Analyzing Obstacles and Exploring Opportunities to Improve Modular Industrialized Construction in Lebanon

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ABSTRACT

Over the past few decades, modular concrete construction emerged as a viable solution for meeting client requirements in getting an early return on investment, a high quality building, and an economically feasible construction. Precast concrete construction offers several green building benefits such as reducing construction wastes, minimizing site disturbances, and increasing flexibility. Although modular construction has been on the rise in Lebanon, many obstacles stand in the way of reaping more value for customers including technical, logistical, and organizational issues. This research aims at assessing the obstacles for efficient industrialized construction and exploring opportunities for improvement. The study reports results from industry-wide interviews covering all modular precast production companies, the major architects and design professionals, and class-A contracting companies. Findings of the study highlight that technical, logistical, and organizational/ cultural factors form the main obstacles, whereas cost, time, sustainability, and flexibility are the areas of opportunity for implementing efficient industrialized construction and increasing the uptake of precast concrete construction.

KEY WORDS

Industrialization of Construction, Modular Construction, Precast Concrete, Off-site Construction.

INTRODUCTION

Precast elements refer to concrete building and structural elements that are cast in molds at a centralized facility and then transported to be assembled on site, (Chan & Hu 2002). Precast concrete construction is a promising alternative over energy intensive traditional construction methods, where savings on material and labor hours are achieved. Although precast concrete construction has many environmental, structural, and economical benefits, several barriers are hindering the expansion of its use in Lebanon over traditional cast-in-situ methods.

Precast construction enables superstructure work to progress off-site while the project is still in early construction phases, boosting the speed of work execution which is a major concern for owners and developers, (Kelly 2005). Precast elements reach the construction site with the mechanical, electrical and plumbing provisions embedded; reducing the corresponding installation time required prior to concrete pouring in traditional in-situ works. Precast construction also appears to be advantageous in congested cities, where the application of just-in-time (JIT) and lean

philosophy in supplying precast elements at the time of onsite installation has tremendous value in alleviating the space constraints for onsite storage and traffic congestion around the worksite (Pheng & Chuan 2001, Meiling et al. 2012).

As per the committee on advancing the competitiveness and productivity of the U.S. construction industry workshop (2008), the use of modularization and offsite fabrication techniques is one of five major activities that could lead to improving the construction efficiency and productivity. Besides the speed of construction, precast construction methods are beneficial in several major areas: less materials' waste, less material exposure to inclement weather, lower site disturbance, safer construction, flexibility, adaptability, and built to suit shorter building times (Smart Market Report 2011).

While industrialized countries such as the United States have enjoyed a rise in precast construction, various challenges are hindering the use and expansion of precast systems in developing countries. These barriers include: the lack of good communication among parties, lack of structural engineers, and the lack of specialty contractors in precast concrete systems (Polat 2010). Although off-site concrete construction is present in fast developing countries such as China, its benefits are still not fully understood and it has not been employed as much as it should be (Zhai et al. 2014).

The precast concrete industry in Lebanon is less mature than that in developed countries. It emerged in Lebanon as a solution for the increasing demand for construction time reduction. The most common precast elements used in the Lebanese market are hollow core slabs, pre-stressed beams, and pre-stressed slabs. Moreover, the use of such elements, mainly hollow core slabs, is becoming more popular due to value engineering carried by the contractors to speed up the program. Although some projects have used 3D modular elements (customized 3D blocks manufactured off-site such as a complete 3D precast room with a floor, walls, and roof), 2D elements (pre-stressed beams, pre-stressed slabs, and hollow core slabs) comprise the majority of market use. While competition should improve quality and reduce cost, the Lebanese precast market is not in a real competition due to the small capacity of precast suppliers. In fact, some large projects required a combined effort of all suppliers to cover their demand.

While modular industrialized construction provides many advantages compared to the conventional cast-in-situ methods, its use still faces many barriers. Although modular construction has been on the rise in Lebanon, many obstacles stand in the way of reaping more value for customers including technical, logistical, and organizational issues. This research is the first of its kind in Lebanon and aims at assessing these obstacles and exploring opportunities for improvement.

