What's driving the uptake of prefabricated housing in Australia?

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Abstract

Prefabrication has been promoted as a means to improve the efficiency of the Australian house building industry. Issues affecting the uptake of prefabrication were identified through interviews with small and medium sized building companies. Prefabrication's specific impact on housing construction and smaller organisations has not been frequently investigated. Similar past research has been conducted without the use of a clear theoretical grounding guiding the identification of relevant issues. The current study is guided by a combination of the Theory of Planned Behaviour (TPB) and the Technology Acceptance Model (TAM). This allowed the identification of a broad range of issues across attitudinal, normative, behavioural control and technology adaptation domains. Results revealed improved quality was often offset against practical cost implications. While a high quality of prefabricated products was reported, key technical challenges included coordinating the transporting of modules, and balancing standardisation and product flexibility. Resistance from traditional industry stakeholders regarding build methods, financing, and openness to encouraging prefabrication was commonly reported. The key role of government decision making in facilitating greater demand and competitiveness of prefabricated businesses in the consumer marketplace was also highlighted. Further research is currently being undertaken by the authors, which builds on the exploratory results of the current study through confirmatory, quantitative surveying.

Introduction

Prefabrication, or offsite construction, has been promoted in the Australian Construction Vision 2020 as one of the eight key 'visions' to improving the efficiency and performance of the Australian construction sector (Hampson & Brandon, 2004). This paper presents the results of the qualitative component of a project investigating the barriers and drivers to the uptake of prefabrication in the Australian house-building industry. A number of previous qualitative investigations have focused on understanding the impact of prefabrication on construction. The state of research into prefabrication has been criticised for a reliance on unstructured evidence and exemplar case studies which do not provide an opportunity for generalised findings (Blismas & Wakefield, 2009). This current paper provides the basis to addresses this gap in knowledge. It examines the beliefs of small prefabricated builders in Australia; the relative strength of which will be tested quantitatively in the next stage of the research.

There has not been a focus on prefabrication in the residential housing market. The residential construction sector is distinguished from industrial or commercial sectors by a high level of client attachment to the project (Koklic & Vida, 2011), fewer subcontractors, and a predominance of smaller firms (Costantino, Pietroforte, & Hamill, 2001). Previous research has given a focus to understanding the attitudes of the largest manufacturers and builders to prefabrication. Gibb and Isack (2003) interviewed representatives from 42 of the largest or most frequent construction client organisations in the UK, explicitly excluding residential builders. Even when targeting residential builders Pan, Gibb and Dainty (2007) focused on the top 100 house builders in the UK market. Their research also highlighted reluctance to adopt prefabrication as greater among smaller residential house builders, who, if anything, usually only adopt minor changes to existing processes rather than wholesale shifts like the adoption of prefabrication (Thorpe, Ryan, & Charles, 2009). The current research hopes to identify the key drivers to turning this situation around.

Australian research

The unique barriers and drivers for the Australian prefabricated housing market have not been comprehensively examined. Blismas and Wakefield's (2009) study provides the clearest existing evidence collected from three discussion workshops and a series of case studies conducted across Australia. Their study scope extended across the residential, civil and commercial construction sectors, identifying process barriers such as high setup and transport costs, increased logistical complexity, and retraining demands. Drivers identified included reduced onsite work, less coordination of multiple trades, reduced waste, and improved building quality, performance and sustainability. No drivers related to the regulatory environment, industry culture or supply chain factors were identified, although some barriers were briefly identified, such as unclear legislative requirements, negative perceptions of prefabrication from clients and finance institutions, and the lack of demand. The current paper extends this previous research by undertaking a more comprehensive examination of individual determinants within a specific market – housing.

Blismas, Wakefield and Hauser's (2010) extended this work with a discussion of a roadmap for the future of concrete prefabricated housing in Australia. Critical requirements for housing elements were first listed by workshop participants, and then barriers to the use of prefabricated concrete products were listed. These barriers to uptake of prefabricated concrete in housing were summarised briefly as being "*adaptability, cost, logistics, system interfaces and services distribution*" (p104). Little in-depth discussion beyond this summary was given, with the roadmap focused primarily on technical build issues to be resolved to increase prefabrication uptake.

Related work is also being conducted through Australia's Sustainable Built Environment National Research Centre (SBEnrc, 2013). This work is complementary to the aims of the current project, focusing on a full lifecycle evaluation of the costs of prefabricated houses from varying stakeholder perspectives. They also seek to quantify the economic, environmental and building quality performance of prefabricated houses, with a view to developing informed policy. This project is in its early stages and as yet has not made its results available publicly. There is thus a growing interest in understanding the many influences on prefabrication adoption in Australia from both economic and social perspectives.

International research

International research has identified a similar set of issues. Bildsten (2011) interviewed representatives from two Swedish builders using prefabrication and identified benefits such as fixed price cost estimation, material standardisation, and increased production through repetition of tasks. These were contrasted by barriers such as low build tolerances, higher development costs, a dependency on particular suppliers and a lack of acceptance among house buyers. While the research drew upon a four-month period of factory observation, there was little detailed discussion of key contextual influences or the reasons behind the barriers and opportunities.

Research in the United Kingdom (UK; Goulding, Rahimian, Arif, & Sharp, 2012) has expanded the discussion to macro issues such as cultural and socio-economic drivers. Interviews with domain experts were conducted alongside follow-up workshop discussions. The results were expressed as numerical comparisons of the importance of influences grouped under the headings of construction, design and manufacturing. Specific issues identified were the need to incorporate prefabrication at the design stage, awareness raising regarding waste reduction possibilities, inclusive training of staff to acknowledge the challenges of role transition, the need to maintain flexibility in prefabricated products, and the key role of supportive automation technology.

