Towards adopting off-site construction in the Western Australian housing sector as a potential source of competitive advantage for the builders

Abstract

Various innovations and advancement have been developed within the construction industry aiming to address the known shortcomings and continuously improve the industry. One of these advancements is the off-site construction (OSC) technique that has existed for a long time but recently gaining leverage from the advances in other relevant sectors such as manufacturing, information technology and material science. OSC carries much potential, so much so that it is even termed as the modern method of construction. Among various benefits, OSC has been identified as an effective solution to address speed and quality issues faced by the construction industry. Particular to the housing sectors, such as in Western Australia (WA), implementing such a technique can be considered essential to deliver quality housing with higher efficiency. Considered being in its infancy in WA, implementing a new technique such as the OSC has been considered risky for the local builders to take up. However, the risk is often a double-edged sword and rewards may be waiting for the builders who are willing to take it on and establish themselves as the main OSC providers. This paper presents the findings from research aiming to explore the potential of OSC adoption as a potential source of competitive advantage to the house builders in WA. A questionnaire survey was conducted followed by semi-structured interviews with relevant practitioners in the WA housing sector. Whilst confirming the potential of OSC adoption as a source of competitiveness, the findings of the research also revealed the barriers and enablers of adopting OSC in WA as well as identifying the critical success factors for the OSM adoption in WA in order to unlock the potential for gaining competitive advantage, particularly for house builders. Even though the findings are derived from WA dataset, the generic nature of the findings also provides insights into the adoption of OSC in other locations and to sectors other than the housing sector.

Keywords:
Competitive advantage; Construction industry; Off-site construction; Residential housing; Western Australia.

Introduction

The construction industry is constantly evolving and there have been numerous attempts to improve its product delivery methods and techniques. From various sectors within the construction industry, its residential sector has often regarded as the most traditional in terms of construction delivery method primarily involving brick and masonry works that have been extensively used in countries such as Australia and particularly in Western Australia (WA) (Sutrisna *et al.* 2018a; Sutrisna *et al.* 2017; ABS 2012). However, traditional construction techniques often receive criticism for its relatively longer construction time, waste generation and lower efficiency in production despite its long history and wide application in the residential housing industry (Steinhardt *et al.*, 2013; Baldwin, *et al.*, 2009; Tam *et al.*, 2007). Attempting to move away from the traditional methods of construction, the off-site construction (OSC) is one of the innovative techniques that can provide various benefits particularly in regards to productivity and quality of residential construction. OSC is mainly defined as a construction technique in which prefabricated

and standardised components/modules are manufactured in a controlled factory environment, transported and then erected/assembled on-site (Khalfan and Maqsood, 2014; Smith 2010; Gibb 1999). Thus, mainly by transferring the majority of construction activities into a controlled environment, OSC provides an effective solution to minimise time delays and quality issues faced by the construction industry (Shazad *et al.*, 2015). As the result, a number of scholars have reported the benefits of OSM over traditional construction (Goulding *et al.*, 2015; Elnaas, *et al.*, 2014; Goodier and Pan 2012; Schoenborn 2012; Gibb and Isack, 2003). For example, decrease in construction waste and reduction of construction time have been reported can be as much as 56% and 20% respectively in a study conducted in Hong Kong (Jaillon and Poon 2009). These reported superiorities have made OSC considered a suitable solution to address housing needs in places such as WA (Sutrisna *et al.* 2018a). In WA it has been forecasted that an extra 800,000 new homes are required to meet the needs of 3.5 million people in the capital of WA, Perth alone by 2050 and the population can reach 6.6 million inhabitants by 2065 assuming the current trends and development patterns continue (DoP and WAPC, 2015; WAToday, 2018). This means a rapid growth in residential sector in WA that needs new and innovative technologies to reduce the delivery time, increase productivity and improve quality of the construction at the same time. Whilst considered a potential way to resolve the housing shortage, OSC has not been widely implemented including in WA. Thus, there is a need to demonstrate further potential advantages that will attract key stakeholders to adopt OSC. One of these has been identified as the potential to gain competitive advantage.

