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Original citation:
Phillips, D; Guaralda, M. and Sawang, S. (2016) Innovative housing adoption: Modular housing for the Australian growing family. Journal of Greenbuilding 11 (2), 147-170. DOI: 10.3992/jgb.11.2.147.1

http://dx.doi.org/10.3992/jgb.11.2.147.1

College Publishing

INNOVATIVE HOUSING ADOPTION: MODULAR HOUSING FOR THE AUSTRALIAN GROWING FAMILY

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ABSTRACT

Housing must be flexible to the circumstances growing families face as their needs change during the family lifecycle. The purpose of this paper is to gather a preliminary understanding of growing families' needs and evaluate how modular off-site manufactured construction could effectively answer those needs. Despite the large amount of research that has gone into off-site manufactured buildings, there is little research that has explored its suitability as a flexible housing typology for growing families. The pilot presented in this paper investigates the specific context of Brisbane, Australia; qualitative data have been gathered from growing families in this city and combined with established theory on flexible building to develop a preliminary understanding of how modular off-site manufactured construction could perform in meeting flexibility requirements in comparison to a traditional lightweight timber framed construction. Findings highlight how the ability to modify a dwelling is a fundamental feature for growing families; a number of other advantages in flexibility were found in modular off-site manufacture and recommendations made to improve this construction typology.

KEYWORDS

modular, off-site manufacture, prefabrication, adaptability, family lifecycle

INTRODUCTION

Off-site manufacture provides numerous benefits to the construction industry, especially in Australia where the construction industry has been characterized as adversarial and inefficient and in need of structural and cultural reform (2005). Offsite construction is defined as "the manufacture and preassembly of building components, elements or modules before installation into their final locations" (Goodier & Gibb, 2007, p. 586). There are various terminologies used for offsite construction, yet their differences are subtle, such as offsite production/fabrication/manufacturing, preassembly, prefabrication, system building, non-traditional building, or Prefabrication, Preassembly, Modularization, and Off-site Fabrication.

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A growing demand for variety and greater inhabitant mobility are some of the forces that have encouraged house building firms to consider new types of product and process design. Therefore, adopting a platform-based technique, such as the Modular off-site manufactured (MOSM) housing - the manufacturing of whole houses or significant housing components offsite in a weather-proof factory prior to installation or assembly onsite - appears to be a very promising option. The Australian construction industry has recently identified MOSM housing as a key vision for improving the industry over the next decade (N. Blismas & Wakefield, 2009). This endorsement has been supported by The Australian Bureau of Statistics' (2011) report into Housing Occupancy and Cost revealing that the current housing situation in Australia needs an innovative housing system for growing families, especially in fast growing cities like Brisbane. The ways in which detached housing is designed and constructed should be reconsidered to incorporate better sustainable practice and reducing resources, but within reasonable cost (Monahan & Powell, 2011). Possible strategies to increase the sustainability of detached houses include consideration of the envelope or footprint of the building, as well as passive design considerations (Johnston, Guaralda, & Sawang, 2014). These paradigms are extensively discussed in the literature, but a less considered strategy is designing buildings that can change or grow over time. This makes it important that housing provides the flexibility to cater to families as they grow. New technologies and construction techniques have been identified as a possible solution (Kieran & Timberlake, 2004).

The background literature suggests that not enough research has been undertaken on providing flexibility for growing families. Instead, prominence has been given to designing for adaptability for the ageing population. Therefore, there is a need to understand how the housing needs of families change after they have children. While a handful of research explores current theories in off-site manufacture (e.g. Schneider & Till, 2005), there is at present no literature that investigates the suitability of off-site manufactured housing in adapting to growing families. Thus, there is a call for unpacking how the MOSM housing can potentially aid in the construction of flexible buildings for growing families. Therefore, the purpose of our study is to develop a preliminary understanding of the potential of MOSM housing in its ability to adapt to circumstances that growing families in Brisbane face as their housing needs change.

The remainder of this paper is organized as follows. In the next section we review the literature on family lifecycle and its housing configuration. Next, we discuss the MOSM housing concept and potential benefits. In the following two sections we then identify the research method and discuss the findings. Based on these findings, we then identify the main flexibility needs for the sample analysed. Finally, in the last two sections, we discuss how MOSM and traditional light frame construction could efficiently respond to these needs as well as discussing the implication and limitation of our study.

Relationship between Family Lifecycle and Housing Changes

Research in housing preference and choice has focused on the economic concept (Sirgy, Grzeskowiak, & Su, 2005). For example, for US home buyers, criteria for a house purchase would be described in terms of the quality of the house, the price range, the proximity of the residence to commercial districts, the community facilities, or other financing arrangements in the purchase of the home [see Luger, 1996; Vale, 1998]. In the Netherlands, more than 40 per cent of the families with children who are presently living in major cities have plans to move. This percentage is much higher than it is amongst the Dutch population as a whole (24

per cent) (Karsten, 2007). One of the reasons why housing occupiers change their attitude toward their house is due to the changes in the family lifecycle (Öst, 2012). Even though families' housing needs change during the family lifecycle, relocation of the family is only accompanied by an increase in family income (Goetz, 2013). As they are most likely to make changes in their housing and have the income at this stage to make changes, growing families were chosen as the focus of this research article.

Literature that was reviewed on housing choice, including dissatisfaction and housing relocation, has shown that the most common variable cited has been the relationship with the stage in the family lifecycle (Jungers, 2010; Walls & Whitbeck, 2012). US families adjust their housing requirements to meet the needs of an expanding or decreasing family size (Winstanley, Thorns, & Perkins, 2002). Similarly, Irish families who live in the central area of the city are predominantly young, affluent and at the early stage of their life cycle, but they are very likely to move to lower density areas outside the central area in the next 5 years (Howley, 2009). The Australian Bureau of Statistics' (2011) finding that housing ownership is strongly related to lifecycle stages confirms this in the present Australian context. The most common research approach is to break up the family lifecycle into stages through which a family is expected to proceed, which represent major stages expected to bring about changes in requirements (Metcalfe, 2006).

Our study applies the Duvall framework of family lifecycle stages (Duvall, 1971), focusing on *Stage II: Families with Infants*; and *Stage III: Families with Pre-Schoolers*. It is noted in many studies that Stage II and III of the family lifecycle also coincide with an increase in family wealth enabling changes in housing to be made. Many housing choices made at this stage are in anticipation of additional pressures related to the eldest child moving up to secondary school, requiring changes in space for study, storage and entertainment (Winstanley et al., 2002). Families in these two stages coincide with a significant increase in the income of the head of the household (Metcalfe, 2006). While housing changes may be forced on a family after having children, it is only the increase in family wealth coincidental to this stage that allows them to act (Crothers & McCormack, 2006).

The Australian Bureau of Statistics (2011) report into Housing Occupancy and Cost further reveals the current situation in Australia in housing needs for growing families. The study found that a majority of these families had more bedrooms than they required, however, more than one in ten indicated they were likely to move in the next twelve months. This indicates, as was also found by McCrea, Stimson and Western (2005), that the number of bedrooms is not a sufficient indicator of housing satisfaction and a lack of bedrooms is not a reason for changing needs in housing. Surprisingly, it was found that Generation X, of which the families in this research article belong, prefer smaller homes to the previous generation (Mccrea et al., 2005). This explains the finding that growing families are now more likely than previously to live in medium and high density housing, including duplexes, townhouses and apartments. While growing families may not always require more bedrooms, the background research has shown that changes in the family lifecycle require housing that can similarly adapt.

Growing families and flexible dwelling

Schneider and Till (2005) state that the traditional housing industry treats housing as a disposable commodity, the occupants moving on to another property when their circumstances change. They provide a broad definition of flexible housing as "housing that can adapt to the changing needs of users" including the "potential to incorporate new technology over

time" (Schneider & Till, 2005, p. 287). Schneider and Till offer a theory of designing flexible housing, proposing two categories: use and technology, which can be made flexible. Another major work on flexible building, Stewart Brand's book "How Buildings Learn," theorizes that different layers of the building can be divided based on the rate that part of the building changes (Brand, 1995).

