alternative for conventional construction method.

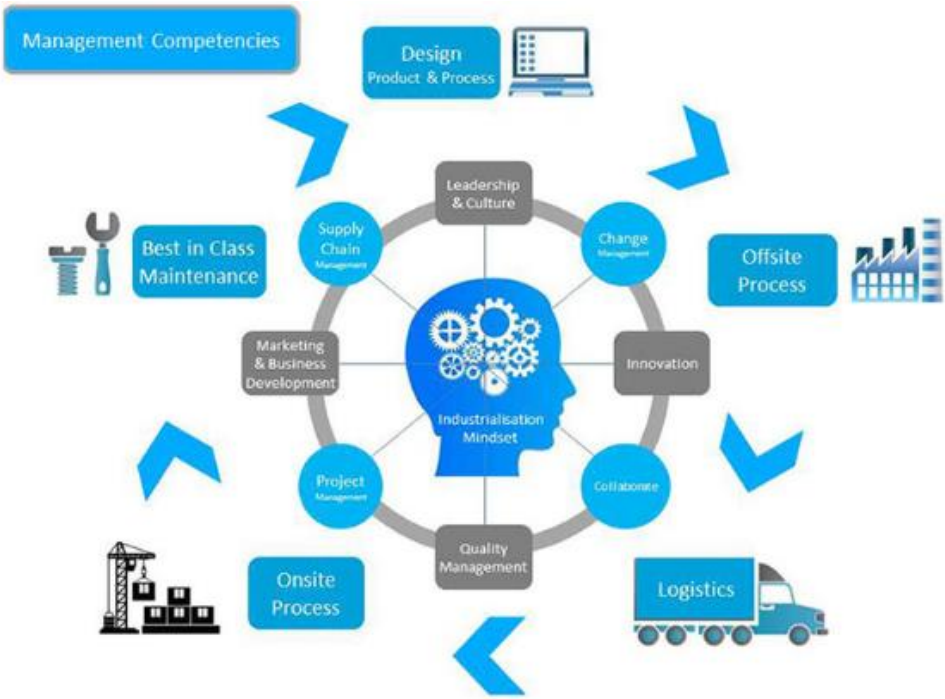

Fig. 1. Industrialisation flowchart, courtesy of the Offsite Management School [17]

3. IMPLEMENTATION OF INDUSTRIAL BUILDING SYSTEMS

The implementation of IBS as an alternative construction method contributes to positive changes to construction projects. Many researchs have been conducted that show project stakeholders who implement IBS as construction method gain benefits in term of reduction in construction cost and time [4, 8, 9]; risk and safety [19]; improved work process in productivity to meet the required quality [4, 8-10]; and enhances sustainability of project compared to conventional construction [10, 20-24].

Construction Global [25] identified the top six benefits of implementing IBS based on lesson learned from several companies in the United States and Australia that start construction process in a controlled factory enviroment;

- *Effieciency and predictability*
  Standardisation and repetitive work process in IBS optimized and simplified the work process, where each time the process is performed could improve the learning curve in factory activities [9, 25]. Off-site construction element designed with repetition process might contribute to simplify effective design process and higher productivity of designer [20, 26]. IBS also might improve predictability, as the impact of bringing building elements produced off-site where the working environment off-site is more controlled rather than on-site [19, 27]. Jaillon and Poon [11] studied projects in Hongkong that optimized their construction process by adopting IBS, in term of efficiency and predictability, demonstrated significant advantages in reducing construction time average up to 20%.
- *Safety*
  Performing construction activities off-site could eliminate safety risk in term of weather and visibility, as well as construction accidents (e.g falling from heighst and equipment accidents), as those activties are more controllabe than the on-site construction [25, 28]. Accident rate in construction project which adopt IBS was on average 63% lower than conventional construction [23].
- *Sustainability*
  Jaillon and Poon [23] stated that the implementation of IBS in Hongkong was the major contribution to waste reduction and material conservation, with average reduction of 56%

compared to the conventional construction method. It also contributed to significant savings in costs [11].

- *Less labour*
  Producing building components manufactured under the IBS method could reduce on-site labour requirement up to 43%. Reduced number of workers would lead to lower direct cost in term of wages for the project as well as the company [25, 29].
- *Less training*
  Compared to the conventional construction method, IBS which optimized work processes will create a narrow activities of worker. IBS puts the worker to specific role in the production line, which leads to simplified training program for improving worker's productivity, as well as reduces cost of training or indirect cost of project [19, 25].
- *No disruption to residents*
  For construction projects in city center or near urban areas, IBS with off-site and prefabrication method provides social benefit by reducing pollution caused by construction project such as dust and noise on site [23]. Moving construction activities off-site creates a cleaner construction site as well as avoids distruption to urban areas surrounding the project [25].