The concept of competitiveness and competitive advantage has become the main-stream business strategy for many industries including construction industry soon after the idea was introduced in the 1980s (Flanagan *et al.*, 2007; Porter 1996). Competitiveness has been regarded superior to the traditional economic indicators such as profitability, productivity or market share as these have been perceived insufficient to enable continuous improvement of performance (Lu, 2006). The typical source of competitive advantage is usually regarded as stemming from the ability of an organisation to differentiate its products or services through the skills of its employees, the capabilities of the processes and technologies and the standard procedures set by the management (Vinayan *et al.* 2012; Kotha and Orne, 1989; Hayes and Wheelwright, 1984). However, timing can also be a source of competitive advantage when a firm implements a value creating strategy by becoming one the first providers to offer a product or service, known as the first mover advantage (Barney, 1991; Lieberman and Montgomery, 1988). A preliminary research in the housing construction sector suggested that the acquisition of OSC technology will be necessary to housing providers in the future to become and stay competitive (Chiang *et al.,* 2006). Unfortunately, there has not been any meaningful follow up research reported and therefore, there is a gap in the existing body of knowledge in terms of achieving competitive advantage from implementing OSC, particularly in the housing sector. Given the housing issues in places such as WA and the potentials held by OSC in alleviating such issues, exploring the potential for gaining competitive advantage can be a crucial motivation for house builders to adopt OSC.

This paper presents the findings from a research set up to explore the potential of OSC adoption as a potential source of competitive advantage to the house builders in WA. The data collection was facilitated through questionnaire survey and follow up semi-structured interviews with relevant practitioners in the WA housing sector. The findings confirm the potential of OSC adoption as a source of competitiveness, also the barriers and enablers of adopting OSC in WA. Furthermore, the critical success factors for the OSM adoption in WA have also been identified to unlock the potential for gaining competitive advantage,

particularly for house builders. Whilst derived from WA dataset, the generic nature of the findings also can be used as insights to adopting OSC in other locations and to sectors beyond the housing sector.

Literature review

Different terms have been used to describe off-site construction (OSC) such as off-site fabrication (OSF), off-site manufacturing (OSM), pre-assembly and prefabrication (Goodier and Gibb, 2004). Although currently OSC is often linked to the computer aided cutting-edge technologies, the history of OSC is not new. In the United Kingdom, off-site construction was applied to deliver a small number of houses after the World War I along with the traditional construction method. The Housing (Temporary Accommodation) Act 1944 boosted the application of prefabrication methods to deliver the housing shortage post World War II in the UK (Hammad *et al.*, 2019; Goulding and Arif, 2013). During the post-war era, surplus of steel and aluminium in many industries has given ways to pre-prefabrication of building components particularly concrete, timber, steel and hybrid framed system as a means to create job, effective use of resources and to provide solutions for new dwellings (Taylor, 2015). At around the same time, OSC was also being implemented in North America (e.g. Lustron home) and other parts of the world (Nadim and Goulding 2009; Gibb 2001). There is evidence, for example, that prefabricated homes were imported to Australia from the UK, USA and Singapore as early as 1837 (Goulding and Arif, 2013). However, the application of OSC in Australia is currently limited despite its early history on prefabricated home and the acknowledgement of OSC as a part of the key vision for improving the Australian construction industry in the future (Steinhardt and Manley 2016; Hampson and Brandon, 2004).