Flexible housing can be designed to be both flexible to the occupants' choice at the design stage and for change in the use of the building over its lifetime; it can be both capable of different uses and capable of different physical arrangements. Schneider and Till (2005) propose to divide the design of housing into two categories, i.e. usage and technology, to ensure flexibility. Usage refers to "the way that the design affects how housing is occupied over time, and generally refers to flexibility in plan," while technology "deals with issues of construction and servicing, and the way that these affect the potential for flexibility" (Schneider & Till, 2005, p. 289). Habraken and Teicher (2000) propose a method to achieve this in commercial buildings by separating the building into the base building, infill systems and subsystems, and designing for easy disassembly.

The buildings can be separated into six layers at different rates: site; structure; skin; services; space plan; and stuff (Brand, 1995). Site is the slowest changing layer while stuff can change daily. For a building to be flexible, Brand argues that the building must allow layers to change independently of each other; the slow changing layers not blocking the faster changing layers. A flexible building is one that allows the faster layers to change without affecting the slower layers. However, most buildings are not designed to adapt well over time. According to Smith (2010), off-site manufacture offers an opportunity to change this. Off-site manufacture has the opportunity to take advantage of these layers by allowing for a system of manufacture where space plan can use removable fixings, services can be removable modules, and structure can be moved from site to site (Smith, 2010).

Off-site Manufactured Housing

Off-site manufactured homes now represent between 15-20% of all homes built in Japan (Oshima, 2008; Smith, 2010). While off-site manufacture has not yet taken off in Australia, the Construction 2020 report into Australia's property and construction industries, conducted in 2004, found that respondents considered it to have a high likelihood of occurrence in Australia in 5 to 15 years and listed off-site manufacturing as one if its nine key visions for the Australian construction industry (Hampson & Brandon, 2004).

However, the potential of off-site manufacturing has yet to be realized in Australia, which is reflected in the limited amount of research conducted in this country, and opportunities exist for research into off-site manufacturing in an Australian context (CRC Construction Innovation, 2007).

Types of Off-Site Manufacture

Off-site manufacture may be divided into a number of categories, depending on the degree of prefabrication and the method for joining components. Kaufman and Remick (2009) divide it into:

- Kit Homes – all the basic structural elements are manufactured off-site and assembled by the homeowner or contractor on site.
- Panelized Homes – wall, roof, and floor sections are manufactured as panels off-site and assembled by slotting into pre-cut grooves on site.

- Manufactured Housing – or "mobile homes" are manufactured as a whole off-site and set up, usually temporarily, on a site.
- Modular Homes – modules are manufactured off-site then transported and placed on permanent foundations and joined together on site where it resembles a traditionally built home.

Our study is concentrated on modular homes, or modular off-site manufacture (MOFM); this technology has been chosen in consideration of the local Queensland market where MOFM manufacturers are emerging as a substantial alternative to traditional technologies (Steinhardt, Manley, & Miller, 2014). A more thorough description of the modular off-site manufactured typology studied is included in the Methodology section.

Benefits of off-site manufacturing

Many of the perceived benefits of off-site manufacture are well known. Luther, Moreschini and Pallot go so far as to say that off-site manufacture "may be the only promise in obtaining a sustainable architecture for our future" (Luther, Moreschini, & Pallot, 2007, p. 1). Blismas and Wakefield (2009) ,however, argue that benefits from off-site manufacture are dependent on project specific conditions, while Smith (2010) claims that commonly perceived benefits such as a reduced cost are not guaranteed by using off-site manufacture. A list of benefits found, from workshops and interviews with stakeholders, in using off-site manufacture in Australia are the following:

- Reduced construction time
- Simplified construction processes
- Provide higher quality, better control and more consistency
- Produce products that are factory tried and tested
- Reduce costs when resources are scarce, or in remote areas
- Result in improved working conditions
- Reduce on-site risks
- Alleviate skills shortages in certain areas
- Revitalize 'traditional' manufacturing regions
- Provide fewer trades and interfaces to manage and coordinate on site
- Reduce waste on and off site
- Improve housekeeping on site
- Facilitate the incorporation of sustainable solutions
- Achieve better energy performance

While there are potential benefits to off-site manufacture in residential housing, especially for growing families, there is at present no literature that investigates the suitability of off-site manufactured housing in adapting to growing families. Thus our study aims to elaborate this aspect and to further develop a set of criteria to compare the potential of modular off-site manufactured housing with other housing construction typologies in their ability to adapt to circumstances facing growing families in Brisbane as their housing needs change.

METHODOLOGY

The background research revealed how young families are more prone to change their dwelling arrangements when the family reaches a certain milestone. The general assumption of the

construction industry is that 'more space' is needed and this is generally addressed providing more bedrooms, but specific research to understand the actual needs for 'more space' in the case of young families introduces the idea that flexibility is the actual requirement. The potential for modular off-site manufacture to aid in the construction of flexible buildings is generally recognized in literature; however, there is currently limited research about how modular housing could actually meet the flexibility needs of young families. The objectives of this article are to provide a preliminary definition of these needs in the case of the growing family in Brisbane, Australia. Off-site manufactured housing and traditional light frame construction are discussed in their potential to fulfill these needs. A series of research methods (Table 1) are used to attain this objective. Statistical data from the Australian Bureau of Statistics have been used to frame the specific context of Brisbane and its house market; interviews with growing families in Brisbane have then been used to develop a preliminary list of needs for this cohort in relation to their dwelling choices. Finally, two technologies are discussed to evaluate their potential in answering the identified needs.

TABLE 1. A summary of research process.

Literature gap	Research question	Objective	Step 1	Step 2	Step 3
A lack of specific research to understand the actual needs for 'more space' in the case of young families introduces the idea that flexibility is the actual requirement.	How modular housing could actually meet the flexibility needs of young families?	To provide a preliminary definition of these needs in the case of the growing family in Brisbane, Australia	To frame the specific context of Brisbane and its house market (using ABS data)	Interviews with growing families in Brisbane have then been used to develop a preliminary list of needs for this cohort in relation to their dwelling choices	Two technologies (Lightweight timber framed construction and MOSM) are discussed to evaluate their potential in answering the identified needs, using criteria in Table 4

PROCEDURE

Research has been conducted into theories on adaptability and flexibility in housing. The main theories as discussed in the background research are from Schneider and Till (2007) and Brand (1995), who offer their own strategies for designing flexible buildings. In order to achieve the aim of assessing the ability of MOSM housing in providing flexibility to growing families in Brisbane, first information must be gained about the growing families.

Data gathered from the Australian Bureau of Statistics' (2011) Housing Occupancy and Costs report, revealed general information about families around Australia (Table 1). However, more detailed information is needed to explain why families move and in particular how much dwelling arrangements influence young families' relocations. A preliminary series of interviews with growing families in Brisbane was used to start identifying actual requirements in terms of dwellings for this cohort.

The interview questions (see Appendix) were to determine if growing families were satisfied with their housing arrangements, to find out what they want in their housing, and to develop an understanding of the needs associated with having a growing family. The scope of the research is investigating more the perceived needs than actual provision in terms of space. The questions were designed in consideration of the literature reviewed as well as to give a specific interpretation to the data in the Australian Bureau of Statistics about young families' relocations.

For the scope of this study, only families following the definition used by Duvall [17] were considered; this meant that only families in Stage II and Stage III were approached. The respondent to the questionnaire was a parent in the family, and personal information such as the respondent's address was not sought.