Although the benefits of implementating IBS has been recognized , many reports and researchs indicate that this system has not been widely used [13, 15]. According to the U.K. government figures that cited in Building4change report [17], the offsite construction sector currently accounts for only 7% of the total construction output in the UK. In the US, as stated by Lu (2007) that cited by Rahman [15], the conventional construction approach still dominated the construction industry. The factory-built housings represents only 20% of the residential sector, while housing projects that were built using Modern Methods of Constructions (MMCs) was only 7%. The same condition also happen in China. According to Ge (2007) that cited by Mao, et al. [14] stated that off-site construction is not widespread and has achieved limited progress.

There are some barriers that have been identified and studied as reasons for low IBS implimentation. Mao, et al. [14] grouped those barriers into five clusters. They are: Industry structure and supply chain, policies and regulations, technological innovation, cost, and market demand. Barries in low implementation of IBS include:

- The conservative culture in the construction industry [13, 30],
- The use of Design-bid-build contracts that separates design from construction [13, 31, 32],
- The focus on the lowest bid price, in particular in the public sector procurement [13, 27, 33],
- The lack of repetition possibilities, which is due to client's procurement and contracting practices, hinder standardization, continuous improvement and investments in both automation and prefabrication facilities [13],
- Technological dependency, which leads to a very low implementation level of industrialized building/ construction in developing countries [34],
- The understanding and misconceptions of the key stakeholders on the potential of industrialized building/construction [35],
- Shortage of skilled labor in implementing industrialized building system (i.e special erection procedure, use of new technology) [2, 4].

Implementation of IBS method in the Kingdom of Saudi Arabia (KSA) is driven by inefficiencies in project performance that leads to project delay that could increase the direct cost of the project [36]. According to Aburas [37] a workshop was organized in Jeddah in November 2010 discussing and evaluating the implementation of IBS or off-site construction in the KSA. Construction project's stakeholders in KSA indicated that off-site construction methods have been used for the past few decades in infrastructure and building projects. Eventhough they all agreed the IBS has benefits for shorter delivery time of project, increased quality, more controllabe in health and safety, and have potential in cost saving; the forum found that the use of IBS has been only on non volumetric, which is the use of off-site construction for only part of the building or structure (e.g: wall panel, half slab, precast column and beam),. KSA's construction industry stakeholder mostly use off-site methods for temporary structure, and they did not see the possibility of using volumetric and modular construction in permanent construction. This workshop [37] identified the barries that construction industry

stakeholders in KSA face in implementing off-site method in volumetric and modular construction. The major barrier is the technical limitation. Compared to other countries, such as US or Japan which mainly use lighter material (i.e. wood), KSA's construction dominated by brick & concrete material. If off-site construction is implemented, this will make heavy panel and building element which will be difficult to transport & lift. Lack of training and educational programs, negative perception, and lack of roads as infrastructure to support the transportation also considered as barriers to implement IBS in KSA. Despite those barries, IBS or off-site methods was considered as an effective alternative improving the construction industry's efficiencies. The forum suggested the introduction of new training and educational programs for architects and designers to change their design paradigms, and consumer education, including government legistation in boosting manufacturing in construction industry.

Recently, precast concrete as one of the system in IBS has been used in the Eastern Province of the KSA for large construction projects, such as the expansion of Saudi Aramco camp in Dhahran with more than 1700 housing units, which is expected to complete in 2018. Other examples include, Al Rashed Residential towers in Khobar and the ongoing housing project by SABIC (Saudi Basic Industries Corporation) in Jubail Industrial City. Currently precast concrete is mainly provided through three companies: Qandar Dywidag Precast Company, AlKifah Precast Company and AlRahed Precast Company.

Saudi Aramco Dhahran Camp expansion project has been divided into many packages, which each package awarded to a different contractor to accelerate the project execution. The unit was designed to have cast in-situ foundations and remaining building elements are built using precast concrete (ie. wall panels, beams and the roof). The adoption of precast concrete shows some benefits compared to the conventional method of construction using cast in-situ concrete and concrete masonry units. The adoption of precast concrete lead to safer and more efficient construction site. It reduced the use of labors up to 60 percent and yielded faster completion time. The adoption of precast concrete construction was identified as the best suitable system for the expansion of Saudi Aramco Dhahran Camp expansion project that started in 2013 due to the urgent need for residential units..