In implementing OSC, a part of building components or the whole building elements can be manufactured in a factory environment by engaging a standardised and more effective use of construction materials (Schoenborn, 2012; Elnaas *et al.*, 2009; Gibb 1999). The key feature of OSC is therefore, the transfer of most activities from an onsite location to a more controlled offsite manufacturing floor, which can offer more benefits in comparison to the more traditional construction (Sutrisna *et al.* 2017; Zhai *et al.*, 2013). Specific to the Australian housing market, its supply-side has been regarded as the main problems resulting in the delayed availability of new housing developments as well as raising the cost of the delivery (Hsieh *et al.* 2012; NHSC 2010). When focusing into the supply side to resolve the problems, there exists a significant risk to the house builders transitioning from traditional construction to OSC methods, as there is a lack of experience and knowledge (Hammad *et al.*, 2019; Khalfan *et al.* 2014). Some of the main issues with OSC implementation include lack of incentives, lack of knowledge/expertise, lack of collaboration, unfamiliarity and support from client/government (Pan and Sidwell, 2011; Elnaas *et al.*, 2009). The lack of understanding of the processes/incentives, requirements for key decisions in the early stages and associated costs are the main barriers to the stakeholders to implement OSC (Sutrisna *et al.* 2018a; Blismas *et al.*, 2010). These have been exacerbated by the negative perception or stigma attached to OSC as a method of producing "cheap and nasty temporary housing" among potential house buyers and hence its lower uptake in the industry (Rahman, 2013; Steinhardt *et al.*, 2013). Despite some success stories for example in WA, the use of OSC in transportation infrastructure Bull Creek Station Project (Blismas, 2007) or the Adara Apartments that has halved the time and generated 10-12% cost savings with 46% reduction of waste by implementing OSC (Green *et al.*, 2014; SBEnrc, 2015), the uptake of OSC is still low as experience (including

mistakes and solution) and lessons learnt are still considered vital for the stakeholders to adopt a new technique such as OSC (Tam *et al.,* 2007). Thus, more is needed to incentivise the housing providers/house builders (i.e. the supply side) to take the risks and receive something extra in return when implementing OSC. The value proposition forwarded in this research is the potential for the house builders, particularly in WA, to achieve competitive advantage by implementing OSC.

A previous study showed that up to 13% return on investment can be expected when implementing OSC in a construction project (Mortenson, 2014). However, the more contemporary business indicator known as competitiveness has demonstrated superiority from the traditional economic indicators such as return on investment, profitability, productivity or market share as these have been perceived insufficient to enable continuous improvement of performance (Lu, 2006). An earlier research in the housing construction sector has suggested that the acquisition of OSC technology will be necessary for housing providers in the future to become and stay competitive (Chiang *et al.,* 2006). One of the main concepts stemming out from competitiveness school of thoughts is the concept of competitive advantage that was introduced during the 1980s (Porter 1985) and has been used as one of the mainstream business strategy and tools since, including in construction sector (Johnson *et al.*, 2017; Flanagan *et al.*, 2007). Whilst the mainstream of strategic management domain typically considers the sources of competitive advantage of a firm to be cost leadership, differentiation and focus (e.g. Montgomery and Porter, 2009; Flanagan *et al.*, 2007; Coyne, 1986; Porter, 1985), other school of thoughts have promoted other factors, such as the first mover advantage (FMA) as an additional source of competitive advantage (Vinayan *et al.* 2012; Bohlmann *et al.*, 2002; Mueller 1997; Barney, 1991; Lieberman and Montgomery, 1988).

Cost leadership typically refers to the firm's ability to minimise their costs in their supply chain and/or internal processes and reflect these savings in the final pricing of their product/services, i.e. lower than their competitor's. From a recent study, it was evident that residential projects built using OSC technique did not necessarily reduce its overall cost (Sutrisna *et al.*, 2018a). As concluded in that study, this phenomenon can be attributed to the lack of continuous demands (volume) as well as the requirement higher degree of customisation, which has inhibited the residential OSC providers to gain the expected level of efficiently from implementing OSC. Instead, the general cost savings in adopting OSC typically derive from reduced reliance on skilled trades or reduced unexpected labour cost and onsite resources in a particular project (Construction, 2011) in a collective effort with other stakeholders in the wider supply chain before the costs benefits can be transferred to the project level (Vrijhoef and Koskela, 2000). Based on a preliminary study that found a strong positive correlation between the proportion of the prefabricated building elements and the cost performance of the project (Shahzad *et al.*, 2015), a novel methodology has been proposed to optimise different aspects of OSC projects with cost being one of the optimisation criteria (Hammad *et al.*, 2019).

