

ENHANCING AUSTRALIAN HOUSING AFFORDABILITY: OFF-SITE MANUFACTURING SUPPLY CHAIN STRATEGIES

Sherif Mostafa¹, Nicholas Chileshe² and Jian Zuo³

ABSTRACT

Housing affordability refers to an ability to pay for the household costs associated with their home ownership. Housing stress refers to a situation when a house customer struggles to pay the housing costs. In Australia, the 30/40 rule is commonly used to measure the housing stress. The *Demographia Survey* in 2014 highlighted the deterioration of housing affordability across 39 housing markets in Australia. The decline is likely caused by housing supply and demand factors. The affordability issues from the demand side have already been focused. To bridge the gap of knowledge, this paper addresses the affordability issues from the housing supply side. Off-site manufacturing (OSM) is a modern construction method which provides some benefits including better finished houses quality, extra housing productivity, and reduction in house prices. In this paper, reviews of the related literature to identify the factors drive the Australian housing affordability are conducted. It aims at introducing OSM supply chain to increase the supply of affordable housing in Australia. The suggested supply chain focuses on two strategies which incorporate lean and agile concepts to manage house building processes.

KEYWORDS

Housing affordability; Housing stress, 30/40 rule; OSM, lean and agile concepts

INTRODUCTION

The calls for affordable housing in Australian built environment have been increased throughout the post-war period (Beer et al. 2006). The homeownership rates have remained relatively unchanged in Australia since 1966. Moreover, the young Australians are either delaying entry into homeownership or not entering homeownership at all (Baxter and McDonald 2004). The affordability problems impact on the private rental sector, which accommodates 20% of all Australian households. Many house occupants are more likely to remain in rental for a longer

¹ PhD Candidate, School of Natural and Built Environments, Barbara Hardy Institute, University of South Australia, City East Campus, GPO Box 2471 Adelaide, SA 5001, Australia, Sherif.mostafa@mymail.unisa.edu.au

² Senior Lecturer, School of Natural and Built Environments, Barbara Hardy Institute, University of South Australia, City East Campus, GPO Box 2471 Adelaide, SA 5001, Australia, Nicholas.Chileshe@unisa.edu.au

³ Senior Lecturer, School of Natural and Built Environments, Barbara Hardy Institute, University of South Australia, City East Campus, GPO Box 2471 Adelaide, SA 5001, Australia, Jian.Zuo@unisa.edu.au

period. Housing affordability is defined as a product income against the costs associated with the home ownership. The commonwealth bank affordability reports for the year 2013 displayed housing affordability index that increased by 9.8% compared to twelve months earlier (HIA-CBA 2013). However, the housing affordability across regional Australia deteriorated during the same year. The *10th Annual Demographic International Housing Affordability Survey* ranks Australia as the second in the severely unaffordable housing market (Demographia 2014). The decline is caused by some factors such as the increasing of houses price (NHSC 2013). The previous studies tended to focus on the housing affordability from the housing demand side (Liu and London 2011). This paper, on the other hand, focuses on the affordability issues from the housing supply (productivity) side.

One of the suggested solutions to improve the housing affordability situation is the adoption of Off-site manufacturing (OSM) (NHSC 2013). OSM provides a controlled manufacturing environment to produce the house components and modules. OSM supply chain could enhance the housing supply and provide houses at an affordable price for the low income group. The involvement of OSM in house building has been recommended to improve the housing supply and to meet the customer demands. The US department of Housing and Urban Development (HUD) confirmed the opportunities of OSM in building better, faster and at lower cost homes (PATH 2002). As a result, the house building industry continues to play a key role in providing affordable and durable housing for America's families. In U.K. house building, the take-up of the off-site construction provides house building organisations with the capabilities to deliver low to zero carbon homes at affordable prices (Pan and Goodier 2012). In Japan, Barlow and Ozaki (2005) highlight the application of OSM in the industrialised housing to produce lower-priced houses.