Earlier work by Nadim and Goulding (2011) utilised a content-analysis approach to identify 'patterns of concern' which they grouped under the categories of business process, product and technology, market, and people. They drew on interviews with suppliers, media groups, designers, developers, software providers, bureaucrats and researchers in Germany, Sweden, the Netherlands and the UK. The authors highlighted the need to consider a broad range of interacting influences on prefabrication uptake including staff opinions, product factors, regulation and business risk. Specific key factors identified included streamlining of business processes to reduce the risk, the high cost and complexity of offsite work; the increased logistics and organisational requirements imposed; conflicting regulatory requirements; the need for evolutionary rather than revolutionary processes to overcome industry resistance; the need for a person-focused approach to ease individuals into new processes; the conflict between individuality and standardisation; the rising importance of quality rather than cost; the need to integrate technology and building information systems; and the effect of fluctuating economic conditions on the viability of prefabrication.

Older work by Pan et al (2007) involved telephone and face-to-face interviews with 36 of the largest house builders in the UK. They noted an overall high degree of satisfaction with traditional build processes and poor feedback on the effectiveness of prefabrication projects. There was however a simultaneous acknowledgement that the industry needed to shift to more offsite prefabrication. High infrastructure establishment costs, a lack of industry incentives, reduced design flexibility, and difficulties aligning with planning laws were noted as barriers while drivers identified included labour skill shortages and improvements to the efficiency and quality of build processes. Smaller scale changes such as introducing wall panels or 'wet room' pods were favoured over a complete shift to offsite prefabrication. In addition to the numerical tabulation of key drivers

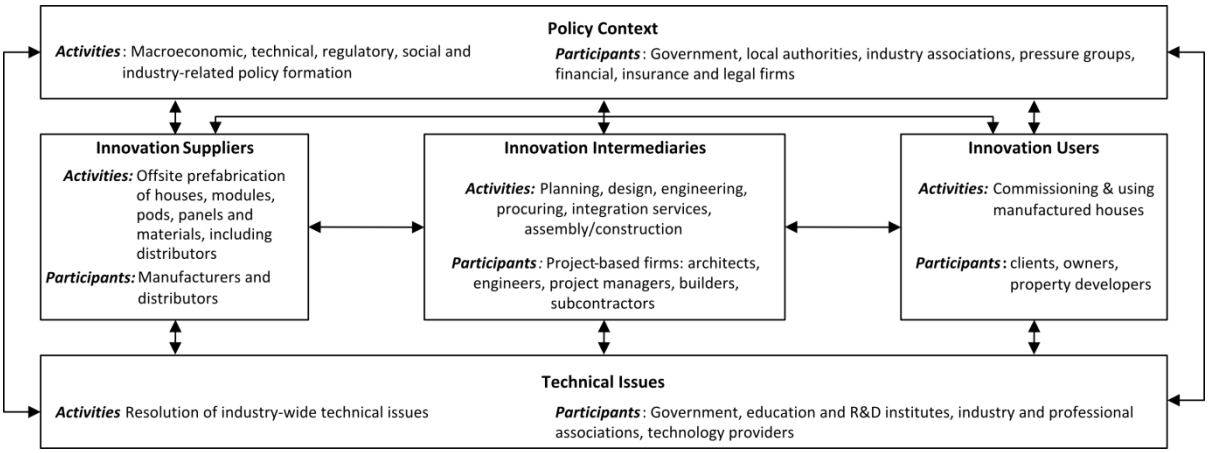
and barriers, a mapping was produced of key stakeholders that could influence prefabrication adoption. Analysis of these influential groups was however minimal and speculative, calling for further research into how they specifically interact to encourage prefabrication uptake.

Similar research on consumer demands for modular housing in the Netherlands (Halman, Voordijk, & Reymen, 2008) sought the opinions of architects, construction firms, suppliers, government groups and consumers. There was a high degree of concordance between each group's responses. Industrialisation housing production was perceived favourably, with identified barriers to its introduction including the protectionist nature of the real estate market and the complexity of regulations. Analysis within groups highlighted specific issues such as architects' design focus, suppliers' materials focus, and the universal perception of builders as a central coordination point for housing projects.

There is a recent growing interest in the applicability of prefabrication to Australia, building on a base of mostly European research. The current project qualitatively explores the reasons underpinning specific barriers and drivers, rather than merely identifying these influences. The current work also adopts a narrow scope to focus only on small and medium-sized builders' opinions of prefabricated housing, recognising that different perspectives and contexts give rise to different sets of influences. Specific recommendations for this population will flow from this more targeted approach.

Theoretical context

The application of a clear theoretical framework has not been used in these previous qualitative investigations. As there is no definitive structure or statistical tests that are universally accepted for qualitative research, an *a priori* selection of a theoretical model guiding qualitative work provides a structure and elucidates specific aims (Gephart, 2004). This program of research uses an open innovation systems model (Gann & Salter, 2000) as the context for understanding the adoption of prefabrication. The innovation of prefabrication is hypothesised to be influenced by the traditional manufacturer-builder-owner supply chain as well as macro policy decisions and technical advances (see Figure 1).



Source: based on Gann and Salter (2000)

Figure 1. *Prefabricated Housing Innovation System*

The stakeholders and activities within the system are examined through the Theory of Planned Behaviour (TPB, Ajzen, 1991), to investigate beliefs about manufactured housing. The TPB is a

social psychology theory stating that planned behaviours result from intentions. These intentions are in turn predicted by beliefs about attitudes, subjective norms, and perceived behavioural control (PBC). Attitudes in this instance refers to the favourable or unfavourable evaluation of the elements of the behaviour, subjective norm to the pressure of key influential persons on the likelihood of taking part in the behaviour, and perceived behavioural control to the perceptions an individual holds regarding their ability and opportunity to perform the behaviour.

The use of a qualitative 'belief elicitation study' prior to formal quantitative surveying is recommended by Ajzen (2006) and TPB research guidelines (Francis et al., 2004). The elicitation phase of TPB research identifies influential beliefs specific to the behaviour being investigated. This process reduces the need to rely on anecdotal evidence or adaptation of beliefs from tangentially-related studies (Curtis, Ham, & Weiler, 2010). TPB belief elicitation studies do not aim to derive consensus, but rather to derive a set of factors that are potential influences on the theoretical beliefs-intention-behaviour pathway. This process has been applied to a range of intentions and behaviours from tax compliance and physical activity (e.g.: Bobek & Hatfield, 2003; Darker, French, Longdon, Morris, & Eves, 2007) to builders' beliefs about sustainability measures (Kientzel & Kok, 2011). These studies usually consist of open-ended or semi-structured interviews, focus groups, or short surveys used to identify pertinent influences that can later be expanded upon by more formal survey research. The questions used address the advantages or disadvantages of the behaviour underpinning attitudes; the individuals or groups that underpin normative beliefs, and the impeding and facilitating factors and circumstances underpinning control beliefs.