Differentiation and focus, on the other hand, typically refer to the firm's ability to offer unique products or services that are sufficiently distinguishable from that of their competitors to favourably influence buyer's decision. The main difference between them is that differentiation typically operates in mass-markets whilst focus operates in niche markets (Johnson *et al.*, 2017; Porter, 1985). Various scholars (e.g. Vanayan *et al.*, 2012; Chen *et al.*, 2004; Gloet and Terziovski, 2004) have linked the concept of innovation as one way to represent differentiation/focus. One of the most prominent view on measuring differentiation and innovativeness of a firm came from the resource-based view (Barney

1991; 1997), which maintained that the configuration of resources in a firm needs to satisfy 4 requirements to gain competitive advantage: (1) it is valuable to the clients, (2) it is rare, (3) it is costly to imitate [also called "imperfectly imitable"], and (4) it is non-substitutable. These questions are later known as the "Barney's Test". Bringing these into OSC's context, potential differentiation aspects of OSC include the delivery of higher quality products with high level of standardisation, shorter delivery time and less reliance towards the increasingly reduced availability of skilled trades (Sutrisna *et al.*, 2017; Goulding *et al.*, 2015; Pan and Goodier 2012; Schoenborn 2012; Smith 2010). However, due to long history of OSC in the construction industry and the common practice of subcontracting in the industry, the uniqueness and innovativeness of OSC providers are mainly stemming from their abilities to synchronise design, manufacturing and construction activities to achieve synergy (Bekdik *et al.* 2018; Sutrisna *et al.*, 2018b; Goulding and Arif, 2013). The competitive performance of a company is often influenced by a number of key components such as productivity, quality, cost, technological innovation and local and international factors such as skilled-labor and financial/economical condition (Momaya and Selby, 1998; Carpinetti *et al.*, 2000; Singh *et al.*, 2008). Thus, the priority of the key components can vary depending on the local and global contexts. The competitive advantage of a housing provider/builder company in WA for example, would likely be different as influenced by its local circumstances and market conditions.

The first mover advantage (FMA) is a concept proposed by scholars (e.g. Lieberman and Montgomery 1988; Mueller, 1987; Glaser 1985) to describe competitive advantages gained by firms by moving early to the market and established themselves as the main providers of a particular product or service. FMA. Even though FMA may dissipate over time, the advantages gained by entering the market early are typically sufficient to establish the firm's reputation, experience, supply chain and internal processes/resources to be competitive. Following its emergence as a concept, however, the FMA has received criticisms regarding the lack of empirical evidence of relationship between order of entry and survival, performance, market share, higher return or long-term profitability (Robinson and Min, 2002; Boulding and Christen, 2001; Golder and Tellis, 1993; Robinson, 1988). In light of these, further development of FMA as the source of competitiveness has been focused towards sectors that provide conducive environment for its firms to capitalise from FMA. One of the main proponents of FMA, Suarez and Lanzolla (2017), provided a framework for analysing the environment suitable for implementing FMA and has advocated sectors with slower technological and market evolution pace as the most suitable to utilise FMA. Thus, the inertia in implementing OSC in the Australian house-building sector (Blismass and Wakefield, 2009) in general and WA in particular (Sutrisna *et al.*, 2017) has actually provided suitable environment for the builders/providers to potentially benefit from FMA (Datta *et al.* 2014). Whilst it will be down to individual house builder/provider to weight the risks of implementing WA against the potential benefits of FMA, this research forwarded this value proposition based on robust theoretical underpinning of competitive advantage and FMA.

For residential builder/providers intending to gain competitive advantage by implementing OSM, the next stage would be to develop an implementation plan. In developing such plan, one of the main factors to consider is the critical success factors (CSFs). CSFs have typically been considered factors that are found exist in successful endeavours/projects (Johnson et al., 2017). Thus, a CSF in itself does not guarantee a successful implementation, but it is typically a part of a successful implementation. Vinayan *et al.,* (2012), for example admitted that there is no one agreed method of measuring sustainable competitive advantage, but advocated critical success factors in determining

the sustainable competitive advantage in their study. Freund (1988) suggested a smaller number of most influential CSFs to be identified instead of identifying as many CSFs as possible. Thus, the intention should be to narrow down the most influential CSFs from a wider possible CSFs (Lu and Yuan, 2010). Following a comprehensive literature review in this research, potential CSFs specific to implementing OSC in residential sector have been identified from key literature and listed in table 1 below.