In Australia, OSM has been suggested in the *Construction 2020 report* as a key vision for improving the Australian construction industry (Hampson and Brandon 2004). The report concludes the benefits of employing OSM for the construction products which include better quality control, higher productivity and greater cost reductions. Blismas and Wakefield (2009) state that OSM is capable of reducing the construction costs. Despite the research work, the decline in the housing affordability across the Australian regions is persisting. More research is required to explore the employment opportunities and the optimum usage of OSM. This research paper aims at introducing OSM supply chain as an attempt to increase the supply of affordable housing in Australia. As such, it may be useful for housing policy makers, construction executives, managers, designers and developers to rethink about housing issues beyond the domain of construction.

REVIEW OF HOUSING AFFORDABILITY IN AUSTRALIA

In general, affordability measures the population's median income ability to obtain a particular item such as a house (Quigley and Raphael 2004). Housing affordability refers to the rent-to-income ratio or house-price-to-income ratio. Three types of affordability are purchase, repayment, and income (Gan and Hill 2009). Purchase affordability refers to capital costs. The repayment affordability is associated to the mortgage repayment. Income affordability is the ratio between the house price and household income (Urbis 2012). The broadly accepted measure of housing affordability is commonly known as the 30/40 rule. It is stated that the expenditure on

housing accounts for no more than 30% of household incomes for the people at the bottom 40% of the income group (Australian Government 2008). Figure 1 demonstrates the weekly earnings and house rental expenses in Australia. It can be seen that the rental expenses in capital cities were greater than the weekly earnings.

The NHSC (2013) reported that rents on houses in capital cities in the second quarter of the year 2012 were increased by 3.2% compared to the year 2011. Rents on other dwellings such as apartments were up by 2% over the year 2012. It can be seen from Figure 1 that the current average nominal rent paid is increased by 75.8% for houses and 91.8% for other dwellings since 2003. Likewise, the average earnings increased by 57% and house prices rose by 69% during the same period (NHSC 2013). On the other hand, the house building activity in Australia remains sluggish to supply affordable housing (HIA 2013). As a result, the Australian housing market experiencing an unaffordable housing situation.

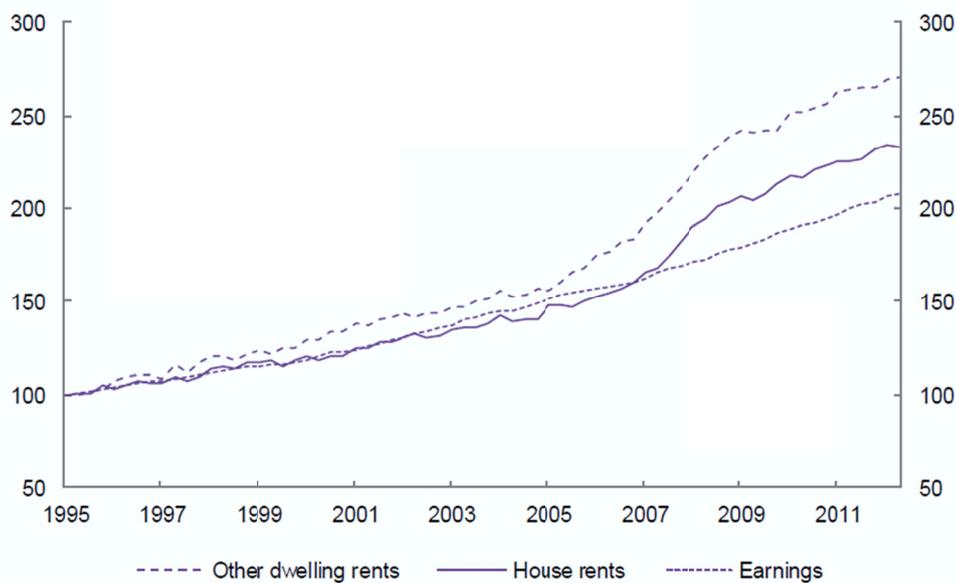


Figure 1: Average weekly earnings and house rental expenses (NHSC 2013).