In addition to these typical components of a TPB belief elicitation study, the current study also draws upon the work of Davis' (1985) Technology Acceptance Model (TAM). The TAM interfaces with the attitudes component of the TPB by considering the perceived usefulness and perceived ease of use of the new technology. Further development of the TAM (Venkatesh & Bala, 2008; Venkatesh & Davis, 2000) has suggested specific determinants underlying these two variables. Perceived usefulness is underpinned by the quality of outputs associated with the new technology, the resulting image of adopters, and the effect on complexity and efficiency of processes. Perceived ease of use is underpinned by the flexibility of the technology and frustration associated with new processes. These factors align well with the discussion of prefabrication and the potential technical challenges it presents compared to traditional house building practices. The combination of the TPB and the TAM as a single theoretical model is shown in Figure 2.

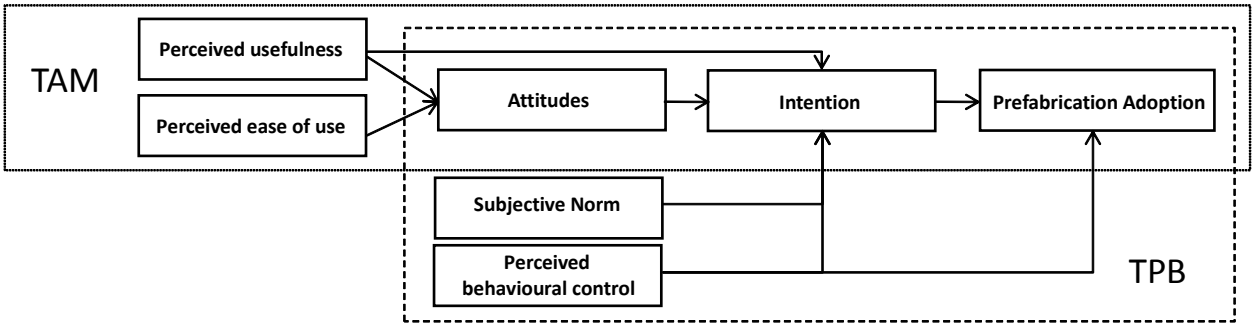


Figure 2. *Combined TPB and TAM model for predicting prefabrication use in house building*

Scope

The scope of prefabrication considered was based on a continuum derived from past research, shown in Table 1. In this paper prefabrication refers to all the categories shown in Table 1, except

for component sub-assembly and materials. The research therefore covers structural building panels, pods, modular units and completely prefabricated buildings. Smaller, non-structural prefabricated elements such as pre-assembled trusses are not considered within the scope of the current research as they are highly represented in traditional building and are unlikely to promote the same advantages as more complex prefabricated elements or houses. A further category of 'hybrid construction' is also considered in the current study, referring to the use of traditional materials or components in combination with the application of complex prefabricated components (Arif, Bendi, Sawhney, & Iyer, 2012; Bell, 2010).

Table 1. *Continuum of prefabricated house construction methods*

Prefab. level	Type	Definition
High	**Complete**	Box-form, volumetric, completed buildings delivered to a building site
	Modular	Structural, volumetric, potentially fitted-out units delivered to site and joined together
	Pods	Volumetric pre-assembly. Fully fitted-out units connected to an existing structural frame such as bathroom or kitchen pods
	Panels	Structural, non-volumetric frame elements which can be used to create space, such as Structural Insulated Panels (SIPs), precast concrete panels and structural wooden panels
	Component sub-assembly	Precut, preassembled components such as doors, and trusses not feasible to produce on site
Low	**Materials**	Standard building materials used in onsite construction

Sources: (Bell, 2010; Gibb & Isack, 2003)

Aims

The current study had three primary aims, the first two being:

1) To derive a set of belief factors corresponding to the combined TPB and TAM predictors of intentions to adopt the innovation of prefabricated housing. Namely:
    a. Overall attitudes
    b. Attitudes towards the acceptance of the new technology
    c. Normative influences
    d. Perceived behavioural control factors
2) To quantitatively identify the most frequently cited belief factors identified in 1)

The results of these two aims will provide a basis for further confirmatory, statistical research into these beliefs. The third and final aim is:

3) To describe and discuss the specific nature of these belief factors through analysis of qualitative interview transcript data.

This final aim is more exploratory in nature, drawing on social science methods to illuminate and contextualise the data collected to address the first two aims.

Method

Participants

Participants represented a wide-scope of prefabricated housing businesses, as shown in Table 2.

Table 2. *Participants and type of prefabrication employed (N=14)*

Prefabrication Type	n
Queensland Builders	
Complete/Modular	3
Panel (insulated)	2
Complete/Modular/Pods	1
Panel (concrete)	1
Western Australian Builders	
Complete/Modular	3
Panel (insulated)	2
Complete/Modular/Site build	1
Modular extensions	1

The broad term ‘builders’ is used throughout the paper, referencing the ultimate role of the businesses in delivering a built housing product to end users. Those businesses with interests in producing volumetric pods, modules or complete houses typically completed the work in a factory setting offsite, encompassing some traditional manufacturer roles. This was also the case for two of the panellised building companies that had integrated operations both manufacturing panels and applying panels to onsite building. Automation of some production, along with manual handling between work-stations, typified these two business’ manufacturing operations. The remaining panellised builders used panels manufactured and supplied by external manufacturers in their onsite construction. The businesses producing volumetric products were not automated, though manual production line approaches involving shifting modules between staff or vice versa were used in two cases. Seven participants were sampled from each of the Australian states of Queensland and Western Australia, where the two respective government research partners to this project are based.