Fourteen respondents participated in the interview. The respondents ranged in age from 20 to 24, to 35 to 49 with children ranging in age from 0 to 2, to 6 to 8. The main intent of the interview was to gather more qualitative information on the needs of growing families and to gather preliminary explanations behind this information. The aim was to develop a preliminary qualitative exploration to frame the need for flexibility young families have in terms of their dwelling. Closed ended questions were asked to gather information on dependent variables. These questions allowed an interpretation of the data obtained from Australian Bureau of Statistics and link statistical trends to actual needs. Open ended questions were also asked to gain information on independent variables in order to explain the results.
The questions were divided into categories on:

- Information about the respondents and their families
- Information about the respondents' dwellings
- Information about the respondents' attitudes to their dwellings

Questions relating to the respondents' socio economic situation were not asked as the questionnaire was intended to enquire about the respondents' attitudes toward their dwellings and their desire to change their dwellings, regardless of whether they could currently afford to change them.

Needs and Case Studies

The data gathered from the Australian Bureau of Statistics, from the qualitative information gathered in the questionnaire, and the research into flexible housing theories were then combined to develop a preliminary list of young families' needs to be then used for the discussion of the two specific technologies selected for this pilot, off-site manufactured housing technology and the typical light frame housing technology. The discussion addresses how these two construction types could address the identified needs and provide potential answers to the contingent situation many young families currently face.

Case studies were chosen to give a clear comparison of the flexibility of modular off-site manufactured housing compared to a typical light frame technology in Brisbane. The type of dwelling was chosen to represent the average house of young families in the Brisance area, on the base of statistical data as well as information gathered by participants. The two cases selected represent a similar typology, but differ in term of construction technology.

Young families' needs have been summarized in criteria for comparing the case studies and were divided into three sections: construction; layers; and simplicity and legibility. Using the criteria the advantages and disadvantages of each case study are discussed in regards to its

flexibility for growing families in Brisbane. After evaluating the outcome of the case studies, a list of recommendations is outlined to allow a modular off-site manufactured housing typology to become more flexible and consequently answer the specific needs of the cohort investigated. This research is also important in enabling a better outcome to be reached in the modular off-site manufactured case study; the flexibility required by young families could in fact be strategic also for other demographics.

Housing Marking in Brisbane based on Australian Bureau of Statistics (ABS)

The recent information from ABS data reveals that the majority of Queensland household composition is family households (72%), 23% is single person household and 5% is a group household. Table 2 demonstrates household and dwelling characteristics in 2010. In 2009–10, almost half of young (reference person aged under 35 years) couple only households, and over half of young couples with dependent children, owned their own home (49% and 55% respectively). The home ownership rate was considerably lower for young lone person households (35%). Home ownership rates generally increased with the age of the reference person. One parent families with dependent children had the lowest home ownership rate (40%) and the highest proportion of renters, particularly public renters, with 13% of such households renting from a state or territory housing authority and 43% renting privately. Lone person households also had relatively high proportions of renters, with 7% renting from a state or territory housing authority and 27% renting privately.

Figure 1 shows the average floor area of new residential dwellings from 1984-85 to 2012-13. There has been a steady increase in the average floor area of new residential dwellings over the 28 financial years to 2012-13. The average floor area of all new residential dwellings increased from 149.7m² to 207.6m² over this time, an increase of 38.7%. New houses increased from 162.4m² to 241.1m² (48.5%), while other new residential dwellings increased from 99.2m² to 133.9m² (35.0%).

TABLE 2. Household and Dwelling Characteristics 2009-2010.

	Proportion of households with characteristic							
	Estimated number of households	Average number of persons in household	Average number of bedrooms in dwelling	One or more spare bedrooms (a)	Living in separate house	Living in flat/ unit/ apartment	Home owner	Renter
Household composition	'000	no.	no.	%	%	%	%	%
Lone person	2 055.2	1.0	2.5	87.4	62.0	21.2	60.1	34.0
Couple only	2 199.9	2.0	3.1	97.5	81.7	9.2	78.2	18.9
Couple family with dependent children	2 206.8	4.1	3.6	68.3	88.7	3.8	76.5	21.1
One parent family with dependent children	535.2	3.1	3.2	46.3	83.8	7.3	39.9	55.9
All households(b)	8 398.5	2.6	3.1	78.5	78.6	10.7	68.8	27.6

Note. (a) As measured against the Canadian National Occupancy Standard. (b) Includes all other family and household types. Source: ABS data available on request, Survey of Income and Housing.

FIGURE 1. The average floor area of new residential dwellings from 1984-85 to 2012-13.

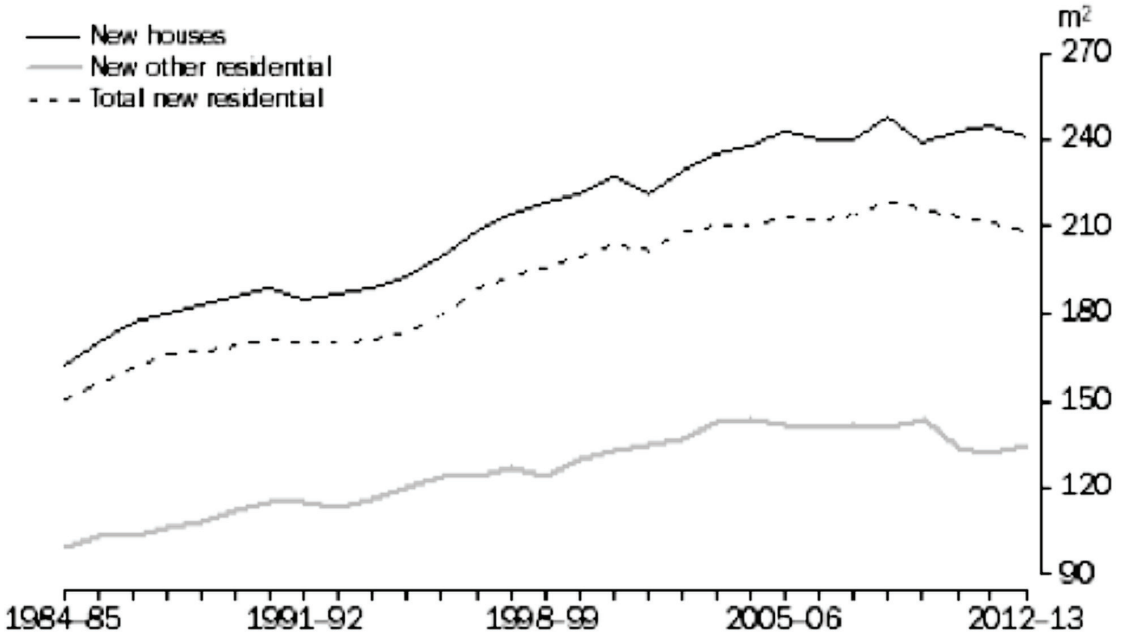


Table 3 shows an increase of 6.0m² (2.6%) in the average floor area of new houses over the ten financial years from 2003-04 to 2012-13. Conversely, the average floor area of new other residential and total new residential dwellings decreased by 8.6m² (6.0%) and 3.4m² (1.6%). The average floor area of new houses increased in Australia by 2.6% over the 10 financial years to 2012-13. The average floor area increased in the Northern Territory (9.6%), Tasmania (6.5%) and Victoria (6.0%). Australian Capital Territory (8.4%), Western Australia (2.5%) and Queensland (0.9%) all decreased in average floor area over the same time period. The average floor area of new houses completed in 2012-13 was highest in New South Wales with 266.2m². The lowest average floor area of new houses for 2012-13 was in Tasmania with 200.3m².

Interview findings

The results of the interviews reveal information about the makeup of the households and housing typology in Brisbane, which corresponds with the information gathered over Australia from the Australian Bureau of Statistics (Table 1). The housing typology question provides valuable information used in determining an appropriate case study selection to compare the modular off-site manufacture case study against. The qualitative data gathered in the questions about respondents' attitudes toward their dwellings provides valuable input into developing criteria for the design of flexible dwellings for growing families and comparing the two case studies.