LITTERATURE REVIEW

3.4 billion tons of Portland cement is annually produced worldwide, (US Geological Survey, 2012), contributing to 5% of global CO2 emissions, (Worrel et al. 2001). The use of precast construction helps achieve significant savings on materials used resulting in lower environmental impacts. In this context, savings up to 55% of concrete quantities, 40% of reinforcing steel requirements, and 70% of timber formwork have been reported in various projects when replacing in-situ construction by precast elements (Yee 2001b, Jailon et al. 2009). Besides savings on material, precast concrete construction provides many advantages over traditional construction manifested in tighter tolerances applied, higher quality achieved, accumulated experience vested in one place, design and manufacturing integrated into one process, and more consistent results in

terms of strength, appearance and color (Yee 2001a; Clarke 2003; Lam et al. 2007; Shen et. al 2009; Lachimpadi et al. 2012; Mao et. al 2013b).

In terms of waste generation, a study performed on the construction of high-rise buildings in Malaysia by Lachimpadi et al. (2012) proved that the waste generated by an industrialized buildings system (IBS), in comparison to a mixed system (precast & in-situ cast) is as low as approximately 50%. In fact, the waste generated from precast (or IBS) construction in comparison to the conventional complete in-situ casting is actually as low as 25% (Lachimpadi et al., 2012). Another study showed that, in certain building components, waste generated can be reduced by up to 100% if prefabrication is adopted. It also showed that long term costs could be reduced despite the relative increase in short term construction costs (Tam et al., 2007).

Despite the various advantages carried by prefabrication construction methods, the low market share figures of the precast industry in many developed countries (USA & Europe) reveal reluctance towards the deployment of such methods (Sacks et al., 2004). Chen et al. (2010) assert in their study that this problem could be alleviated should a decision making tool that aids the selection of appropriate construction methods be available. Thus they develop the Construction Method Selection Model that assesses whether prefabrication should be used on a project and the extent to which it should be employed (Chen et al., 2010).

To respond to the lack of value-based decision criteria that could help organizations identify and recognize the advantages of off-site construction, a 3-level decision criteria matrix consisting of more than 50 criteria, clustered into 8 categories, was developed, (Pan et al., 2012). The corresponding matrix is coupled with a 5-step structured decision process extracted from the industry's preferences: clarifying the decision context, establishing decision objectives, identifying decision criteria, clustering the criteria, and assessing the criteria. The process along with the matrix was thought to aid the house-building construction industry in making more informed value-based construction method decisions (Pan et al., 2012). It is useful to note how the house building organizations (interviewees) in this study in the UK, a developed country, thought that the criteria categories of sustainability, and health and safety were obligatory, and thus no trade-off could be negotiated. This is mainly due to the increasing concerns, awareness, and strict governmental requirements and regulations in the UK-factors that are lacking in many other developing countries such as Lebanon.

From a technical perspective, the structural behavior of the building under seismic effects is a major concern before adopting a precast solution, especially because of beam to column connections. Analyzing several types of these connections, Yee et al. (2011) recommend the avoidance of some (ex: field welding) while advancing other precast connection types (ex: Dywidag Ductile Connections) that are capable of withstanding large vigorous earthquake events with minimal structural damage.

METHODOLOGY

The paper investigates various challenges faced by the precast concrete construction in the Lebanese market. Structured interviews with experienced professionals from several design, contracting, and precast concrete firms were conducted to collect the desired data. The biggest sixteen contractors working in the Lebanese market were interviewed (31% of sample size interviewed, responsible for more than 60% of the precast projects executed in Lebanon). Interviews also were conducted with 10 design managers of the top six Architect/ Engineer (A/E) companies

with both architectural and structural background (60% of sample size interviewed, responsible for more than 70% of the precast projects built in Lebanon). On the other hand, interviews with the managers of precast suppliers were also conducted to understand the challenges they face in the local market, identify the precast products they produce, and understand the nature of the industry in Lebanon. Table 1 summarizes the four main sections addressed in the survey along with corresponding criteria. The survey was developed after (Jaillon et al. 2009) and adjusted to meet the Lebanese construction context, and data was collected using a 5 point Likert scale (1= least important, 2 = less important, 3 = neutral, 4 = important, 5 = very important).