4. CONCLUSIONS

The review of literature identified barries in implementing Industrial Building Systems. Those barriers are in line with barries that were found in KSA's construction projects that incorporated IBS's construction methods. There are three main barries which are: technology depedency; misconception and negative perception in implementation of IBS, including lack of training and educational program which impacted to lack of skill labour; and lack of supported infrastructure to transport oversize load of off-site building element. However, initial case studies of construction projects that adopted IBS in KSA, shows some benefits that include safer and more efficient construction site, reduced onsite labors, and reduced construction completion time. To meet the demand gap for the housing shortage, the implementation of Industrial Building Systems would be the appropriate approach. To enable the implementation of IBS in the KSA, the follow up study will assess the current practices of utilizing IBS in the KSA construction industry; identify the barriers and the enablers for developing such system; and to propose a framework for developing IBS for the KSA construction industry.

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REFERENCES

[1] United Nations, "World Urbanization Prospects The 2014 Revision," United Nations, New York2014, Available: https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.Pdf, Accessed on: 4 August 2017.

[2] T. Yashiro, "Conceptual framework of the evolution and transformation of the idea of the industrialization of building in Japan," *Construction Management and Economics*, vol. 32, no. 1-2, pp. 16-39, 2014/02/01 2014.
[3] H. Pourghazian, "Industrial Construction Methods for Cost-Effective and Sustainable Multi-Storey Buildings " Doctoral, Architecture and the Build Environment, KTH, Stockholm, Sweden, 2008.
[4] Y. F. Badir, M. R. A. Kadir, and A. H. Hashim, "Industrialized Building Systems Construction in Malaysia," *Journal of Architectural Engineering*, vol. 8, no. 1, pp. 19-23, 2002.
[5] United Nations, "World Population Prospects The 2017 Revision," New York2017, Available: https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf.
[6] D. Dudley. (2014, March 2014) Saudi Arabia's Housing Shortage. *The Middle East Magazine*. Available: http://www.themiddleeastmagazine.com/wp-mideastmag-live/2014/03/saudi-arabias-housing-shortage/
[7] S. Kerr, "Saudi housing crisis proves taxing," in *Financial Times*, ed, 2016.
[8] N. Blismas and R. Wakefield, "Drivers, constraints and the future of offsite manufacture in Australia," *Construction Innovation*, vol. 9, no. 1, pp. 72-83, 2009/01/16 2009.
[9] A. Gibb and F. Isack, "Re-engineering through pre-assembly: client expectations and drivers," *Building Research & Information*, vol. 31, no. 2, pp. 146-160, 2003/01/01 2003.
[10] L.-y. Shen, V. W.-y. Tam, and C.-y. Li, "Benefit analysis on replacing in situ concreting with precast slabs for temporary construction works in pursuing sustainable construction practice," *Resources, Conservation and Recycling*, vol. 53, no. 3, pp. 145-148, 2009/01/01/ 2009.
[11] L. Jaillon and C. S. Poon, "The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector," *Automation in Construction*, vol. 18, no. 3, pp. 239-248, 2009/05/01/ 2009.
[12] Engineers Australia. (2016, 4 August 2017). *Analysing the benefits of off-site construction*. Available: https://www.engineersaustralia.org.au/portal/news/analysing-benefits-site-construction
[13] J. Larsson, P. E. Eriksson, T. Olofsson, and P. Simonsson, "Industrialized construction in the Swedish infrastructure sector: core elements and barriers," *Construction Management and Economics*, vol. 32, no. 1-2, pp. 83-96, 2014/02/01 2014.
[14] C. Mao, Q. Shen, W. Pan, and K. Ye, "Major Barriers to Off-Site Construction: The Developer's Perspective in China," *Journal of Management in Engineering*, vol. 31, no. 3, p. 04014043, 2015/05/01 2015.
[15] M. M. Rahman, "Barriers of Implementing Modern Methods of Construction," *Journal of Management in Engineering*, vol. 30, no. 1, pp. 69-77, 2014/01/01 2014.
[16] CIDB, " Industrialized Building System (IBS) Roadmap 2003-2010," Kuala Lumpur2003.
[17] D. Carr. (2015, 4 August 2017). *Offsite is key to Construction 2025*. Available: http://www.building4change.com/article.jsp?id=2627#.WZcCwVEjGCh
[18] R. Ågren and R. D. Wing, "Five moments in the history of industrialized building," *Construction Management and Economics*, vol. 32, no. 1-2, pp. 7-15, 2014/02/01 2014.
[19] S. S. Jackson. (2013) Off-Site Modular Construction Improves Quality and Safety of Projects. *Constructor*. Available: http://www.constructormagazine.com/off-site-modular-construction-improves-quality-and-safety-of-projects/#.WZck8FEjGCj
[20] A. Baldwin, C.-S. Poon, L.-Y. Shen, S. Austin, and I. Wong, "Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional construction," *Renewable Energy*, vol. 34, no. 9, pp. 2067-2073, 2009/09/01/ 2009.
[21] M. T. Gorgolewski, "The Potential for Prefabrication in UK Housing to Improve Sustainability," in *Smart & Sustainable Built Environments*: Blackwell Publishing Ltd, 2008, pp. 119-128.
[22] Z. A. Hamid and K. A. M. Kamar, "Aspects of off‐site manufacturing application towards sustainable construction in Malaysia," *Construction Innovation*, vol. 12, no. 1, pp. 4-10, 2012/01/13 2012.