Household Makeup

The results of the household makeup section indicate the makeup of the households involved in the questionnaire and provide a good indication of the makeup of growing families in Brisbane. Overall, the majority of households include just one child, with the average number being 1.5 children per household. The ages of the children in the households are spread evenly between 0 to 5 years old, with just two respondents having children aged between 6 and 8.

TABLE 3. Household and Dwelling Characteristics 2009-2010.

	Proportion of households with characteristic							
	Estimated number of households	Average number of persons in household	Average number of bedrooms in dwelling	One or more spare bedrooms (a)	Living in separate house	Living in flat/ unit/ apartment	Home owner	Renter
Household composition	'000	no.	no.	%	%	%	%	%
Lone person	2 055.2	1.0	2.5	87.4	62.0	21.2	60.1	34.0
Couple only	2 199.9	2.0	3.1	97.5	81.7	9.2	78.2	18.9
Couple family with dependent children	2 206.8	4.1	3.6	68.3	88.7	3.8	76.5	21.1
One parent family with dependent children	535.2	3.1	3.2	46.3	83.8	7.3	39.9	55.9
All households(b)	8 398.5	2.6	3.1	78.5	78.6	10.7	68.8	27.6

Note. (a) As measured against the Canadian National Occupancy Standard. (b) Includes all other family and household types. Source: ABS data available on request, Survey of Income and Housing.

Housing Typology

Responses to the section on housing typology in the questionnaire align with statistical data and reveal that growing families in Brisbane are most likely to live in a detached house. They are more likely to own the house than rent and the house is likely to be a timber framed house with a steel roof.

The housing typology reveals that growing families in Brisbane generally live in the dwelling type and tenures as was found generally in Australia in the Australian Bureau of Statistics data. In Australia it was found that families were now less likely to live in detached housing than in the past, with 78% of households with children living in detached housing in 2010 (Australia Bureau of Statistics, 2011). The questionnaire data reflects this with 79% of respondents living in detached housing. As this type of housing is still lived in by the majority of growing families, the detached house is used as the typology to compare case studies.

The majority of growing families interviewed own the houses they live in. This was also in line with the general data for Australia which found that 64% of families own their own houses (Australia Bureau of Statistics, 2011). Families in Brisbane who responded to the questionnaire had lived in their current homes for an average of 2.3 years.

It was found that of the households who responded to the questionnaire, 43% have four bedrooms, confirming the background research finding that a lack of bedrooms is generally not a factor in growing families' housing dissatisfaction, as families are likely to buy houses with the number of bedrooms to suit their anticipated future needs (Mccrea et al., 2005).

The questionnaire data establishes that a growing family in Brisbane is much more likely to live in a lightweight timber framed house with a steel roof. Respondents were asked to identify the construction of the dwelling by indicating the material of external walls, frame construction, floor construction and roof. As shown in Figure 2, a large majority of respondents, at least half

in each section, indicated the walls, frame and floor of their dwellings are made of timber and have a roof made of steel. A number of respondents answered they did not know the materials that make up their dwelling or did not respond to the question.

The alignment between the preliminary questions included in the interviews and data obtained from the Australian Bureau of Statistics allow make it possible to infer the relevance of the answer obtained for the population studied. This preliminary study, although limited to 14 participants, provides a preliminary pattern of the lifestyle choices of young families in Brisbane; the response pattern also indicate saturation for the population studies with late interviews confirming data already collected in earlier ones.

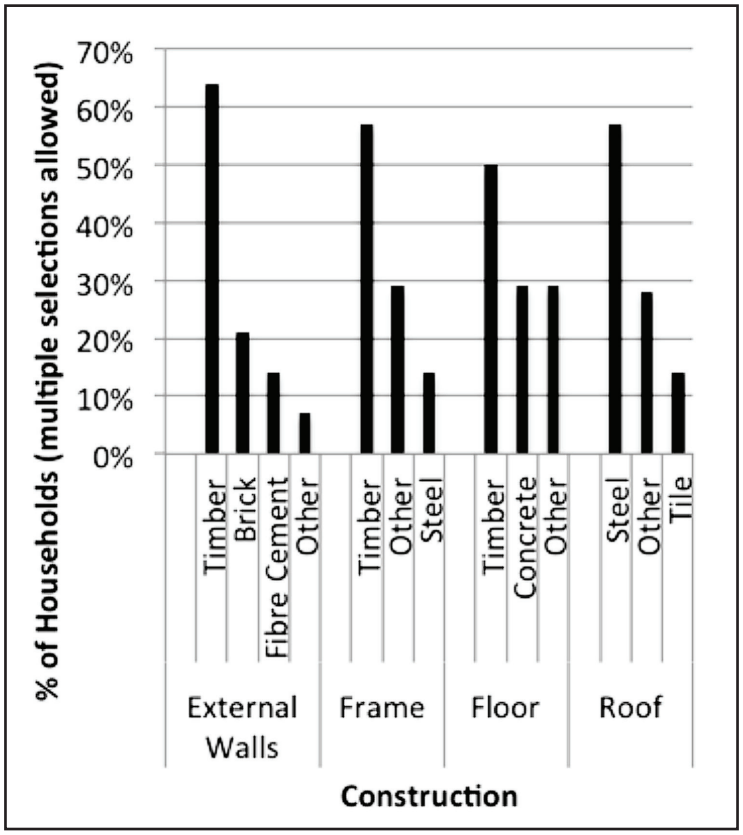


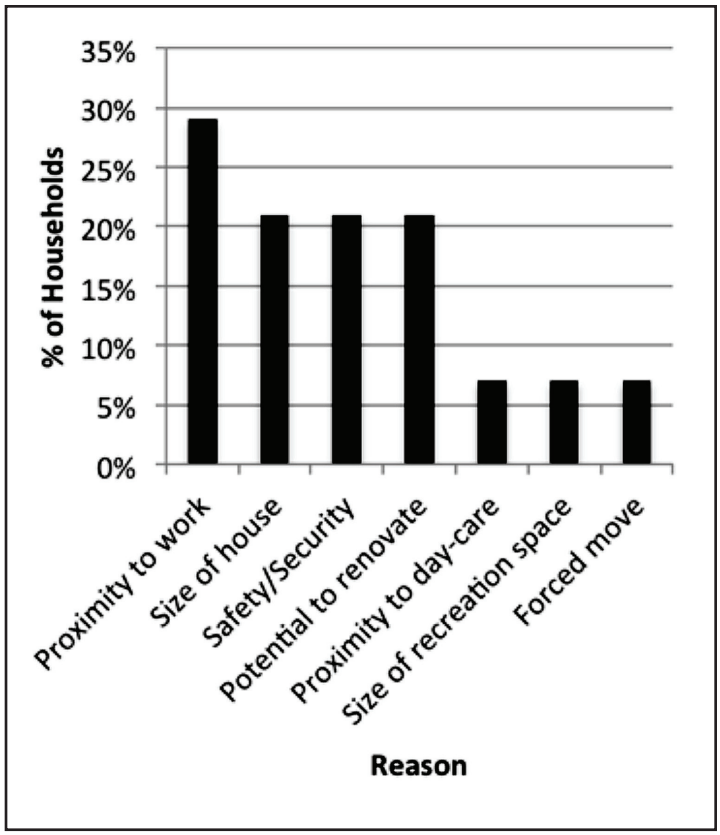
FIGURE 2. Construction of dwelling.

Attitudes towards House

A significant finding of this questionnaire is that the majority of growing families have been forced to move since having children. The questionnaire found that the majority of respondents had moved since having children, while only just over a third of respondents had made any changes to their dwelling, including those who had both moved and made changes.