Housing affordability measures

The Housing Industry Association–Commonwealth Bank of Australia (HIA–CBA) index measures the ratio of median household disposable income to the qualifying income required for a typical first home loan. The index increased by 5.1% in September 2013 Quarter to a level of 84.1. This is due to the interest rate reductions by the Reserve Bank Australia (RBA) from 7.05% to 2.5% since 2011 (HIA-CBA 2013). The source of median price data is generally collected from CBA new housing loans, and this would be subject to volatility. However, it is unidentified how qualifying income is calculated and what assumptions are used. The Demographia (2014) survey ranks Australia as the second in the severely unaffordable house market among the nine countries surveyed: Australia, Canada, Hong Kong, Ireland, Japan, New Zealand, Singapore, the United Kingdom and the United States (Table 1).

Table 1: Ranked housing affordability for Australian market from the most to least affordability (modified from Demographia 2014)

International affordability rank	National rank	Metropolitan market	Median Multiple	Median house price	Median household income
218	1	Karratha, WA	4.1	\$679,000	\$166,800
224	2	Galdestone, QLD	4.2	\$400,000	\$94,200
248	3	Mildura, VIC	4.5	\$213,000	\$46,900
248	3	Townsville, QLD	4.5	\$346,000	\$76,400
257	5	Shepparton, VIC	4.6	\$237,000	\$51,400
264	6	Launceston, TAS	4.7	\$250,000	\$53,200
268	7	Alice Springs, NT	4.8	\$469,500	\$97,100
268	7	Rockhampton, QLD	4.8	\$318,300	\$66,600
268	7	Tamworth, NSW	4.8	\$260,000	\$54,500
277	10	Bunbury, WA	4.9	\$380,000	\$77,200
277	10	Mackay, QLD	4.9	\$420,000	\$86,300
277	10	Orange, NSW	4.9	\$317,000	\$64,600
282	13	Bathurst, NSW	5.0	\$313,300	\$63,200
282	13	Port Hedland, WA	5.0	\$818,000	\$163,700
289	15	Canberra, ACT	5.3	\$562,200	\$106,400
289	15	Geraldton, WA	5.3	\$379,000	\$71,500
289	15	Wagga Wagga, NSW	5.3	\$333,700	\$63,500
297	18	Hobart, TAS	5.4	\$322,800	\$59,500
297	18	Toowoomba, QLD	5.4	\$309,000	\$57,500
306	20	Ballarat, VIC	5.5	\$290,000	\$52,500
306	20	Cairns, QLD	5.5	\$351,500	\$63,600
312	23	Albury-Wodonga, NSW	5.8	\$320,000	\$55,200
312	23	Albury-Wodonga, VIC	5.8	\$320,000	\$55,200
312	23	Brisbane, QLD	5.8	\$442,100	\$75,900
319	25	Bendigo, VIC	6.0	\$315,000	\$52,700
319	25	Newcastle-Maitland, NSW	6.0	\$385,700	\$64,800
319	25	Perth, WA	6.0	\$508,000	\$84,800
327	28	Adelaide, SA	6.3	\$392,000	\$61,800
329	29	Darwin, NT	6.5	\$673,500	\$103,600
332	30	Fraser Coast, QLD	6.8	\$290,000	\$42,600
332	30	Mandurah, WA	6.8	\$390,000	\$57,600
332	30	Wollongong, NSW	6.9	\$430,000	\$61,900
338	33	Coff's Harbour, NSW	7.1	\$355,000	\$50,000
339	34	Geelong, VIC	7.3	\$405,000	\$55,700
344	35	Gold Coast, QLD	7.7	\$472,100	\$61,500
347	36	Sunshine Coast, QLD	8.0	\$440,000	\$55,300
350	37	Port Macquarie, NSW	8.1	\$378,000	\$46,600
351	38	Melbourne, VIC	8.4	\$595,500	\$70,800
354	39	Sydney, NSW	9.0	\$722,700	\$80,500
Australian Housing Market Median Multiple			5.5		

Table 1: (continued)