<Insert Table 1 Here>

Table 1. The identified critical success factors

Research methodology

The research methodology discussion will typically begin with a discourse on the philosophical position taken by the researcher followed by the specific research design including its sampling, data collection procedure, data analysis method and the research finding's credibility to address specific research questions, aim and objectives (Sutrisna and Setiawan 2016; Saunders *et al.* 2009). This research is leaning towards the critical realist paradigm, recognising that reality is accessible to human observers but in a limited manner, therefore accepting the co-existence of objective and socially-constructed reality (Sutrisna 2009; Lomborg and Kirkevold 2003). The ontological and epistemological stance taken in this research means accepting competitive advantage as both an objective measurement in the housing sector that determines the survival/performance of residential builders in the sector the as well as a socially constructed abstract concept used by firms in the housing sector to articulate/describe their mind-set and also as an aspiration in their firms. As a consequence, competitive advantage in this research is understood from both internal and external perspectives of the firms in the housing sector. This was considered important in better understanding how adopting OSM can potentially be a source of competitiveness and hence, the way forward. This has also influenced the selection of the data collection method in the research that was facilitated by questionnaire survey to identify current practices and semi-structured interviews to unveil the meanings ascribed to or the reasoning behind actions.

Following a comprehensive literature review to identify relevant factors and themes in implementing OSM as a potential source of competitive advantage, a survey questionnaire was administered followed by semi-structured interviews Questionnaire survey has been regarded the most suitable method of data collection in a research that are collating input from wider pool of respondents (Robson 2011; Gill and Johnson 1997). The questionnaire survey conducted in this research aims to better understand the residential construction sector in WA, identify how OSM can benefit builders in the sector (particularly in gaining competitive advantage), determine how the competitive advantage can be sustained in WA residential construction environment and establish the critical success factors to increase the likelihood for successful OSM implementation in WA residential sector.

A list of relevant shareholders in WA was collated to form the population of the questionnaire survey. A total 227 relevant stakeholders were identified for the questionnaire survey and contacted individually via e-mail and telephone calls to respond via an online survey links. A total of 43 respondents participated in the online questionnaire survey. The questionnaire respondent's profiles are presented in table 2 below

<Insert Table 2 Here>

Table 2. Profiles of the survey participants

The quantitative data was analysed in a descriptive manner allocating weights 1-5 in a 5 level Likert scales with 3 as the threshold of collective acceptance.

Aiming to capture rich data and more in-depth understanding of the WA residential sector as well as the potential of OSM to be implemented in the sector for its builders to gain competitive advantage, these respondents were then also invited to elaborate their answers in the follow up semi-structured interviews (Robson 2011; Bryman 2001) as well as recommending other potential respondents to be interviewed. This sampling technique is known as snowballing technique allows for expansion of participant's population whilst at the same time retaining the credibility criteria of the population (Longhurst 2009; Noy 2008). A total of 17 respondents were involved in the interviews. The interviews were conducted among mid-to-senior level experts and the average year of experience of the participants was 18.2 years. The respondent's profiles are presented in table 3 below.

<Insert Table 2 Here>

Table 3. Profiles of the interview participants

The semi-structured interview technique is usually chosen to enable direct interactions between the researcher and the respondents, allowing the meaning of individuals' specific reality to be discovered and interpreted (Galvin 2015; Thorns 2012). The captured data in audio format in this research was then transcribed and analysed following the principles of content analysis technique (for a detailed explanation on content analysis, please refer to Weber 1990). To ensure accuracy as well as maintaining ethics in conducting research, a copy of interview transcript was sent to each participant for review and approval. Subsequently, a holistic analysis process involving both quantitative data from the questionnaire survey and qualitative data from interviews in a process of 'constant comparison' was performed to identify themes or factors in an attempt to construct relationships leading to improved understanding of the matter being research (Burnard *et al,* 2008). The validity and reliability of findings was demonstrated through the triangulation of the literature review, the questionnaire survey and semi-structured interviews that has indicated convergence (Sutrisna 2004; Hubermann and Miles 1994; Jick 1979). Triangulation has been considered an important feature in a mixed methods research (Amaratunga *et al.* 2000) such as in this research.