Table 1. Survey Sections and Description

Section	General Information	Construction Methods & Waste Minimization	Benefits & Challenges of Precast Concrete Industry	Precast Products Demanded in Lebanon (addressed to suppliers only)
Description/ Criteria	Organization & interviewee information.	Identify the main decision factors taken into account when choosing a construction method, and distinguish the work components considered the most waste producing, and highlight the significance of waste minimization.	Determine the benefits and barriers for adopting prefabrication in Lebanon and the importance of each factor that affects the process.	Recognize the precast elements that could be provided by precast suppliers and the level of demand for each type.

RESULTS AND DISCUSSION

Data responses were broken down into six categories: selection of construction methods, industrialized vs. cast in-situ methods comparison, potential to reduce waste using modular and off-site construction, benefits of modular and off-site construction, barriers to implement modular and off-site construction, and the overall satisfaction with the current off-site industrialized construction. Regarding construction method selection, survey results show that major concerns focus on constructability, cost and time considerations with rankings above 4, while waste reduction gains little attention at this stage.

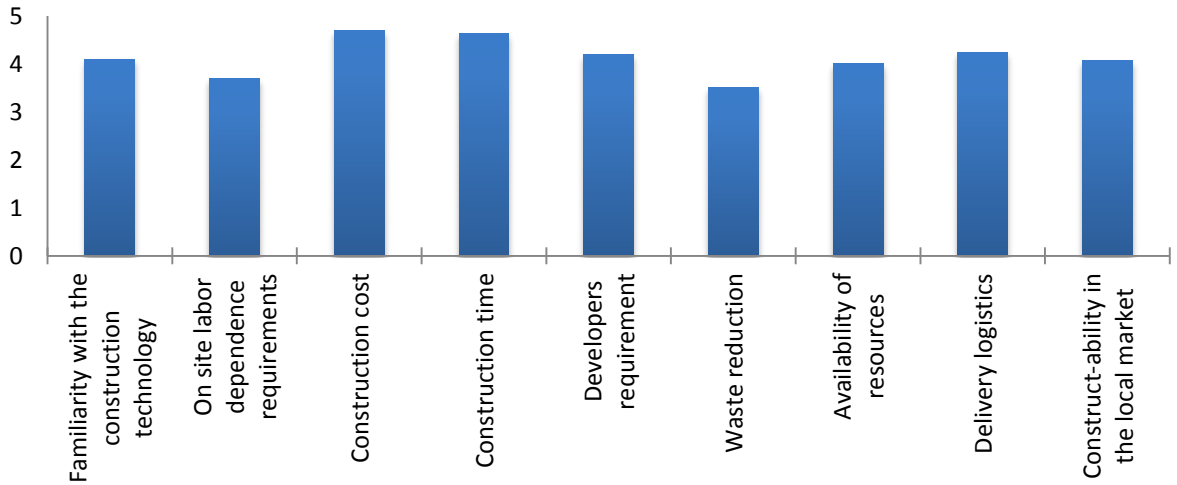

Figure 1. Selection of construction methods

Comparison between precast and cast-in-situ reveals various attitudes depending on whether the interviewee is a designer, a contractor, or a precast supplier. However they all agree on the role of off-site construction in reducing overall project cost, material waste, and project duration. However, one alarming result is that of "partnership between companies" where all three stakeholders had a pessimistic view of the potential for the precast concrete method to improve project collaboration and partnerships. This result reflects also the non-collaborative nature of the industry in Lebanon.