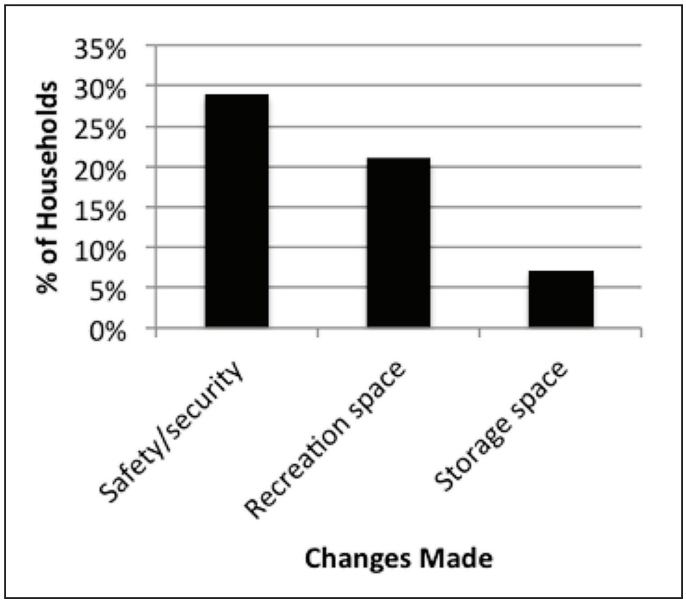
Respondents were asked to briefly comment on their reasons for moving. The comments, although varied, could be grouped within a number of common reasons as shown in Figure 3. The most common reason growing families gave for moving was to move closer to their work place. The next most common reasons were the size of the dwelling, the safety or security of the dwelling, and to move to a house with more potential to renovate. Other reasons given were the proximity to day-care facilities, the size of recreation space and forced moves. Many respondents remarked generally on the size of their dwelling such as the need for "bigger size", "more space inside", "larger house" as a reason for moving without specifying what this meant.

FIGURE 3. Reasons for moving..



Only just over a third of the respondents had renovated or made changes to their dwelling. The most common reason growing families gave for making changes (Figure 4) was related to the safety of the dwelling. Respondents made modifications such as to provide a "child friendly environment", "childproofing a staircase" and made changes to unsafe finishes in the dwelling. Another common reason respondents gave for making changes to their dwelling was to provide recreation space. This space was generally provided by the addition of a deck.

FIGURE 4. Changes made to dwelling.



A final question in the questionnaire asked respondents what changes they would like to make to their dwelling but have so far been unable to. A key finding from the respondents' comments were that having flexibility in the layout of the house was the major change desired (Figure 5). Other changes growing families would like to make were to increase recreation space, improve surveillance, security and safety and to generally increase the space in the dwelling and storage space in the dwelling.

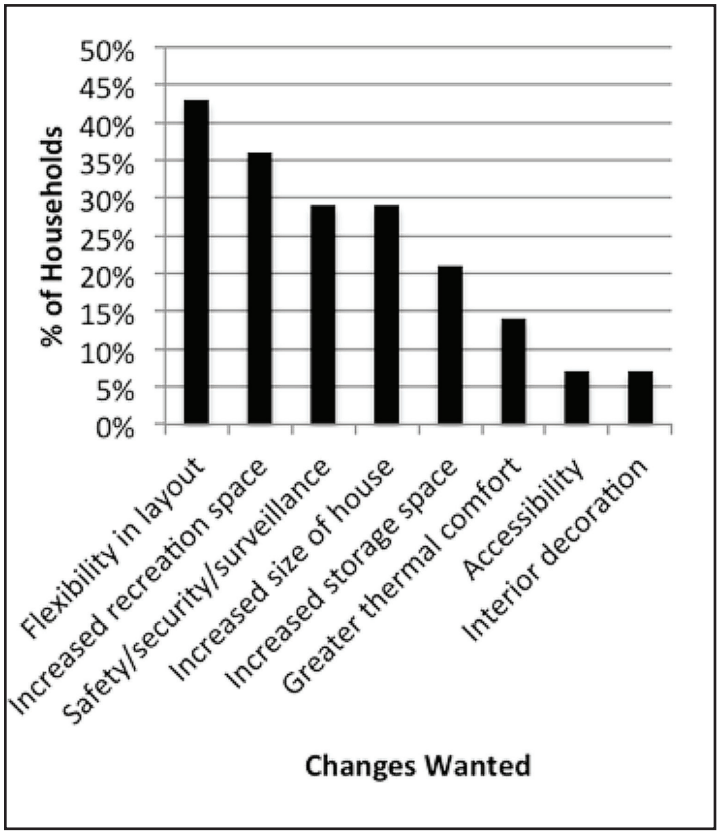


FIGURE 5. Changes wanted in dwelling.

The most common form of flexibility required was the ability to generate separate multifunctional child zones and adult zones at different times of the day. One respondent commented on the desire to "separate kids' rooms to close off for sleep time, but open up when the kids wake, would love the wall… to slide open to create a mega room… hallway walls to open up so the verandah, living, hallway and kids rooms are all one big play area." The same respondent indicted the need for "an adult living area… able to separate off the kids rooms after hours so adults can entertain." One respondent planned to use a formal dining room as a children's play zone until the children were older, when it would be converted back to a dining room, while another respondent expressed the desire to have a room convert to a children's study at a later time.

Relocation of service spaces, such as kitchens, bathrooms and laundries, for surveillance and safety issues are another common change that growing families desire. It was important for growing families to have a dwelling that allowed for surveillance of children, and it was apparent many respondents lived in dwellings that did not allow this. One respondent wanted "more transparency to the back yard, all living areas to be seen from

the kitchen" and further commented that the "kitchen HAS to look out onto the yard for surveillance, laundry next to the bathroom so I can do washing while they bathe." Similarly, another respondent wanted to relocate the kitchen to allow surveillance of and access to outdoor recreation spaces. Other respondents expressed concerns with safety, including unsafe stairs while one respondent was happy with their home commenting "the home is one level so it's perfect for our family."

Another response was again related to children's zones but specifically to recreation spaces. Similar to the responses for changes already made, respondents indicated they would like to add decks to their dwellings while others indicated they would like to add space outside for children's play areas.

The final common concern among respondents was simply to increase the space in the dwelling and to increase the storage space. Respondents gave similar comments like "more space would be nice," "more space and storage" and "more storage space for toys." Other changes that were discussed were related to better thermal comfort, accessibility, and interior decoration.

INTERVIEW DATA DISCUSSION

Housing typology

The key findings in relation to the housing typology of growing families in Brisbane live in are that respondents have a sufficient number of bedrooms for their household yet most desire "more space", and that growing families are most likely to live in detached timber framed houses. Respondents consistently expressed a desire for "more space" however did not indicate where this space was required or what it would be used for. This may indicate that growing families are looking for undefined space, which can be used for a variety of purposes, or that they are unable to use the space they have in their dwellings in the way they would like. Space in this instance may not always mean adding more rooms to the dwelling, but also making the existing rooms more flexible to the living requirements of the family.

From the data gathered on the construction of respondents' dwellings, it can be interpreted that most growing families in Brisbane live in detached lightweight timber framed homes. In the background research conducted it was found that this housing typology was considered to be the most flexible (Kennedy, Hockings, & Webster-Mannison, 2005). This may indicate that growing families have chosen their dwellings based on the ability to provide flexible living. This assumption is backed up by comments in the questionnaire that respondents have chosen new dwellings because of the potential to renovate to suit their lifestyle and comments on the need for flexibility. This housing typology is also therefore a suitable comparison to the modular off-site manufactured housing.

A number of respondents did not comment on the construction of their dwellings or did not answer the question. This suggests that the construction of the dwelling was not obvious to the respondents.

Attitudes towards Dwelling

The questionnaire found that most growing families in Brisbane have had to relocate since having children. Compared to the number of growing families who have made changes to their dwellings since having children, this demonstrates the difficulty of adapting houses

to families in this stage of the family lifecycle. While most growing families have relocated because of proximity to work, this is a common factor for relocations across the population and was not considered to be specific to growing families in Brisbane. For this reason this article focuses on the other main reasons given for relocation.