Procedure

Interviews were conducted over the phone, except for two which were conducted in-person. The interviews generally lasted for approximately 30-40 minutes, with a range from 20 to 80 minutes. Recordings of the interviews were transcribed verbatim by the same researcher within 48 hours of their completion.

Interview Questions

Participants were asked a series of questions in a semi-structured format relating to each of the theoretical TPB/TAM predictors. These questions were:

- **Overall attitudes:**
    - What are the advantages or positive aspects of using prefabrication?
    - What are the disadvantages or negative aspects of using prefabrication?

- **TAM attitudes - Perceived usefulness:**
    - In what way does prefabrication affect the:
        - quality of the house build?
        - image of the business?
        - efficiency of processes?
- **TAM attitudes – Perceived ease of use:**
    - In what way does prefabrication affect the:
        - ease of building?
        - flexibility of the business?
        - complexity of processes?
        - frustration of processes?
- **Subjective norm**
    - What is the overall perception of prefabrication among external people or groups?
    - Who are the key people or groups that influenced your decision to use prefabrication?
    - Are there particular people or groups that are supportive or unsupportive of your use of prefabrication?
- **Perceived Behavioural Control**
    - Is adopting prefabrication entirely up to you/your business or are there external influences?
    - What are the key contextual influences that affect your ability to use prefabrication?

Participants were also given the opportunity to raise any other important factors or issues in an open-ended fashion at the conclusion of the interview.

Analysis methodology

The majority of the previous qualitative studies analysing prefabrication barriers and drivers have suffered from a reductionist approach by collapsing complex issues to bullet pointed conclusions or tabulations without allowing the participants' views to be expressed in their own words or in detail (Goulding et al., 2012; Pan et al., 2007). A thematic analysis process was used in the current study to analyse verbatim, electronic transcripts of the interview data, grouping segments of text responses under each of the headings proposed by the TPB/TAM model. Segments of text were grouped under several parts of the model where applicable. The appropriate mix of numerical and text analysis in presenting the results of qualitative data has long been the subject of debate (Silverman, 2013). Numerical analysis of qualitative data can reassure the reader that vivid individual cases have not been overweighted, or conversely that valid data outside a dominant pattern has not been discarded. However, numerical analysis should not present misleading percentages based on small sample sizes, or serve as a definitive analysis point obscuring further discussion (Sandelowski, 2001). Thus, the current paper seeks to draw on the benefits of both numerical and text analysis methods. Basic frequency counts of responses to determine the most commonly raised issues were conducted, with these counts built upon through further discussion and representative quotes. Gephart (2004) states it is "*important where possible to include raw or primary qualitative data (for instance, actual talk by respondents)*" (p460), so long as it is interpreted and analysed.

Bluhm et al (2010) provides a list of best practice elements which qualitative studies should seek to incorporate to increase validity, reliability and objectivity. These include a number of factors addressed by the current study such as counting the 'countables' (counting of beliefs), giving voice to participants (discussion and highlighting of pertinent quotes), multiple levels of analysis (both numeric and text-based analyses incorporated), a strong theoretical foundation (TPB/TAM and overarching innovation systems model), and a transparent outlining of the analysis method used. Miles and Huberman (1994) also suggest that identified themes should be comprehensive and

mutually exclusive.

Influential published research within the leading construction management journals has employed similar methods in several previous investigations. Most relevant is the work of Nadim and Goulding (2011) where issues related to prefabrication were coded and grouped under headings such as process, market and people. Issues grouped under each heading were then discussed in detail with extensive use of relevant quotes. Other similar recent studies in related fields include an investigation of UK building energy use based on thematic coding using highlighting quotes (Christina, Dainty, Daniels, & Waterson, 2014); a Hong Kong focus group study of critical factors influencing public engagement in megaprojects using tabulated topic summaries and extensive quote-centred discussion of themes (Leung, Yu, & Chan, 2013); and work on regulatory influences on sustainable development using a tabulation of key themes drawn from case studies supplemented with key examples and quote-led discussion (London & Cadman, 2009). These leading examples support the validity of the approach adopted in this research.

Results and Discussion

The results of the analysis are presented corresponding to each of the theoretical components of the combined TPB and TAM model shown in Figure 2. As TAM attitudes drive the process, these are analysed first.

TAM - Attitudes

Table 3 presents the frequency with which interviewees identified particular advantages and disadvantages associated with prefabrication. As the participants were builders with an in-depth knowledge of day-to-day technicalities, the issues identified were able to be grouped within the TAM components of perceived ease of use and perceived usefulness. The codes assigned to each of the advantages (A1-A8) and disadvantages (D1-D8) shown in Table 3 are referenced in the following discussion of participants' responses where appropriate.

Table 3. *List of advantages and disadvantages by frequency reported*

Advantages	**n**	**Disadvantages**	**n**
Perceived Usefulness			
(A1). Better quality to traditional builds	14	(D1). Inability to reduce project costs	12
(A2). Cost-effective niche applications	9	(D2). Designs differ from traditional builds	11
(A3). Improved speed of construction	9	(D3). Historical image of poor quality output	5
(A4). Improved energy efficiency during operation phase	4	(D4). Increased post-occupation maintenance	1
(A5). Reduced construction waste	3		
(A6). Improved workplace safety	2		
Perceived Ease of Use			
(A7). Improved coordination of staff and tasks	9	(D5). Increased transport logistics	8
(A8). Simplification of tasks	3	(D6). Risks in adapting to new processes	8
		(D7). Greater preparatory work required	7
		(D8). Difficultly aligning to traditional designs	7

Perceived usefulness

Better quality (A1) versus historical image (D3)

All of the respondents stated that they believed the houses or components they were producing were of a better quality than many traditional builds (A1). This view was particularly supported in regards to the high structural quality necessitated of transportable modules:

> *"Our product is over-engineered for the majority of sites that we service because they are designed to withstand the rigours of transport."*

The historically negative image of all forms of prefabrication was however recognised as pervasive (D3), particularly for those currently delivering lightweight, timber-based products.