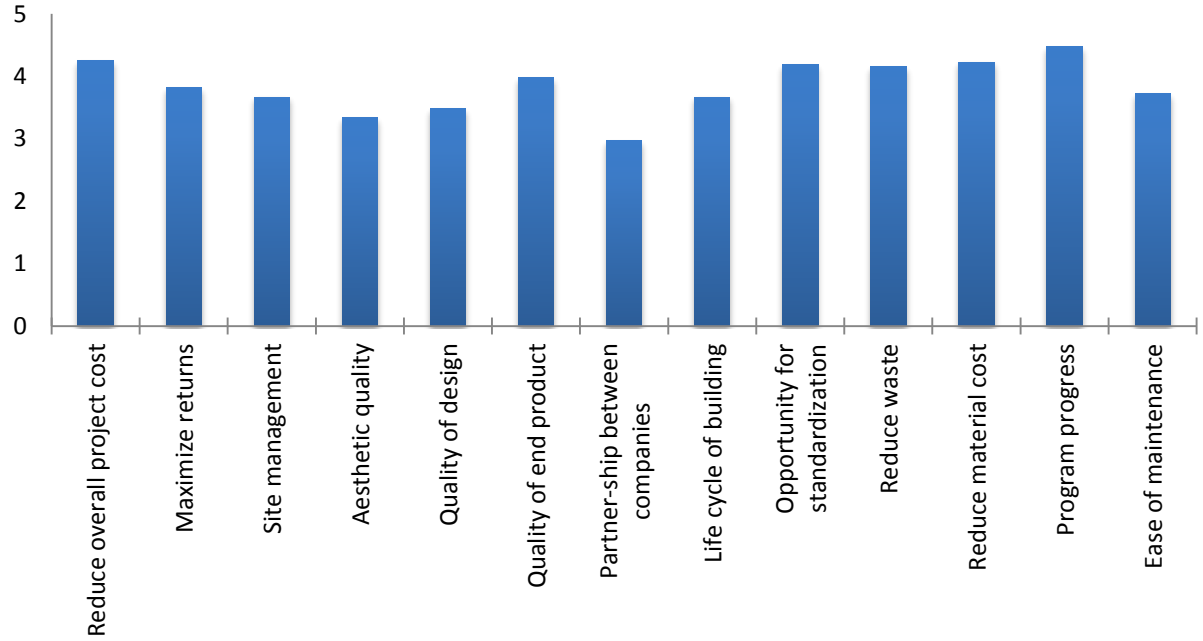

Figure 2. Industrialized vs. cast in-situ methods comparison

The third category uncovers an underestimate of the waste reduction accompanying the use of precast which reflects a lack of awareness among interviewees, mainly designers, on the amount of waste encountered in conventional on site construction and possible reduction using precast.

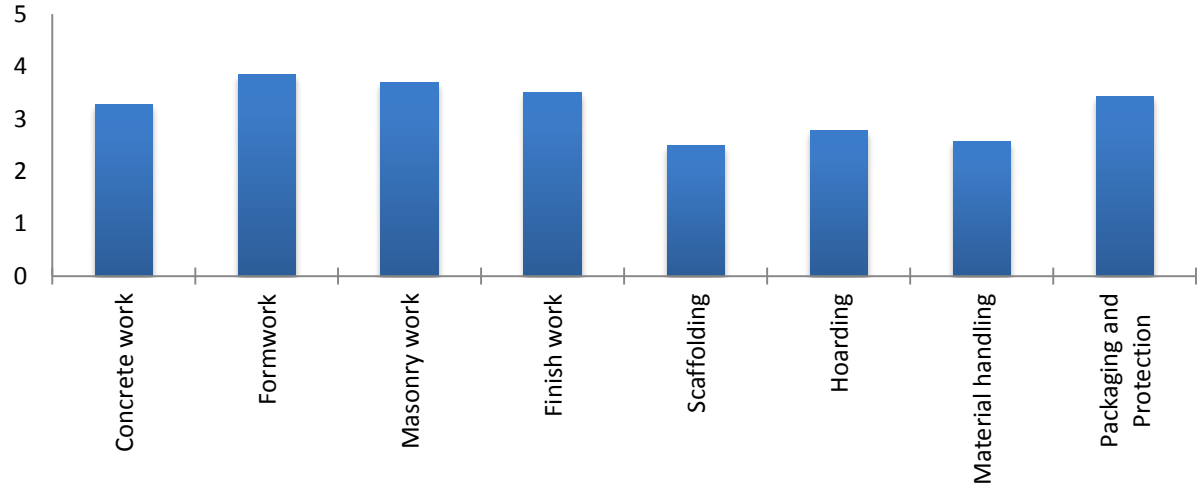

Figure 3. Potential to reduce waste using modular and off-site construction

The benefits of precast construction are well manifested in the fourth category; however, the biggest discrepancy was between "reduction of design time" and "reduction of construction waste" because of corresponding low A/E ratings. On the other hand, almost all barriers investigated were neutrally approached by interviewees except the "high overall cost" which surprisingly scored a 2.2 and hence, it is not considered a barrier.