The survey used the median multiple measure to rate the housing affordability. The measure related the median house price with the gross annual median household income. The survey ranked the housing markets into four categories using the median multiple; affordable (Median Multiple ≤ 3), moderately unaffordable ($3.1 \leq$ Median Multiple ≤ 4), seriously unaffordable ($4.1 \leq$ Median Multiple ≤ 5) and severely

unaffordable ($5.1 \leq \text{Median Multiple}$). At international level, the Australian market came the second in the severely unaffordable category with ($\text{Median Multiple} = 5.5$). In Australia, the survey covered 39 markets in the Australian States and Territories as shown in Table 1. It can be seen that Australia has 14 seriously unaffordable markets and 25 severely unaffordable markets. There is no affordable or moderately affordable housing market in Australia (Demographia 2014).

RESEARCH METHODOLOGY

This paper aims to enhance the affordability of the Australian housing by introducing OSM supply chain incorporation with lean and agile concepts. The paper explores the gap of knowledge in housing affordability and OSM in Australia. It is suggested that the literature review can be elaborated using the purposive selection approach in which only related articles pivotal to the research topic are chosen to be reviewed (Randolph 2009). The literature selected for this paper is limited to the previous OSM, and lean and agile studies in the Australia and international house building context. Studying the literature can be carried out through various peer-reviewed and scholarly sources including books, journals articles, conference proceedings, seminars, reports. One of the most efficient ways for searching the literature is the electronic resources (Leavy and Hesse-Biber 2011).

The literature review and the selection of appropriate sources were conducted through the following electronic databases: Emerald, Elsevier, Taylor and Francis, and Google Scholar. Some specialised and governmental published works on house building from Australia including Housing Industry Association (HIA), National Housing Supply Council (NHSC), Australian Housing and Urban Research institute (AHURI), Coalition of Australian Government (COAG), Australian Institute of Health and Welfare (AIHW), Demographia and Australian Bureau of Statistics (ABS) were additionally searched.

RESEARCH FINDINGS

A total of 169 publications from 1992 to 2014 were collected. The second stage involved scrutinising the selected resources. It revealed that the term OSM has been used interchangeably with Off-Site Production/Fabrication (OSP/OSF), preassembly, modularisation, and off-site fabrication (PPMOF) (Pan and Goodier 2012), pre-work and manufactured houses (Song et al., 2005), mass customization house building (Schoenwitz et al. 2012), the industrialised building (IB) (Zhang et al. 2014) and the industrialised building systems (IBS) (Yunus and Yang 2013). Some of the collected resources for this research were obtained from various areas of knowledge and disciplines in maintenance performance evaluation (Pan and Gibb 2009), ecological performance (Yunus and Yang 2013), and greenhouse emissions (Mao et al. 2013). As a result, 25 articles were eventually selected. The findings contained the aspects of housing affordability, OSM, and lean and agile concepts within house building which are discussed as follows.

FACTORS CONTRIBUTE TO HOUSING AFFORDABILITY IN AUSTRALIA

The Australian housing affordability is influenced by both housing supply and demand factors (COAG 2012). This paper identified these factors through extensive

literature review on the related reports and articles to the Australian housing (Figure 2).