> *"[there are] parts in Australia which are dominated by modular buildings. On the whole they are pretty cheap, nasty, flimsy, lightweight constructions. As much as they are getting better I suppose there are quality attributes that are inherently lacking."*

Even if prefabricated products have traditionally targeted the low-cost, low-quality market, this did not necessarily need to be the case. Prefabricated house builders have been able to distance themselves by adding higher quality, but higher cost inclusions (A1 / D1). This also allows a distinction between the high-volume, project home builders which dominate the highly competitive lower end of the housing market.

> *"Quality is not the issue, but we've never dabbled in the bottom end of the market. We've built some cheaper homes, but we don't position ourself in the project home market, simply because we can't compete with them on a square metreage against dollar cost. So, we've made a conscious effort of not being in that market, and we do that through other elements of our specification as well. We definitely don't sort of come up against that sort of stigma of not being able to achieve that certain look a client wants, because we've costed into that middle market, as a minimum"*

> *"I think we have a very good image. People see that we are architecturally focused, and we are about style. We are focusing ourselves in the residential market and for that purpose. There's plenty of modular construction out there, and it has been for years. It's probably served mining - it's the donga-type, it's the portable. People can clearly differentiate between the two these days."*

Regardless of the quality of the build itself, the regional preference of Western Australia to brick housing was also raised as needing to be addressed if alternative, lightweight construction is to be accepted.

> *"Is it quality? Yes. But of course the end user in Western Australia is blinded. They only see one dimension. They see brick exterior and concrete floors. The timber frame section of the market is so small that we haven't been able to market our product."*

The fact that the traditional consumer preferences like brick do have technical advantages such as reduced maintenance (D4) reinforced that it may be a slow process to improve the comparative image of prefabricated timber products in this space.

> *"I believe an exterior cladding will have to be developed that can match the maintenance of brick, or is better. Concrete slabs are pretty damn good, regardless of*

how much they cost. Low-end profile, low maintenance, stable - the maintenance aspects of our claddings do put people off."

For the still-developing companies, being able to demonstrate the range and quality of their work to the market was also a challenge:

"I suppose one of the bigger problems we do have being a small company and a start-up is that we don't have a lot of the fancy showrooms that more established places do. And clients do want to touch and feel sometimes."

The higher insulation and energy performance of most prefabricated products compared to traditional builds was however raised by a number of the participants as a central competitive quality factor that could be promoted (A4). The previous industrial application of insulated panels was particularly noted for its inherent advantages.

"We're a six, seven, eight star product, it's a coolroom product. In a cold climate we have to insulate the floor!"

Cost-effective niche applications (A2)

Particular advantages were associated with the use of complete or modular systems for niche markets; particularly regional, rural and remote builds. Substantial reductions in costs and delays associated with transporting skilled tradespeople over long distances were seen as possible if buildings could be completed at a central location and a finished product transported to remote locations as a single or small number of shipments:

"So, in a lot of ways what we're doing is a simple arbitrage between the cost of a plumber or electrician in say Brisbane [metropolitan capital city] *compared to the cost of a plumber or electrician in Roma or Emerald or Kununurra* [rural towns] *or anywhere you like."*

The more remote the build location, the greater the advantages. The extreme example reported was a delay of two years for remote clients seeking an onsite build. As high volume, low profit project builders were not seen as able to compete in the niche rural market, a number of the factory-based builders delivering complete or modular solutions moved in:

"We're better off to stick what we do - into a [rural] *market where there isn't as much competition. If all of a sudden the onsite builders, and the multi-building project home builders decided they wanted to spread out into our market… but I really can't see that happening because there's not the concentration for them."*

The identification of niche markets where prefabricated products could be applied profitably was regularly raised. Other niches targeted included cyclone and weather resistant houses, or the construction of smaller dwellings such as modular 'granny flats' or holiday homes.

Designs differ from traditional builds (D2)

Almost all interviewees felt that prefabrication cannot offer a finished house, indistinguishable from traditional builds, at a lower price (D2/D1). The challenges in reaping the cost efficiencies of prefabrication while still being able to retain modern, mainstream styles was recognised as being necessary for success. As one modular builder noted:

> *"I would say it depends on whether the prefabricated dwelling looks 'prefabricated.' For us, one of the keys to be able to give yourself the best chance of success into the mainstream market is being able to accommodate the builders' requirements and yet still provide them with an automated manufacturing capability."*

Another participant recognised this as a typical shortfall of their factory-completed product:

> *"Most of my problems are marketing problems, and they're not physical or fundamental issues. You know, transportable housing tends to be boxy - it reduces the excitement of the thing"*

Traditional build methods such as concrete slab-on-ground, masonry constructions were noted for their competitive cost and prime position in the Australian industry, particularly in Western Australia.

Improved speed of construction (A3) does not reduce project costs (D1)

Increased construction speed was seen as a key advantage by the majority of participants (A3).

> *"The rhetoric for the industry is pretty well-known. That basically you accelerate a project timeline by building in a factory-controlled environment with production line style like efficiencies. You effectively remove the need for what are potentially archaic methods of construction: i.e. guys laying bricks in the tropical Australian sun, as they've effectively been doing for thousands of years. Or putting them into a shaded, factory controlled environment and looking for efficiencies that way."*

Three participants pointed to inherent advantages of factory-based work such as reduced time lost due to rain or other weather issues. Though efficiency improvements were frequently identified, this did not translate directly to a reduction in an individual project's cost (D1). Accelerated timelines were however noted as facilitating an increased frequency of new project starts, which can increase turnover and indirectly contribute to greater overall profitability.

> *"Economics 101 says the cheaper I sell, the more units I've got to get out the door to cover my overhead. The compelling reason you should, even though it doesn't save you any money on a job basis, if you can knock 20 days of labour off a job out of 120 man days of labour, that's a lot less work you've got to supervise. You can, providing you've got the sales, start more projects in a year."*

Preventing the loss of earning potential through injuries to staff was also mentioned as an advantage of factory based work. This was attributed to an ability to better organise, monitor and refine work processes (A6).