Findings and discussion

OSC in the WA residential construction sector

The residential sector in WA has been dominated by more traditional builders who typically provide somehow limited range of products aimed for a single-family, owner-occupation consumers (Sutrisna *et al.* 2018a). This mimics what has been happening in the rest of Australia with traditional masonry construction accounts for up to 70% of houses constructed (ABS 2012). Although the supply-side factors in Australia are considered the main factors influencing new residential development in Australia (Hsien *et al.* 2012; NHSC 2010), there are also influences from the demand side, particularly in determining the type

of construction to be implemented. Thus, traditional 'brick and mortar home' has been the most popular choice in Australia (Sutrisna *et al.* 2017) and has been confirmed as still currently the most popular in WA (respondents 1, 4, 8, 10, 11, 14, 15, 16). From the buyer's point of view, brick-and-mortar houses have been perceived as providing higher durability and therefore will more likely yield higher resale value of the house in the foreseeable future that has made them being perceived as a safer investment (respondents 8, 10, 16). Whilst current literatures have pointed out negative past experiences with OSC concerning its perceived substandard quality (e.g. Rahman, 2013; Steinhardt *et al.*, 2013), the perception has been exacerbated in WA, mainly due to the extensive use of OSC in the provision of mining pods (respondents 7, 10, 12) that has reinforced the stigma of OSC as the less appropriate technique for residential buildings. For example, brick manufacturers in WA have been actively and aggressively promoting the robustness of brick as the most appropriate materials for house building (respondents 1, 5, 10, 14, 15, 16). All of these have accumulated and manifested into a lack of confidence, including from the banks and financial institutions in financing OSC projects. Whilst one of the main benefits of OSC is to speed up construction time by prefabricating the panels or volumetric units as early as possible (Goulding *et al.* 2015; Khalfan and Maqsood 2014; Schoenborn 2012; Smith 2010; respondents 2, 6, 10, 15), banks and financial institutions have been reluctant to release the funds to OSC house builders at these earlier stages of construction that has created financial challenges and risks for OSC builders in WA (respondents 3, 11, 16). Perception towards risks has been regarded one of the most prevalent factors that inhibit the wider adoption of OSC (Sutrisna and Goulding 2019).

The traditional house-building process is typically characterised by the requirement for a higher degree of uniqueness and individuality in each project from the demand side so much so that it has been regarded as epitomised by "unique choices of technical solutions, a limited use of platforms, uniquely combined teams and scarcely developed logistics and procurement strategies" (Lessing 2006, p. 90). In other words, in the house-building sector, a builder is expected to provide bespoke solution that has created higher reliance towards skilled trades (AHURI 2015). The bespoke nature of the house building itself has made the industry to gear up for less standardised process and more traditional style of construction and hence typically resulted in lower volume of OSC demand in WA from what would be required to achieve the economies of scale (respondents 3, 5, 6, 13, 14). Thus, most of the stakeholders in the entire supply chain have been gearing up for the traditional construction, including in terms of specialised trade skills (respondents 4, 14). This dependency towards specialised trades also brought its own problems where such specialised skills are in shortage such as in WA (respondents 3, 4, 9, 10, 15, 16). Although OSC has been regarded as a method that theoretically reduces dependency towards skilled trades by using semi-skilled or lower-skilled operatives, capitalising from higher degree of standardisation and repetition in a controlled manufacturing environment (Nadim and Goulding 2009), the current lack of volume and high degree of customisation of OSC in WA has not resulted in reduced dependency towards skilled trades. Thus the current situation in WA reflects the paradox of volume required to effectively benefit from OSC raised by Chiang *et al.,* (2006) and as a result, simply bringing the same traditional processes (and problems) into the controlled environment (Arashpour *et al.* 2018) that can eventually be considered a failure in fully capitalising from the potential advantages offered by OSC (Sutrisna *et al.* 2018b).