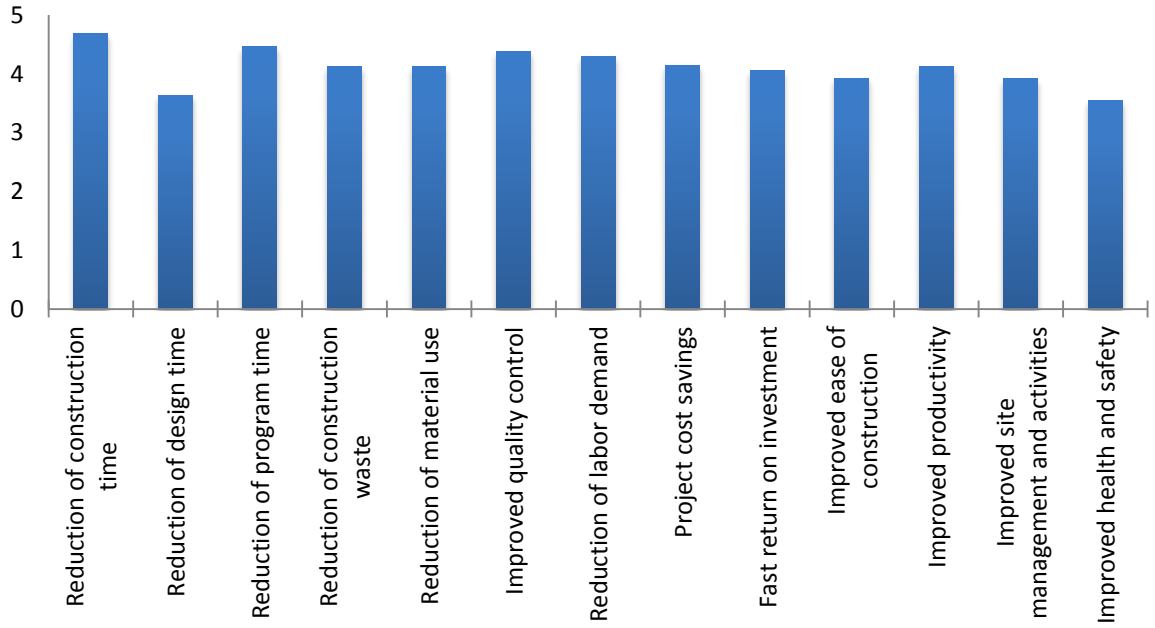

Figure 4. Benefits of modular and off-site construction

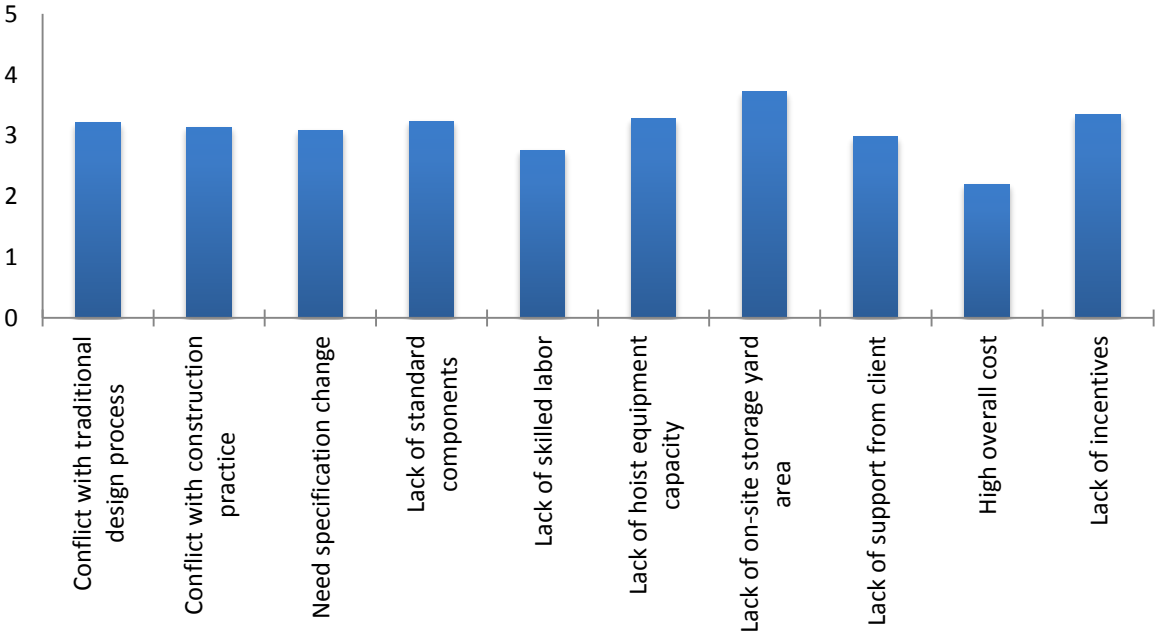

Figure 5. Barriers to implement modular and off-site construction

The sixth category grades the overall satisfaction with precast concrete construction. Interviewees were satisfied