> *"You can build into the product process often by virtue of the way the product is configured or setup, safer ways of installing those building elements."*

Reduced construction waste (A5)

Finding and maximising the benefits of prefabrication within the highly competitive Australian housing industry was noted as challenging:

> *"It's one step back before you get two steps forward. You've got to make sure you're getting the two steps forward."*

This was seen as a driver for continual innovation among prefabricated builders, a specific example being the reduction of waste associated with controlled, manufacturing methods:

> *"You need to produce the same quality and the same options as those guys but at a cheaper rate. And how you try to do that is you become more environmentally friendly, recyclable, and stuff like that.*
> …
> *The storage of materials is a lot better in a factory environment. And the recycling of materials and the reuse of materials is a lot better in a factory environment. In a traditional build what's left over is chucked in the pile and off it goes. With us, we can actually control that environmental policy and create larger profits by using leftover materials."*

Perceived ease of use

Improved coordination (A7) and simplification of tasks (A8)

Frequent mention was made of the improved coordination of both staff and tasks associated with using prefabricated products (A7). Simply moving the build process inside a factory was noted for the benefits of a central coordination point for organising staff across multiple projects. Two of those interviewed that had adopted further automation innovations were critical that moving traditional building methods inside a factory did not go far enough to realise the potential benefits, because some builders were:

> *'…not transforming how they build, but transforming how they transport."*

Though moving work processes to an undercover setting may serve as an initial stepping stone to further automation for some operators, this has not been a universal movement. The further integration of prefabrication with advanced prefabrication technology was however signalled as a means to simplify everyday building tasks (A8).

> *"…they are efficient because of computer technology. It just astounds me that you can draw incredibly complex rooves into a computer program and send it back out to a workshop. My $20 an hour lads who can walk and chew gum on a good day, can put together these components and bugger me, they go out 100 kilometres and they put them up, and all it fits – it's staggering. I believe prefabrication is far from finished, as a matter of fact it's only just started."*

Similar advantages facilitated by using simple-to-assemble prefabricated panels onsite were also highlighted (A8). Fewer and less diverse staff requirements translated to reduced organisational overhead and onsite hassles.

> *"We use it because it comes pre-finished, with proper paintwork. The advantages are ease of handling - a lot smaller number of subbies* [subcontractors] *needs to be involved in the construction"*

Increased transport logistics (D5)

The transport of large modules or pods was frequently referenced as adding complexity to the build process. Issues included dealing with the bureaucracy surrounding escorts and pilot vehicles, and limitations to the dimensions of modules that can be routinely transported without incurring additional costs.

> *"For all of the efficiencies of modular built, transport is a big thing in the minus column you have to offset."*

> *"There's always issues in getting permits from transport, rail, police, trying to get them all to line up together. Obviously there's only a certain amount of escort officers available, and if they're busy on other loads sometimes you've got to put things back. If it rains, if it shuts down roads, that kind of stuff."*

The necessity for the use of cranes to place the transported modules was also noted as introducing complexity and potentially eroding efficiencies gained elsewhere.

> *"The crane companies are one industry that seems to not have to give you a fixed quote. Just 'ah, it's this much an hour.' Everyone else has to take on risk. So you kind of have some intangibles. And the problem with that is that it actually reflects on our business model. We need to be able to tell people that we can put a studio in your backyard and it will cost you two grand. Where are my efficiencies? Because they all went out the window with the crane truck. You're exposed."*

The costs and logistics associated with cranes were reported as factors driving more local-based and panellised work for one of the builders who had also previously offered modular solutions.

> *"You've got to have heavy cranes, you've got to have the footings done. We're concentrating on the local markets, granny flats, without the great craneage costs."*

Risks in adapting to new processes (D6)

There are substantial financial and process risks associated with a builder changing to a new system. The high initial costs to establish a factory setting of any kind were seen as a disadvantage, especially compared to the minimal outlay required of traditional residential building start-ups:

> *"You start as a residential builder; you don't need too many overheads. You can work out of your bedroom if you like. We obviously needed to have a yard and offices, so quite a lot of outlay."*

One panellised builder highlighted that even without a wholesale shift to factory processes, it is not a decision that can be made without significant dedication to continual process improvement. Even if a new build system may eventually be easier to use, liaison with the upstream supplier and training of trades is required to harness these advantages.

> *"To take the panels out to random builders is a very costly exercise. Because for a builder to take on one of these types of builds ad hoc, at random, they're going through the same learning curve that we've been going through the last two years. That's why we made the conscious decision… just to dedicate to this system until we actually got it right."*

Others however pointed to the relatively fast adaptation of trades to new processes, so long as they were not revolutionary changes.

> *"Things change but a carpenter is a carpenter. I built a lot of steel framed houses a few years ago – they whined like hell about it – but they knew what they were doing, they were able to do it, and they did it."*

Greater preparatory work required (D7)

Establishing the use of new products and methods was frequently noted as adding a further layer of complexity. The required planning, design and specification work necessitated by prefabricated products was noted as both expensive and time consuming. This was particularly so for the staff of smaller builders without dedicated administrative staff. In particular, engaging with other technical staff and those responsible for approvals was seen as critical to simplifying processes, over and above the technical details of using a new system.

> *"Specifically consider engineers and local authorities. If you let them run their natural course of what they want to do it can become an elongated and a very detailed process. You have to be prepared to put a lot of effort and work into monitoring the performance of the product, identifying simplifications of the processes, engaging the authorities and the engineers and working through those processes."*

Simplification of a task also does not imply it is error-proof or that novel problems will not be introduced. One of the participants noted that a simple task such as erecting a panel with pre-installed service conduits could result in a significant design fault if it was not oriented correctly. Identification of this problem led to a symmetrical redesign of the panel with conduits on each side. Developing complete prototype products that could be certified was seen as one way of proving new methods, though it was acknowledged that this would not always be feasible for small businesses with time and capital shortages.

Difficulty aligning to traditional designs (D8)

The interaction between standardisation of products and the flexibility of housing products delivered was noted as a trade-off between reducing product variability and costs on one hand, and attempting to meet clients' common requests. This was noted as a potential area for improvement for the industry, and one being pointedly addressed:

> *"We're not modularised or industrialised to a point where 'sorry, you've got to work on 1200* [millimetre] *centres and you can only have a 1200 wide window cause that's what fits between the frame'. Because that's where you run into the issues of them saying 'you know what guys, as much as you can save me ten thousand dollars on a house, I'm not actually getting the house I want' and it looks… well, you can't hide some of those things."*

While those building modular or complete using craft methods inside a factory setting were not hampered by specific dimensions of pre-made components, they acknowledged the restrictions on the dimensions that were feasible to transport.