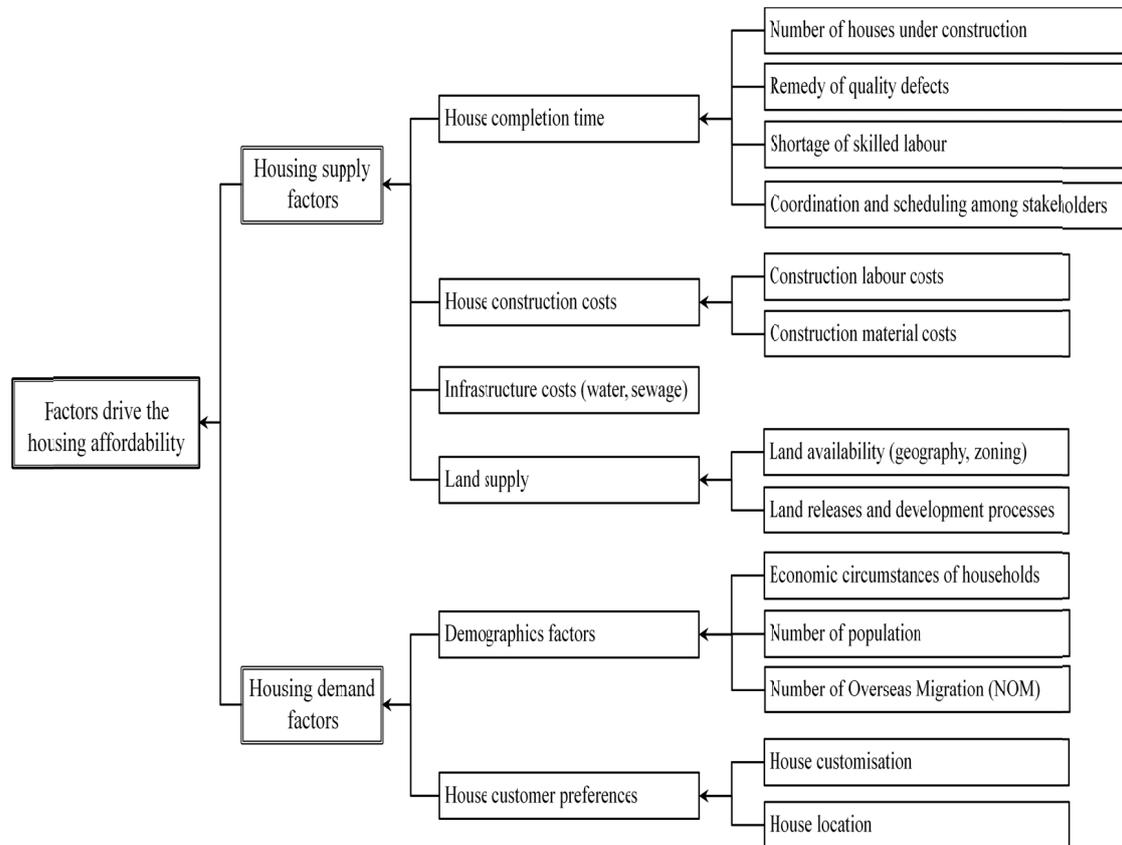


Figure 2: Factors contribute to housing affordability in Australia.

The housing supply factors include house completion time, construction costs, infrastructure costs, and land release and development. The house completion time is considered as a key factor indicating the quality of housing delivery to house customers. An increase in the average Australian house completion time has been reported, while the production rate has found to be relatively stagnant (Gharaie et al. 2010). The house completion time increased as a result of the number of houses under construction, remedy of quality defects, coordination between stakeholders involved, and shortage of skilled labour (Dalton et al. 2011). The construction costs refer to construction labour and material costs (NHSC 2012). The study of Liu and London (2011) state that the construction costs are responsible for a higher proportion of the increase in house prices in some regions. It is concluded that the construction costs are a significant component of the poor performance of the Australian new housing supply.

On the demand side, the affordability is influenced by other factors such as demographics, economic circumstances of the household and customer customisation. Demographic factors include population growth and net overseas migration (COAG 2012). The latest Australian demographic statistics released by the ABS (2013) provides an overview on natural population growth and net overseas migration (NOM) from September Quarter 2012 to September Quarter 2013. The data reveals the rate of

population growth of 1.8% and NOM of 1%, with over 241,000 people arriving in Australia. These records are higher than the last period of 2011-2012. The population growth is a significant factor for the housing market as it creates more housing demand. House customer preferences include house customisation and house location. It refers to customising the house design to suit the customer requirements (NHSC 2012). The housing demand factors has been reflected through higher rental prices, extremely tight rental vacancies, and pressure on home prices.