with the precast methods given the average result for "overall satisfaction" is 4.39. On the other hand, "communication with other members of the project team" ranked lowest with an average of 3.68.

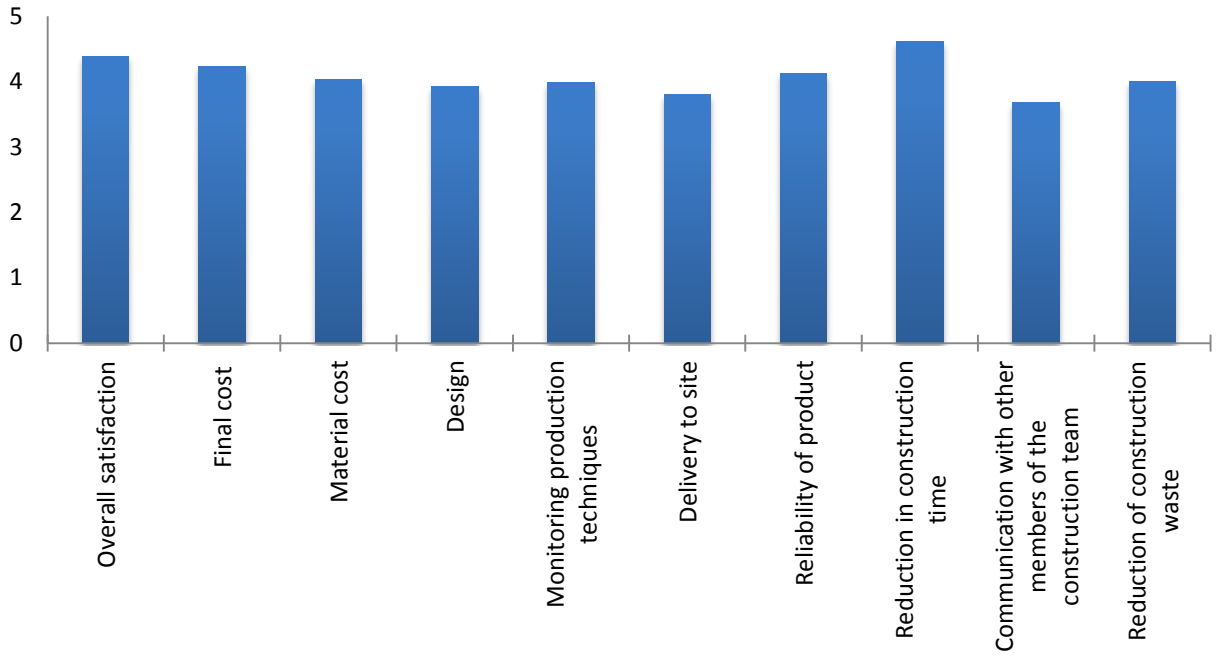

Figure 6. Overall satisfaction with the current off-site industrialized construction