The need for a growing family's dwelling to provide more flexibility was a key finding of this research. As has been discussed, flexibility can be related to the need for "more space." Respondents provided many comments on needing space as well as comments directly on flexible space, such as using the same space for different needs at different times, both in the short and long term. Respondents indicated that they would like a space that can be transformed both during the day and as their children grow. The background research revealed this to be a problem of rooms being designed for a very specific designation, which were difficult to change at a later time (Schneider & Till, 2007). This indicates the need for a dwelling in which the layout is not static, but is able to change over time, or even the ability to change room designations during the day.

Respondents indicated that as well as a desire for "more space" as discussed above; they relocated to increase the safety of their children. This implies that the houses they previously lived in were unable to adapt to the changing safety needs as their family grew. Similarly, of the respondents who had made changes to their dwellings, most had made changes in regards to safety issues. An issue that growing families were found to have wanted to change was also related to safety as in the ability to relocate or modify the service areas of their houses: kitchens; bathrooms; and laundries, to provide greater surveillance of their children. This was something the growing families involved in the study had been unable to do and the houses they lived in did not provide the opportunity to easily change.

The qualitative data gathered in the questionnaire reveals valuable information about the requirements growing families in Brisbane have for the construction of their dwellings. The requirements can be summed up in a number of key groups: flexibility in layout; safety and surveillance; and recreation space. These requirements have been used to develop a set of construction criteria for designing housing for growing families in Brisbane.

NEEDS OF YOUNG FAMILIES

The analysis of the interview data in parallel with ABS data was used to summarise young families' needs into a set of criteria. The intention of this set of construction criteria (Figure 8) is to be used as a preliminary guide to understand how construction techniques could address growing families' needs in Brisbane. This criteria are also based on the work by Schneider and Till (2007) and those of the open building movement (Kendall, 1999) for multi-residential and commercial buildings..

Based on the interviews, the following sets of issues were identified and summarized by the following criteria:

- The construction must address the ability to alter safety, security, and surveillance as the family grows, including relocating service areas; opening up areas to views of recreation space; limiting access to off-limits areas.
- The construction must address the need to increase functional space and make changes to the layout as the family grows, including adding extra storage space; changing room designations in the short and long term; making rooms larger or combining rooms; variable child and adult zones.

- The construction must address the ability to add recreation spaces as the family grows, including adding decks; increasing surveillance to outdoor recreation areas; providing safe access to recreation areas.

These requirements lead to a preliminary set of criteria for the construction of dwellings for growing families in Brisbane with the potential to provide flexibility as the family grows (Table 4). The criteria have been divided into three sections: construction; layers; and simplicity and legibility. Construction details how the constructional system, the structure and the foundations, could provide a base for flexibility. Layers details how different elements of the construction need to be designed to be altered at different rates. Simplicity and legibility describes how the constructional system must be visibly flexible to the occupants in order to provide visual clues that it can be flexible.

TABLE 4. A preliminary set of criteria for the construction of dwellings for growing families in Brisbane.

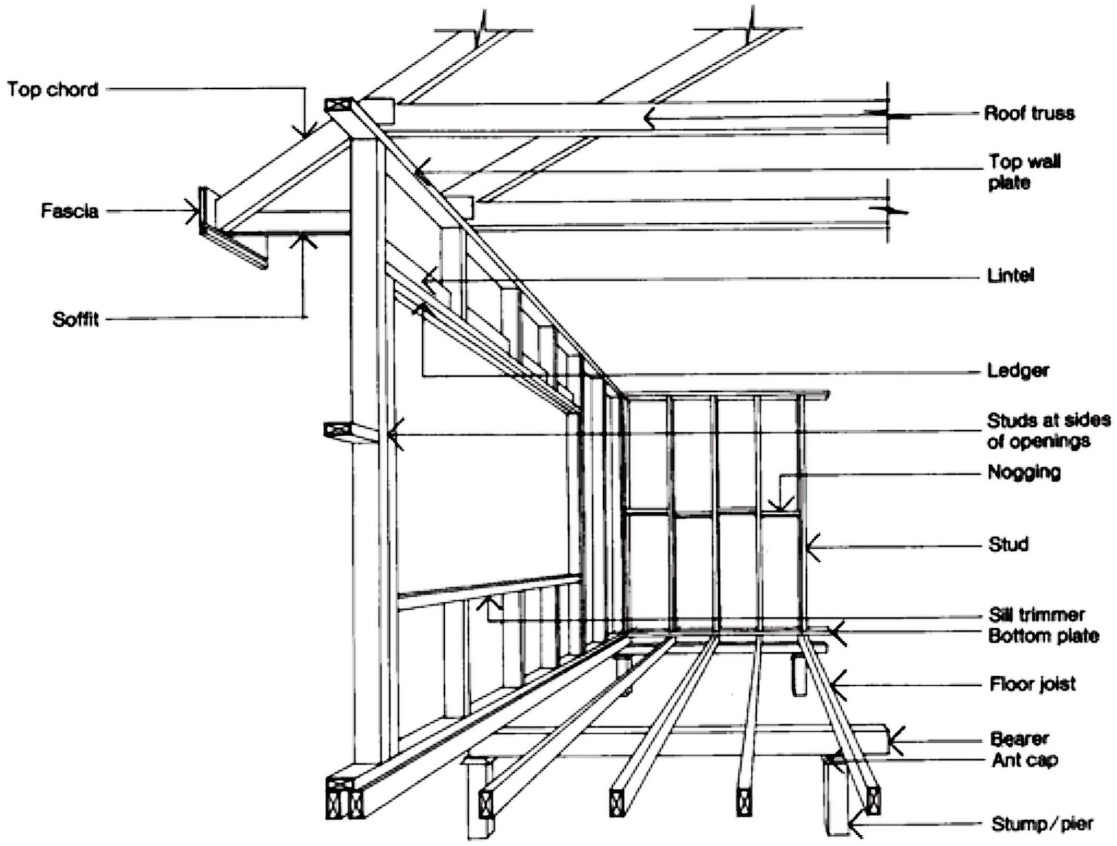
Main criteria	Sub criteria	Definition
Construction		Designing construction methods and the size of foundations and structural members to take into account the changes that occupants are likely to make over the family lifecycle. Designing components of the house to be interchangeable and easily disassembled.
	Structural Frame	The structural frame allows for clear spans across the house making changes to the layout possible.
	Structural Frame	The members of the structural frame are as open as possible allowing occupants to add openings for access to and surveillance of external recreation spaces.
	Foundations	Foundations are sized to allow occupants to make additions to the house and designed to allow occupants to change the location of non-load-bearing partitions.
	Components	Methods of fixing components together allow for occupants to separate components later with minimal damage.
	Components	The use of bespoke components is avoided allowing occupants to easily make changes to the house in the future using easily available components.
Layers		Recognizing that different elements in the building will be changed at different rates throughout the family lifecycle and separating out these elements in anticipation of the changes being made.
	Structural Frame	The structural frame is separate to the partitions, services and fittings, allowing occupants to make changes to the layout of the house, combine or divide rooms, relocate service rooms such as kitchens or add storage space.
	Structural Frame	The structural frame provides a support structure for services to be attached to. Occupants are able to move service areas over time without affecting the structure and are able to move partitions over time without affecting services.
	Partitions	Partitions are non-load-bearing and do not contain electrical or other services. Occupants are able to move or remove partitions over time and provide the opportunity for moveable partitions to create multifunctional spaces throughout the day without affecting other layers.
	Partitions	Partitions are inherently separate from the structural frame, and wall, floor and ceiling finishes continue behind partitions, allowing occupants to move or remove partitions.
	Services	Services are located in permanent structural frames allowing the occupants to make changes to other elements of the house without having to relocate services.
Simplicity and Legibility		Designing the building in a way that occupants are aware of the separate layers of construction and which elements are permanent and which can be modified as well as providing clues to the methods used to make changes.
	Partitions	It is clear which walls are load-bearing and which are not. Occupants are able to easily make changes to non-load-bearing partitions.
	Services	The location of services is legible allowing the location of services to be changed and informing the occupants of where new services should be located to keep the construction flexible.