HOUSING SUPPLY RESPONSES TO CHANGES IN AFFORDABILITY

The *Housing Supply Responses to Changes in Affordability* report documented the response of the housing industry in Australia to the decline in affordability (Urbis 2012). It included changing the type of product and method of construction. Three key points of the housing industry response including reducing dwelling sizes, changing dwelling product and sourcing cheaper or more efficient materials that reduce house completion time. These key responses to the decline in affordability are described below.

Reduction in Dwellings sizes

A reduction in dwelling and lot size has been a major change as noted by the housing industry. Some stakeholders quoted a reduction in floor space in average two-bedroom apartments from over 80m² to around 60m² over the last decade (Dalton et al. 2011). A range of forms in this reduction has been explained including more open-plan living (e.g. dining/living rooms and kitchens combined), more one- and two-bedroom homes being built instead of three- and four-bedroom homes, and reduced circulation areas such as hallways, lobbies and stairways (NHSC 2013).

Construction materials and methods

Some builders anticipate the trends of using cheaper materials to deliver more affordable dwellings (NHSC 2012). Some builders buy housing materials from overseas, although challenges were noted in establishing regular supply chains. Other builders remain a sense of national loyalty by sourcing house materials locally. Many builders look for new house building materials and new methods of construction. One example of new material is using light-weight bricks in preference to traditional clay bricks. A new method is such as employing off-site manufacturing (OSM) with pre-cast concrete walls and building facades (Urbis 2012). The adoption of OSM in Australian house building has been slow (Blismas and Wakefield 2009). Moreover, a hesitation from house builders to produce new products such as modular designs duo to two concerns is noticeable. The first concern is whether the new style products will be accepted in the market. The second concern is related to the investment required to train staff to work in a changed construction environment. Despite the raised concerns, Urbis (2012) states that some of the largest house builders are beginning to explore more innovative practices such as OSM.

Partnership with government

The study of Urbis (2012) identified opportunities to work with the Australian Government, at state and federal levels, to deliver innovative and affordable housing. The study highlighted that the government often holds prime sites in desirable inner-

city areas to mainly serve the infill development. Several examples of partnerships were noted where governments had contributed land to projects and in several cases innovative construction techniques had been used. The possible role for governments to act as a catalyst for innovation in their own projects, either by leading in their own projects or by requiring innovation in contracts with the private sector.

OFF-SITE MANUFACTURING

The majority of responses to the decline of housing affordability are concentrated on three approaches namely reducing dwelling sizes, changing dwelling product and sourcing cheaper or efficient materials (Urbis 2012). As a result, the construction time and house price would be reduced. Although, these approaches seek to respond to the changing needs of the market, they have limited impact on overall housing affordability. The *Housing Supply and Affordability* report of the NHSC (2013) emphasised on applying innovative construction methods to respond to the declining of housing affordability. Substantial improvements to affordability in housing might be achieved by applying the off-site manufacturing (OSM) (Urbis 2012).

Off-site manufacturing (OSM) is the general term used in the Australian housing industry. OSM has recently been suggested in the *Construction 2020* report as a key innovation for the future of Australian house building due to its capacity in meeting the growing housing demand, green construction, and fewer requirements for labour force (Hampson and Brandon 2004). OSM describes the fabricating of house components or modules at off-site factory as well as their subsequent construction activities onsite (Russell et al. 2012). Hampson and Brandon (2004) view OSM as a key vision for the future of Australian house building over the years from 2004 to 2029. Blismas and Wakefield (2009) identify the drivers and barriers of OSM in Australia. Further research is required in order to improve the uptake of the OSM in Australia. Some manufacturing concepts successfully have the applicability to manage the house building process. These concepts include lean and agile. These concepts emphasise on the supply chain operations (Vidalakis et al. 2013).