The potential of adopting OSC as the source of competitive advantage in WA

In light of the discussion so far, it can be concluded that the situation in WA residential sector is leaning more towards traditional (in-situ) construction and is not yet conducive for implementing OSC. This very situation, on the other hand, has indicated a potentially suitable environment for implementing strategy to capitalise from the First Mover Advantage (FMA) as advocated by Suarez and Lanzolla (2007). The slower technological and market evolution pace in WA commercial construction have made it suitable to benefit from FMA. The respondents agreed that there are potential benefits for OSC providers/builders to take the risks and be one of the first in the market (respondents 16, 17). Many of them, however, opined that there will be a significant but gradual learning involved for relevant stakeholders before they can fully understand the benefits of implementing OSC in WA and actually take the first steps to do so (respondents 2, 3, 4, 7, 8, 11, 16). It has been suggested that learning occurs more effectively in a more stable/steady environment and when occurs, this more effective learning situation will typically favour the first few firms who are considered the first movers in a particular market (Suarez and Lanzolla, 2007; Polanyi, 1983). Thus, different from a fast pace technological market such as the IT market (rapid technology development) or a fast pace market evolution such as the pharmaceutical market (rapid market growth as soon as a new product is introduced), a more stable/steady market such as residential sector in WA provides the best environmental conditions for FMA to occur in order for the providers to gain competitive advantage. To measure the potential for implementing OSC in WA residential sector as the source of competitive advantage, the Barney's test was administered to the survey participants with the results presented in Table 4 below. Due to the use of weighting system applied on 5 Likert scale, a mean of 3 and above is considered as collectively accepted by the respondents.

<Insert Table 4 Here>

Table 4. Descriptive Statistics of competitive advantages of OSC

The strongest agreement from the respondents was that OSC provides a sustainable competitive advantage for the house building ($\bar{x}$ = 3.93) followed by the result that OSC is considered providing values to clients ($\bar{x}$ = 3.84). Whilst OSC is still reasonably rare in WA commercial sector ($\bar{x}$ = 3.23), it is not particularly rare to imitate ($\bar{x}$ = 2.84) nor non-substitutable ($\bar{x}$ = 2.44). Whilst the benefits of OSC have been regarded supportive factors for companies to gain competitive advantages in the WA residential sector, both 'values to the client' and 'rare methods' were also rated as significant aspects of ensuring competitive advantages. Similar findings were also found in a study done by Aliakbarlou *et al.* (2018) reporting that client-perceived value reflects and stems from the client satisfaction. The findings here are in-line with the implementation of FMA to gain competitive advantage. As most product/services capitalising from FMA strategy are not aiming for protection from means such as patents for example but by establishing themselves as one of the first in the market and sustaining their competitive advantage by continuously being at the forefront of innovation and development in the sector.

The study also analysed the competitiveness of OSC's key components (including cost competitiveness, construction productivity, quality and defect management and manufacturing, transportation, logistics, and site operation) of competitive advantages using ANOVA Test. Aiming to assess the relative significance and possible associations

among these measures that determined the competitiveness or non-competitiveness of OSC, the results are presented in table 5.

<Insert Table 5 Here>

Table 5. ANOVA Test of competitiveness or non-competitiveness of OSC

Table 5 above shows that out of the key determinants, "Manufacturing, transportation, logistics, and site operation" emerged as the most significant factor. From the foregoing analysis, it can be concluded that there is a significant positive impact of manufacturing, transportation, logistics, and site operation on the overall competitiveness. This is an interesting finding as it reflects the local industry priorities in Western Australia. Although cost, productivity and quality are often regarded as the key determinants of the company success as outlined in the literature review, in the case of the OSC in Western Australia, manufacturing, transportation, logistics and site operation have been identified as the most important factors to ensure competitive advantage. Whilst this situation has been somehow indicated in Goulding *et al.* (2015), this further highlighted the context of WA being one of the traditional and somehow more isolated economies in the world (CEDA, 2017). Thus, bringing the local manufacturing facilities and the rest of its much needed supply chain up to a level that can sufficiently support OSC would be crucial to ensure its competitiveness against the more traditional and established construction methods.

Critical Success Factors for implementing OSC in WA

A set of CSFs were rated by the local experts in the questionnaire survey to identify the most relevant factors for companies to be successful in implementing OSC in WA. The identified CSFs (originated from the literature review) were then presented and scored by the survey participants based on the importance and relevance in WA construction industry. The data was analysed using IBM SPSS version 25. The percentile ranking is used to determine the most important factors in order to successfully implement Offsite construction in WA.