CASE STUDIES REFLECTING THE CONSTRUCTION CRITERIA

The case studies selected for analysis are as follows:

1. Lightweight timber framed construction (Figure 6).

FIGURE 6. Lightweight timber framed construction. (TRADAC, 1985).



Features:

- Timber members make up braced frames, sometimes prefabricated off-site
- Vertical structural members called studs provide a structural skeleton to attach interior and exterior finishes
- The floor frame is built onsite over a slab or posts, then wall frames are erected and the roof is added
- Frames are joined with nails or nail plates

2. Modular off-site manufactured construction (Figures 7 & 8).

Features:

- Modules manufactured in a factory with all finishes included and transported to site where they are fixed together to form a dwelling
- Parallel Flange Channel (PFC) structural floor beams around edge of module with lightweight steel joists
- Square Hollow Sections (SHS) steel columns for vertical structural members with lightweight timber framing between

- SHS steel roof beams around edge of module and between columns
- Modules stacked vertically with a 200mm gap between for service runs
- The horizontal joint of modules creates a double thickness wall

The three sections of criteria discussed above were used to make a comparison between the lightweight timber framed house, which was established as the most common house lived in by growing families in Brisbane, and the modular off-site manufactured house, in order to determine the suitability of the latter in providing flexibility in construction. A list of favorable points and recommendations to improve the construction of the modular off-site manufactured house follows. The implications of the findings and limitations are then discussed.

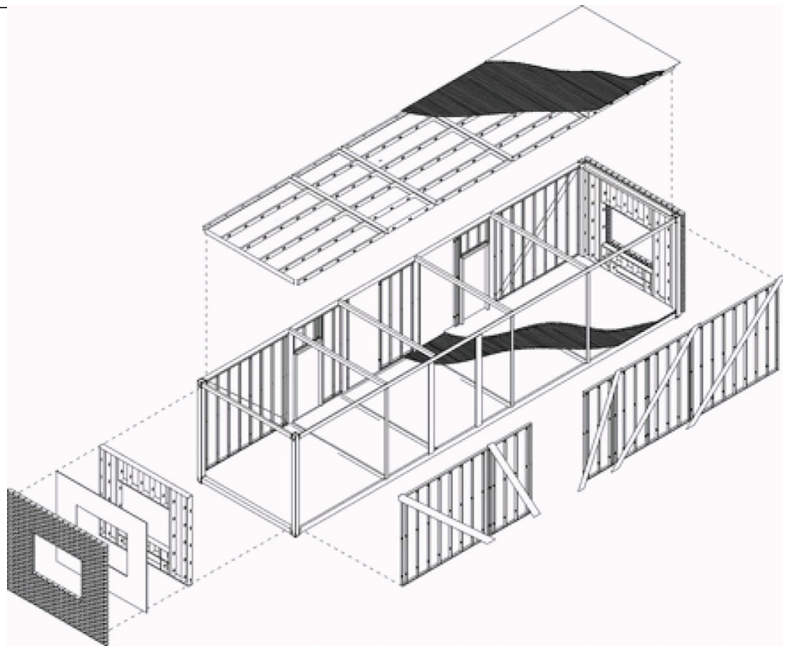


FIGURE 7. Modular off-site manufactured construction (Garrison & Tweedie, 2011).

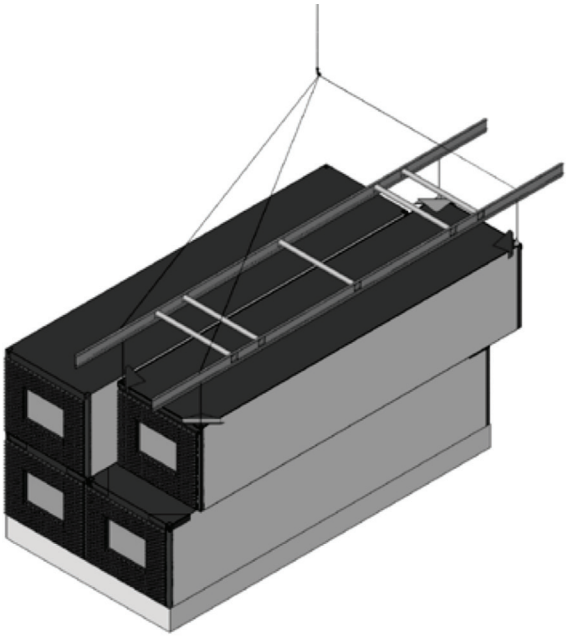


FIGURE 8. Joining modules on site (Garrison & Tweedie, 2008).

Construction

Under the criteria for construction, the structural frame, foundations, and methods of connecting components have been compared. The modular off-site manufactured typology was found to have advantages in that the structural frame was clearly defined and the internal layout could be easily modified.

An advantage of the structural frame system used in the modular off-site manufactured typology is that it allows for a clear span across the entire width and length of each module, enabling the internal layout of the dwelling to be easily modified without modifying the structural frame. This is limited however by the relatively narrow width of the module, determined by transport regulations. Each module width can be constructed up to 4.2m wide without requiring extra money to be spent on transport escorts, enabling a wide variety of internal layouts. The lightweight timber framed typology in comparison consists of a structural frame designed to provide spans based on the layout of the dwelling and the roof design as it was initially designed. Changing the layout of the lightweight timber framed typology may require additional structure to be built in place of load bearing walls which must be determined by professional inspection.

In order to allow for the addition of recreational spaces such as decks, and openings for surveillance, the vertical members of the structural frame should be as open as possible. The vertical structural members in the external walls of the modular off-site manufactured typology are located in accordance with the layout of the modules. Depending on the fixing system used, the vertical structural members can be relocated to allow access to outdoor recreation space. Lightweight timber framed construction also allows this access to outdoor recreation space by removing studs and adding lintels.

To permit the structure to be changed in the future, the foundations must be designed to allow for anticipated changes. The foundations of the modular off-site manufactured project are designed to support point loads, and therefore are located only below the exterior walls, allowing internal partitions to be moved and extra internal partitions to be added. The foundations of the lightweight timber framed case study are also designed to support point loads, located in a grid layout also allowing internal partitions to be moved and added. Both case studies must consider the sizing of foundations if vertical additions are to be made to the structure such as placing another level on top of the dwelling.

Fixing components using a system that leaves no damage when it is disassembled allows growing families to make future changes without as much cost or time. The components of a lightweight timber framed house are fixed using nails or nail plates. This makes damage more likely when removing or disassembling components. Modular off-site manufactured dwellings may use either welding or bolts to fix steel elements together. If bolts are used to fix the components of a modular off-site manufactured dwelling it allows for future disassembly and reassembly without damaging the components and allows components to be easily removed or added. It must be noted that both case studies used in this example use nails or screws to fix internal partitions to floors and ceilings, with some damage likely when the internal partition is removed.

Using bespoke components should be avoided if a dwelling is to be flexible to a growing family's future needs. Bespoke components often use fixing systems and elements that may be unavailable in the future, making any changes to the dwelling difficult. Both the modular off-site manufactured and lightweight timber framed case studies use readily available elements in the construction, making additional materials easier to purchase. The history of off-site

manufacture has shown that using bespoke elements has resulted in unsuccessful designs that cannot easily be modified at a later stage (Smith, 2010).

Layers

In order to allow different layers of the building to change at different rates, the structural frame must be separate to the partitions, services and fittings, as the frame changes more gradually than other layers. The structural frame of the modular off-site manufactured case study is separate to the internal partitions. Services and fittings are attached to a lightweight timber frame within the structural frame members, allowing changes to the layout, services and fittings without changing the structural frame. Locating services within the timber frame between the structural members provides a support frame for locating services. The floor frame of the case study includes a 200mm void for the location of services without affecting the structural frame.