LEAN AND AGILE CONSTRUCTION

Lean concept origins are traced to Toyota Production System (TPS) (Towill and Christopher 2002). Lean concept has significant interest in the construction sector since Koskela (1992) has presented the Transformation-Flow-Value (TFV) theory in construction. In TFV theory, construction is conceptualised in three corresponding ways namely transformation of materials into building structures, flow of materials and information through various building processes, and value generation and creation for customers through the elimination of value loss. Lean construction can be defined as a model of building production management based on production management theory. It aims to make the value stream as the centre in the delivery process of construction project by using the professional skills and methods to achieve maximisation of the customer value and minimisation of waste (Abdelhamid et al. 2008). Lean construction practices include pull system, visual management, continuous improvement, Last Planner System (LPS), 5S process, reduce batch size, standardise work structuring and error proofing.

The initiative of agile construction was established in direct response to the Latham report (Lee 2003). The report highlighted the UK construction industry

requirement to reduce the construction cost by 30% by the year 2000. To achieve this target the whole industry needed to change. Benchmarking was one method to stimulate the required change in the construction practices. Agile construction exemplifies the characteristics of visibility, responsiveness, productivity and profitability. Agile comprises some management tools such as virtual enterprise, concurrent engineering, information technology (i.e. Computer Aided Design/Computer Aided Manufacturing (CAD)/ (CAM)) (Daneshgari 2010).

Integration of lean and agile is the best solution to answer all the production issues in the world class market competition (Agarwal et al. 2006). Combining lean and agile within the whole supply chain can be accomplished by using the decoupling point and known as *leagility*. The leagility term was firstly introduced by Naylor et al. (1999). In general, the decoupling point separates the leagile supply chain into lean in the upstream and agile in the downstream (Mason-Jones et al. 2000). For competition, Christopher and Towill (2000) emphasise that supply chains must be in touch with market demand changes which can be divided into three critical dimensions; variety, variability (or predictability), and volume. Lean concept is the best alternative where there are high volume, low variety, and low predictable change environment. Agile concept is the best option where there are high variety, low volume, and high predictable change environment.

SUGGESTED OSM HOUSE BUILDING SUPPLY CHAIN

The OSM house building supply chain suggested in this paper can be visualised as in Figure 2. It comprises the suppliers, off-site factory, contractors/sub-contractors, construction site, and retailers/customers. The supply chain controls the off-site and on-site. It has four roles including improving the interface between site activities and supply chain, improving the supply chain, transferring activities from the site to the supply chain, and integrating off-site and supply chain (Vrijhoef and Koskela 2000). The OSM housing supply chain must be managed to maximise the customer value. It can be attained from maximising house customisation by employing the agile concept. Besides, the house completion time and cost can be minimised by employing lean concept.