<Insert Table 6 Here>

Table 6: The ranking of the key factors (n=43)

The study found that among 20 factors, productivity, quality, cost, manufacturing and transportation, and market demands were the top critical success factors (respectively) of OSC in the residential markets in WA. Local companies needs to carefully consider these factors in gaining competitive advantages and the first mover advantages.

15 project features (cost, value, aesthetic/quality, productivity, government support, regulations, codes and standards, project interface, environmental performance, reputation, safety, simplicity of construction, availability of technique and tools, availability of material, availability of skilled labour, availability of knowledge and information) were also investigated through the questionnaire survey to investigate whether the features

support or work against traditional construction (TC) and offsite manufacturing (OSM). Combination/both means it can or cannot be a benefit or barrier for either type of construction. About 6 project features (such as cost efficiency, construction productivity, better project interface, environmental performance, worker safety and simplicity of constriction) out of 15 were identified as benefits to OSC in WA. Among various features, resale value, reputation, availability of the local knowledge and information were the key benefits and strength of the traditional construction. These are not surprising given that the method has been practiced in WA for long time. On the contrary, productivity, environmental performance and workers safety were amongst the top benefits and strength of the OSC in WA.

A framework to gaining competitive advantage in WA residential sector has been put forward by considering both key factors and main benefits of OSC. Figure 1 captures the findings in this research that are inter-linked to provide a framework for house builders to gaining competitive advantage in WA residential sector. Certainly, the emerging technology such as OSC needs to ensure balance between supply and demand of the local market to attain the first mover advantages. However, considering the local residential market in Western Australia, the study found that the competitive advantage has been significantly driven by the cost leadership (such as productivity, cost and manufacture and transport) and differentiation (quality and market demand) of the project.

<Insert Figure 1 Here>

Figure 1. A framework to gaining competitive advantage in WA residential sector

Conclusion and further research

With WA being one of the isolated economies in the world, its residential sector has distinct characteristics peculiar to maintaining the traditional construction approaches and has been slow in implementing new innovative technologies. This study was set aiming to analyse OSC as a potential source of competitive advantage to the house builders in WA. A questionnaire survey was administered followed by semi-structured interviews with relevant practitioners in the WA construction housing sector. The study found that the residential construction industry in WA is profoundly relying on the traditional construction techniques including brickworks. This is underpinned by the fact that the reputation, reliance upon local knowledge/information and the assurance of resale value of dwelling properties of traditional ways of working have been deeply embedded in the fabric of the society as the proven and hence highly acceptable norms by local residents in WA. Despite the profound need for new housing in WA combined with numerous reported benefits and superiority of OSC, especially in the context of productivity, environmental performance and workers safety, this research attempts to better understand the reasons behind insufficient uptake of OSC, particularly in WA. Working on the premise that OSC is one of the much needed techniques to alleviate housing issues in places such as WA, this research collected data through questionnaire survey and interviews with relevant practitioners from construction housing sector in WA to explore the potentials of OSC as the source of competitiveness to house builders in WA through the FMA concepts.

Various key components of the local competitiveness in the construction industry: manufacturing, transportation, logistics and site operation have been identified as the most

important factors to ensure company's competitive advantages in Western Australia (as presented in Table 5). The findings confirmed the potential of OSC adoption as a source of competitiveness, particularly in WA. Further findings of the research also revealed the barriers and enablers of adopting OSC in WA as well as identifying the critical success factors for the OSC adoption in WA in order to unlock its potential for house builders to gaining competitive advantage. The findings of the study have been aggregated into a framework to gaining competitive advantage in the housing sector in WA. This framework would be useful for house builders and developers in WA and Australia in considering and selecting OSC as a robust house building technology. Although the study mainly focuses on the residential housing market in WA, the findings of the study can also be used in developing construction strategies and policies in Australia. The findings of this study implied that full supports from the government particularly in endorsing and recognising OSC is urgently needed in WA to alleviate doubts instil confidence to the entire supply chain of the building sector, including the clients and financiers . Although the scope of the study was limited to residential housing sector, it is envisaged that further study can be conducted to analyse the applicability and prospect of OSM in other sectors such as the commercial buildings sector whilst the strategies for securing competitive advantages through implementing OSM underpinned by FMA concepts can be further developed in the future.

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