[23] L. Jaillon and C. S. Poon, "Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study," *Construction Management and Economics,* vol. 26, no. 9, pp. 953-966, 2008/09/01 2008.
[24] V. W. Y. Tam, C. M. Tam, S. X. Zeng, and W. C. Y. Ng, "Towards adoption of prefabrication in construction," *Building and Environment,* vol. 42, no. 10, pp. 3642-3654, 2007/10/01/ 2007.
[25] Construction Global. (2014, 4 August 2017). *Top Six Benefits of Offsite Construction*. Available: http://www.constructionglobal.com/majorprojects/311/Top-six-benefits-of-offsite-construction
[26] L. Jaillon and C. S. Poon, "Design issues of using prefabrication in Hong Kong building construction," *Construction Management and Economics,* vol. 28, no. 10, pp. 1025-1042, 2010/10/01 2010.
[27] A. G. F. Gibb, "Standardization and pre-assembly- distinguishing myth from reality using case study research," *Construction Management and Economics,* vol. 19, no. 3, pp. 307-315, 2001/04/01 2001.
[28] F. Haas, "Preliminary Research on Prefabrication, Pre-assembly, Modularization and Off-site Fabrication in Construction," The Construction Industry Institute, Austin, Texas2004.
[29] C. M. Tam, "Impact on structure of labour market resulting from large-scale implementation of prefabrication," in *Advances in Building Technology*Oxford: Elsevier, 2002, pp. 399-403.
[30] A. Kadefors, "Institutions in building projects: Implications for flexibility and change," *Scandinavian Journal of Management,* vol. 11, no. 4, pp. 395-408, 1995/12/01/ 1995.
[31] M. P. Culmo, "Accelerated Bridge Construction Manual - Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems," Federal Highway AdministrationFHWA-HIF-12-013, 2011, Available: https://www.fhwa.dot.gov/bridge/abc/docs/abcmanual.pdf.
[32] P. Simonsson, "Buildability of Concrete Structures: Processes, Methods and Material," Doctoral, Civil, Environmental and Natural Resources Engineering, Luleå University of Technology Luleå, 2011.
[33] N. Blismas, C. Pasquire, and A. Gibb, "Benefit evaluation for off‐site production in construction," *Construction Management and Economics,* vol. 24, no. 2, pp. 121-130, 2006/02/01 2006.
[34] G. Polat, "Precast concrete systems in developing vs. industrialized countries," *Journal of Civil Engineering and Management,* vol. 16, no. 1, pp. 85-94, 2010/01/01 2010.
[35] R. Yunus and J. Yang, "Improving ecological performance of industrialized building systems in Malaysia," *Construction Management and Economics,* vol. 32, no. 1-2, pp. 183-195, 2014/02/01 2014.
[36] A. Al‐Kharashi and M. Skitmore, "Causes of delays in Saudi Arabian public sector construction projects," *Construction Management and Economics,* vol. 27, no. 1, pp. 3-23, 2009/01/01 2009.
[37] H. Aburas, "Off-Site Construction in Saudi Arabia: The Way Forward," *Journal of Architectural Engineering,* vol. 17, no. 4, pp. 122-124, 2011/12/01 2011.