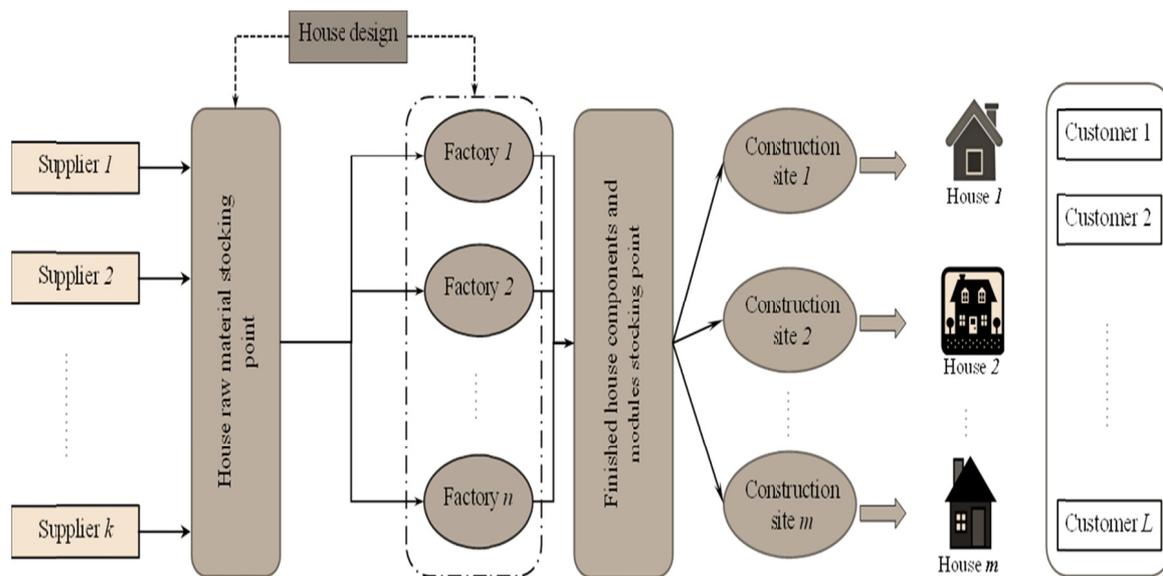


Figure 2: Proposed OSM supply chain strategies for house building.

Lean and agile concepts could be integrated within OSM supply chain by positioning the decoupling point to best suit the need for responding to a volatile demand. The lean concept is the best for high volumes, low variety and predictable change in environment. The agile concept is best where there are high variety, low volume and less predictable change in environment. The decoupling point is the point at which market pull meets upstream push. Agility beyond decoupling point is explained by the principle of postponement by using generic or modular inventory to postpone the final commitment, where final assembly or customisation depends on real demand.

STRATEGIES FOR HOUSING AFFORDABILITY IN AUSTRALIA

It is emphasized in this paper that the OSM supply chain for Australian house building is to be employed using the decoupling point which suggested by Olhager (2003). Two positions for the decoupling point in developing the two house building strategies are suggested in order to enhance the housing affordability in Australia.

BUILT-TO-STOCK

The location of the decoupling point is suggested after construction and finished the house building. This strategy is suitable for volume house building. In this case, the Australian public and private sectors could ensure its capacity to serving large accommodation projects for low income group. Panelised house building designed by Monarch Building Systems presented in Blismas (2007) is an example of the built-to-stock strategy. Therefore, the activities before selling should be lean to fit the costs. Agile is suitable after the decoupling point to diminish the delivery time and speed of return on investment.

SELF-BUILDING HOUSES

The decoupling point is suggested to be at house components suppliers that support self-building houses. In this strategy, the house owner is involved in every house

building process. The house owners are at their own responsibilities to hire builders to assist them with some onsite construction activities. The Australian houses are built by small to large organisations. In 2013, 63% of all residential dwellings were constructed either by small builders or in the form of self-building houses (HIA 2013). The key role of house building organisation is to supply the house modules and components to the suppliers. The organisations should aim at making the house designs as simple as possible. House building organisations should provide variable designs to meet different types of house needs. Moreover, the Australian States and Territories should support this strategy through adopting the self-building strategy. The State of Victoria introduces group self-build initiative to support house owners building their group. The group usually consists of 12 homes within or nearby area. Each group of participants receives a bridging loan from the director of housing to purchase land and build their houses (State Government of Victoria 2013). Lean is suitable to run the factory to produce house modules, while agile is the best option for quick responses to demands of self-build house suppliers.

CONCLUSION

Off-site manufacturing (OSM) has been introduced to increase housing affordability in Australia. The employment of OSM can be recommended to any building organisations that search for more efficient and responsive strategies to answer growing house demands. In Australian house building sector, synergising lean and agile concepts may require more study to examine their impacts on time reduction and cost overrun. The sector is a part of construction industry which lies under the residential building section. Any studies undertaken within the construction industry may provide common knowledge that could be related to house building. The cutting-edge knowledge in manufacturing sector may provide potential solutions to the improvement of OSM needed in the house building sector.

An OSM house building supply chain has been proposed to enhance prefabricated house building in many countries. The supply chain includes two house building strategies namely built-to-stock and self-building houses. It could be considered as a framework for further research relating to OSM house building in Australia. In a broader sense, the synergistic supply chain can be seen as an attempt to increase the supply of affordable housing. As such, it may be useful for housing policy makers, construction executives, managers, designers and developers to rethink about housing issues beyond the domain of construction. For comprehensive realisation of OSM house building benefits to Australian, more research that rooted in understanding the theory of manufacturing and construction is strongly recommended.

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