> *"Because it has to fit on a truck you can only have it twenty metres long by four and a half metres wide, by and large."*

A greater flexibility in the final housing design was possible for those builders using the smaller structural panels as their primary component. The generally prefinished nature of many of these products did however introduce further overheads that needed to be passed on to the consumer if an alternative finish was required.

> *"We can achieve any type of finish we want, but a lot of the types of products that we*

are using are prefinished. If you don't want that, then you have to go through the process of actually joisting it out, gyprock, flushing it all off and providing a traditional ceiling type look. And obviously you're paying money for the roof in the first place and then you're paying again to skin it off in order to achieve a certain look. So, for those people who want a traditional look but all the advantages and all the benefits of the system, there are cost implications."

Subjective norm

A number of key groups of persons were identified by respondents as normative influences on adoption of prefabrication as shown below in Table 4. The influence of the key groups of government departments and the finance industry are discussed in the following PBC section as they are not only normative influences but also potential controlling factors for the industry overall.

Table 4. *List of normative influences by frequency reported*

Normative influences	n
Trades and subcontractors	14
Consumers	11
Government and regulatory bodies	10
Finance industry / banks	9
Suppliers	7
Industry representative bodies	6
Architects and designers	4
Developers	3
Engineers	3

Trades and subcontractors

Traditional trade resistance to new methods of building, whether panellised construction methods or factory-built housing, was acknowledged by a majority of interviewees. This was not however seen as a persistent barrier once tradespeople had sufficient experience with the new methods. Entrenched views from industry stalwarts and a lack of experience outside of dominant forms of building (such as brick masonry builds in Western Australia) were noted. Only a minority of tradespeople were seen as willing to trade their stable, profitable work environments for new and potentially unproven methods. Significant effort on the part of the builder to encourage and incentivise the adaptation of tradespeoples' skillsets to new methods was noted. Any change of methods and systems was seen as introducing a degree of risk to be offset by hands-on investment in training and supervision.

"When you ask them to think outside the square and stop and put time and energy and effort into learning a new system. For every good one that's really interested, and really knows their stuff, and wants to get involved, and wants to know about the product and system, you'll get three or four that really don't give a toss. And you know, they just want to turn up. You've got to be over their shoulder all the time, and even then they're not really on with the program. And that can be very cost-demanding as well."

Conversely, incorporating panels alongside traditional build methods, or simply moving craft build processes inside a factory was not seen as a particularly strong barrier to overcome.

"There is still some traditional resistance against it but we use carpenter tradies. It still has the traditional nature of needing bracing and support etcetera. They accept it once they start

working on it."

The need to identify those that are interested in new methods of building was seen as a simple preference issue for one respondent.

> *"Well, it's been a mixed bag really. You'll come across some old school tradespeople that will find that they would like to work in that* [factory] *environment. Then you'll find others that would not like to turn up to the same place day in day out. It's like every job - it's horses for courses. Not everyone will enjoy that environment, but it does suit some people."*

Moving processes inside a factory setting was seen as offering a number of well-received benefits for sub-contractors and trades. These included providing consistent work and wages unaffected by weather or site conditions; certainty of build locations; and the removal of the need for fly-in-fly-out schedules for remote area builds.

Consumers

The lack of a strong demand and preference from the consumer market was noted by a majority of participants. Following from the quality and flexibility issues discussed in the previous section, the raised off-ground profile of many prefabricated designs was noted as being easily identifiable by consumers. There was a noted strong historical link between such transportable houses and their use as cheap, temporary accommodation for classrooms or more recently in mining camps (referred to in Australia as 'dongas' or 'humpies'). There was however a divide between rural and urban areas as to the degree of perceived acceptance of the transportable designs.

> *"The acceptance of our product in the rural areas, with the elevated floor, is an advantage. It is traditionally been the case with 'Queenslanders'*[1]*, built on stumps for however many hundred years. In terms of your traditional, metropolitan type housing, there would be some negative connotations to it being transportable, and that probably comes from the fact that a lot of manufacturers, ourselves included, are still building a lot of traditional, boxy manufactured house product."*

Strong consumer support for traditional brick masonry methods, in line with information promoted by industry bodies, was particularly raised by the Western Australia respondents. The potential for the dominance of brick to fade over time as new pressures into the market was however suggested.

> *"There is a big market evolving, and especially with the younger generation they are a bit more savvy to star ratings, to energy efficiency, to sustainability and they are looking for something other than the old double brick construction."*

This growing demand for different building methods was however rejected by another builder as nothing more than a fledgling niche market.

> *"Oh, not in the consumer market, it's got some traction in the professional market, but consumers hardly see it."*

Countering this however, one of the builders noted that consumers who had built multiple houses differentiated themselves from first home builders in their desire to seek out new and potentially improved building methods.

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[1] A 'Queenslander' is a typical form of house in the Australian state of Queensland, typified as a wooden house, raised on stumps with a verandah. See Craik (1990) for further descriptions of this house design.

"The first home builder is probably not aware of this – they're probably not going to care - they just want to get a house built. The second and third one, I think people start to become more aware."

Suppliers

While good business relationships with upstream material suppliers were generally noted, one panellised builder noted a lack of dedicated support leaving them as a '*lone-wolf*' to promote their own product. This may be representative of a still-developing relationship though, as noted by another participant:

"In the early stages it's hard to get anyone interested in dealing with you too much. But as the work picks up, you get a little more loyalty from them I suppose."

Factory-based builders were less dependent on particular suppliers, who reported being able to regularly compare prices and swap suppliers. Benefits such as the consistent ordering of particular products, a consistent delivery location and the presence of onsite staff to receive goods were reported as well-regarded by suppliers.