CONCLUSION

This paper studies the benefits of precast concrete construction and the barriers facing the precast industry in Lebanon. Results from structured interviews with industry professionals are presented. Findings highlight several barriers and benefits in several categories including: technical, aesthetic, logistical, commercial, environmental (sustainability), organizational, and cultural. Precast construction emerged in Lebanon as a solution for the increasing demand for construction and for reducing the construction time. Some suppliers can nowadays provide modular concrete multi-story buildings that are way faster than conventional methods. The study highlights that several organizational and cultural factors can influence the choice and success of precast concrete, including the lack of collaborative mentality in the construction industry, poor communication between project participants, and the lack of collaborative contracts or incentives that foster collaboration between several parties on a construction project. Therefore, several factors play in favor of precast construction such as cost, time, sustainability, and flexibility, while other factors inhibit its wide application in Lebanon such as technical, logistical, and organizational/ cultural reasons.

REFERENCES

Chan, W. T., Hu, H. (2002). "Constraint programming approach to precast production scheduling". *Journal of Construction Engineering and Management*, 128(6), 513-521.

Chen, Y., Okudan, G. & Riley, D. (2010). "Decision support for construction method selection in concrete buildings: Prefabrication adoption and optimization". *Automation in Construction*, pp. 665-675.

Clarke, M. (2003). "Sustainability of off-site produced precast concrete". *Concrete*, 37(11).

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

Kelly, P. (2005). "Precast concrete in stadia". *Concrete*, 39(7), p. 10.

Lachimpadi, S. K., Pereira, J. J., Taha, M. R. & Mokhtar, M. (2012). "Construction waste minimisation comparing conventional and precast construction (Mixed System and IBS) methods in high-rise buildings: A Malaysia case study". *Resources, Conservation and Recycling*, 63, 96-103.

Lam, P., Chan, A., Wong, F. & Wong, F. (2007). "Constructability Rankings of Construction Systems Based on the Analytical Hierarchy Process". *Journal of Architectural Engineering*, 13(1), 36-43.

Mao, C., Shen, Q., Pan, W. & Ye, K. (2013a). "Major Barriers to Off-site Construction: The Developers' Perspective in China". *Journal of Management in Engineering. DOI: 10.1061/(ASCE)ME.1943-5479.0000246*

Meiling, J., Backlund, F., and Johnsson, H. (2012). "Managing for continuous improvement in off-site construction". *Engineering, Construction and Architectural Management*, 19(2), 141 – 158.

Pan, W., Dainty, A. R. J. & Gibb, A. G. (2012). "Establishing and Weighting Decision Criteria for Building System Selection in Housing Construction". *Journal of Construction Engineering and Management*, 1239-1250.

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

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

Sacks, R., Eastman, C. & Lee, G. (2004). "Process model perspectives on management and engineering procedures in the precast/prestressed concrete industry". *Journal of Construction Engineering and Management*, 206-215.

Shen, L., Tam, V., Li, C. (2009). "Benefit analysis on replacing in situ concreting with precast slabs for temporary construction works in pursuing sustainable construction practice". *Resources, Conservation and Recycling*, 53(3), 145-148.

Smart Market Report (2011). "Prefabrication and modularization: increasing productivity in the construction industry". McGraw-Hill Construction, pp. 56.

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

U.S. Department of the Interior (2012). "Mineral commodity summaries 2012". *U.S. Geological Survey*, 38-39.

Worrell et al. (2001). "Carbon dioxide emissions from the global cement industry". Annual *Review of Energy and the Environment*, 26, 303-329.

Yee, P. T. L., Bin Adnan, A., Mirasa, A. K. & Abdul Rahman, A. B. (2011). "Performance of IBS Precast Concrete Beam-Column Connections Under Earthquake Effects: A Literature Review". *American Journal of Engineering and Applied Sciences*, 93-101.

Zhai, X., Reed, R., and Mills, A. (2014). "Addressing sustainable challenges in China". *Smart and Sustainable Built Environment*, 3(3), 261 – 274.