Non-load-bearing internal partitions allow for growing families to make changes to the internal layout over time. Internal partitions should not contain electrical or other services, making removal easier. Floor, wall and ceiling finishes that continue behind the internal partitions allow for more options such as moveable partitions and make the removal of partitions easier. Internal partitions in the modular off-site manufactured case study are made from lightweight timber or steel and are inherently separate to the structural frame allowing them to be easily removed or even reused when relocated. There is the potential to use re-locatable or moveable internal partitions, as no internal partitions are load bearing. Internal partitions in the lightweight timber framed typology however often contain services, which are costly to relocate when changes are made to the layout of the dwelling. Both case studies may be designed to allow finishes to continue behind internal partitions. This must be considered in the design stage.

Services located in permanent structures allow components that may change more frequently to be free to do so. Services are designed to run vertically through the external walls of each module and horizontally through the void created between modules stacked on each other. This allows for greater freedom to make changes to the internal layout of the modular off-site manufactured dwelling, including the relocation of service areas such as kitchens and bathrooms. The lightweight timber framed dwelling however contains services in both permanent and non-permanent components.

Simplicity and legibility

To enable changes to the internal layout it is helpful if the growing family is able to identify that this is possible. Buildings that have been designed to be flexible in the past have failed because later occupants have not known of the potential to change the building (Schneider & Till, 2007). The width of the walls in the modular off-site manufactured typology provide a clue as to how the layout of the dwelling can be easily changed. Non-load-bearing internal partitions are half the width of the wall joining the modules. This provides a visual clue that these walls are not structural. The lightweight timber framed typology in comparison consists of partitions of consistent width, making the identification of load-bearing walls difficult without professional advice.

In order for service areas to be moved the location of services must be known. Likewise in order to remove an internal partition, it must be known that there are no services located inside. The location of services in both case studies could be made more legible. The location

of vertical and horizontal service runs in the modular off-site manufacture case study aids flexibility, but without providing visual clues of this to the occupants they are unlikely to understand this benefit.

Recommendations

Considering the criteria developed on the base of the interviews and their correlation with the Australian Bureau of Statistics data, the modular off-site manufacture typology showed a potential for providing flexibility to growing families in Brisbane in the following ways:

- Clear spans across the width and length of each module
- Foundations allowing the internal layout to be modified
- The potential to use fixings that allow easy disassembly
- The use of commonly available components
- Clearly defined layers that can change at different rates
- Avoidance of services within internal partitions
- A clear visual difference between load-bearing and non-load-bearing partitions

In order to improve the constructional system of the modular off-site manufactured typology the following recommendations can be made based on the findings in this research:

- Each module should be made as wide as possible to permit a variety of internal layouts
- Fixings should be used which allow the structural frame to be disassembled and modified
- Foundations should be sized considering the possible future requirements of the dwelling
- A method of fixing internal partitions which enables disassembly should be used
- Detailing of the floor and ceiling joint of internal partitions should provide a visual clue to the semi-permanent nature of these partitions
- A method of making the location of services within structural walls and floors visible should be developed.

IMPLICATIONS OF THE FINDINGS

The findings indicate that modular off-site manufacture has advantages in key areas to address the needs of young families in Brisbane. A core focus for young families is the need for flexibility in the provision and use of space with particular regard to functional and leisure space, as well as the safety and surveillance of small children. While both case studies are inherently flexible in some criteria, flexibility has to be designed into light frame houses, while changes are generally easier in the case of modular technology. This research highlights the potential of the modular off-site manufacture to answer young families' need for flexibility and provides a preliminary set of suggestions about how to implement the use of this technology in the specific context of Brisbane.

Limitations

The research focused only on the area of Brisbane. Further research is required to identify growing families' needs in other areas, as differences may occur. Although many types of off-site manufacture exist, this study looked at only the one type of modular homes. Other

types of off-site manufacture, such as Structural Insulated Panels (SIPs), will vary greatly when assessed against the criteria presented in this study. SIPs, for example, consist of custom cut panels, which may prove to be very difficult to alter once manufactured. Further, one can argue that our sample size was relatively small and thus can limit our findings. Nonetheless, it is controversial to suggest what constitutes a sufficient sample size (in contrast to quantitative studies for example). Qualitative researchers often suggest that a sample size is sufficient when the data collected has become saturated. With the literature review, we found only seven sources that provided guidelines for actual sample sizes, ranging from 10 to 50 interviews (see review from Mason, 2010). However, these authors do not tend to present empirical arguments as to why these numbers are sufficient. While some researchers provide some guidelines for qualitative samples, others researchers do not strictly adhere to them. Thomson (2004) reviewed 50 qualitative studies and found sample sizes ranging from 5 to 350. We would like to indicate that our findings are preliminary and future research can be carried out to expand or replicate our study in order to confirm generalizability; possible future research directions could also include a discussion of the findings of this pilot with architects and developers, but at this stage this was outside the scope of our research.

CONCLUSION

The purpose of this research article was to develop a preliminary understanding of young families' needs and how these could be met by the use of modular off-site technology. A questionnaire was conducted, which, combined with established theory on flexibility, was used to identify a preliminary set of needs that were summarized in three criteria. When these criteria were used to compare modular off-site manufactured construction with lightweight timber frame construction, it was suggested that modular off-site manufacture has a number of advantages for growing families in Brisbane, however, both construction typologies have the potential to be flexible when this is considered early in the design stage. Using the criteria, a number of recommendations were provided in order to improve the implementation of the modular off-site manufactured construction system.

Other studies have established suggestions for the design of multi-residential buildings based on guidelines used for commercial buildings. These studies have been based in Europe and America using construction techniques and materials not as common in Australia. This research article applies this knowledge in a local Brisbane context to the detached dwelling based on the needs of growing families. While many studies have investigated the design for adaptability for an aging population, this research brings the idea of design for flexibility closer to the beginning of the family lifecycle.

The recommended outcome of this research is that designers consider how the dwelling should be flexible over the family lifecycle and how the selection of a construction technology can facilitate this flexibility. Further research is needed into the needs of families at other stages in the family lifecycle as these stages can be very different, for example when children grow up and leave the dwelling.

Other opportunities exist for further study, which have been identified during this research. The cost and time involved in ensuring flexibility in construction systems must be studied. The finding that most growing families relocate to be closer to the workplace may provide an opportunity to investigate the criteria needed to provide a flexible constructional system for allowing work to be done from the home more easily. Opportunities also exist to

apply the typology of modular off-site manufactured constructional systems in other contexts. The system investigated in this article has many other advantages beyond just flexibility, with one being the ability for manufacture using non-skilled trades (Smith, 2010). An opportunity exists in Queensland for research into the prospect of creating employment opportunities in rural areas by using locally made modular off-site manufacture as a means of manufacturing dwellings.

Although it has been proven that modular off-site manufacture is not the only solution for growing families, it is hoped this research will encourage further research in Brisbane and Australia into the potential of this emerging construction typology.

The data gathered from the questionnaire and criteria presented in this research have revealed valuable insights into the requirements of growing families in the early stages of the family lifecycle. This research also aims to encourage architects to consider the family lifecycle at all stages and design dwellings flexible enough to adapt to families throughout the lifecycle.

Appendix: Interview questions

1) How many children are in your household?
2) What is the age in years of the eldest child in your household?
3) What is your age in years?
4) How many years have you been living in your home?
5) Do you own your home?
6) What type of home do you live in?
7) What best describes the construction of your home?
8) How many rooms are in your home? (include all rooms, e.g. kitchen, living, bathrooms, bedrooms)
9) How many bedrooms are in your home?
10) How do you feel about your home?
11) Have you moved home since having children? If Yes, why?
13) If yes please say a little about these changes and the reason you made them.
14) What other changes, if any, would you like to make to your home since having children?

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