Industry representative bodies

The majority of interviewees were members of either the Housing Industry Association or Master Builders Association and had received support through these representative groups in their day-to-day operations. Specific support for prefabricated building methods from these representative groups was not commonly reported. Competing industry support groups representing traditionally dominant building methods have also historically led marketing campaigns which may require a gradual, generational change to oppose.

"The brick industry did the world's greatest sell about 30 or 40 years ago. If it's not brick, it doesn't exist. And that was true 40 years ago but things have changed in that time."

Architects and designers

Challenges were also identified in working with architects to produce prefabricated products which do not dictate a particular architectural style and are variable enough to meet consumer requests. A need was espoused for earlier collaboration between those designing houses and the builders which are limited practically by the materials they are working with. An example given by one participant regarded costly redrawing and redesigning of plans to remove small variations in sizings which did not match with the strict dimensional limits of modules. The required time and capital to invest in detailed architectural support to bridge the divide between technical issues and designs was not however always an option given the need to be cost competitive.

Developers

As smaller and niche builders, the majority of the interviewees had little interaction with the high-volume developer market and did not see it impacting on or interacting with their business in the short term. With the tight budget requirements of most development projects, where profit is spread over many individual builds, any new system would have to first prove itself to be cheaper than existing methods to drive uptake among developers.

"…no matter what negotiations you go into in this industry, people only care about one thing and that's the big number at the front of the contract. You're comparing a compounding, vaguely tangible benefit, versus a particular tangible cost. 'Why would I

give you the work when I can do the work myself?'"

Specific targeting of rural developments was however seen as a possibility if costs associated with transport of trades could be reduced. The high levels of risk associated with large development projects were overall seen as too risky for new, smaller innovators.

Engineers

Resistance to prefabrication was noted by one participant as being concentrated among the '*laggard*' onsite building contractors, with engineers and those involved in technical product development being more accepting of a process shift. Having said this, negative preconceptions and a need to convince engineers of the validity of new prefabricated methods was noted:

> *"And often, especially with engineers you have to go down the track of 'Okay, we'll do it your way.' And then come out to site and take a look at what we're doing, and then we can show you why we think it's going to be simpler and easier to do it the other way."*

Perceived Behavioural Control

The PBC component of the Theory of Planned Behaviour relates to whether adopting prefabrication is entirely up to the person, or whether there are outside influences which constrain their practical choices. As such, the following section particularly summarises major structural issues affecting builders' opportunities to adopt prefabrication. The tabulated behavioural control factors by frequency are presented in Table 5.

Table 5. *List of behavioural control factors by frequency reported*

Behavioural control factors	**n**
Competitive viability	12
Financing support	9
Government and regulatory support	8
Overall economic conditions	5
Energy efficiency requirements	4
Labour and skills availability	3
Climate change	2

Participants' responses for each factor are discussed in turn, with the exception of the combining of the two related factors of 'Energy efficiency requirements' and 'Climate change.'

Competitive viability

Market forces acting to support and guide prefabricated business decisions were frequently highlighted, as one participant bluntly noted:

> *"The concept of fair doesn't really enter my mind. It's free-market. You either work out how to do it better or you don't have a place in the marketplace."*

The inability for builders to reduce their costs was seen as a major barrier to shifting away from traditional processes. The relative isolation of Australian urban centres and subsequent lack of economies of scale to encourage a manufacturing approach to building were seen as a specific limiting factor to the theoretical advantages.

> *"There are structural cost advantages, where you can, if you can or when you can achieve the right levels of volume. … There are economies of scale that can be realised through automation."*

> *"Prefabrication hasn't reached the level of sophistication in Australia that I've seen in overseas programs – Germany – and I believe it's to do with economies of scale. We're so far flung that I can't build a factory that just makes prefabricated units."*

There was also an acknowledgement that competing on the basis of method of construction is not sufficient to attract buyers who may be more concerned with amenity issues.

> *"The priority for them is more about living space, and the lifestyle factors associated. Accessibility to infrastructure, walking. They are more interested in the space than the built product. They don't really have a great concern whether it's tile or steel roof. It's more about amenity."*

There was an acknowledged need for culturally-embedded perceptions surrounding prefabrication to shift to increase uptake. As raised in the previous section's discussion of normative influences, Western Australia has a uniquely high predominance of brick construction in housing. Timber and raised housing was seen as more favourably accepted in the eastern Australian states such as Queensland. Evolving and changing attitudes both among locals and immigrants to the area may serve to break this long-term trend and increase the competitive nature of the prefabricated industry. One interviewee optimistically pointed to an undercurrent of innovative changes yet to be fully realised.

> *"I think the general public side of things has started to happen. Slowly, over the years. Australia's a quite innovative place really. And as much as people say they don't like change, they do."*

Financing support

A majority of the interviewees specifically raised the lack of support from the financial sector for prefabricated businesses. Those building complete or modular products which are transported to site particularly highlighted challenges. Traditional financing where progress payments are made as various build milestones are reached onsite was reported as not being routinely available. This lead to businesses having to internally finance an entire project until the finished module or house can be delivered. Such measures were seen as prohibiting taking on large and potentially profitable contracts. Several of the builders pointed to a resistance among the financial sector to engage in collaboration or rearrangement of the long-established funding processes. Government intervention to encourage banks to change their processes was also not perceived as likely (one participant reflected: "*Why would they?*"). The strong position and profitability of the major lenders in the Australian traditional housing market was also seen as a major deterrent to expanding their interests.

> *"They already get too much work. And we all see the bottom lines of banks. We all see that they don't really need the money. And yet it's the chicken and the egg argument. The first one of these banks that actually looks and listens and puts into place* [processes for modular builders], *they will just take the whole market on and there will be a huge change. And they will gain a lot of business out of it, but at the moment it's in the 'we don't need it, we don't care basket.'"*

Government and regulatory support

A role for both high-level and local government changes to either regulations or through process changes was noted. Though government housing contracts were seen as a potential way to boost

business for early innovators, a number of the participants noted an inability to harness this potential. Issues raised included government contracts favouring companies that were able to comply with criteria based on traditional build methods, that had established relationships with government, and that had the immediate capacity to produce a large number of builds with low costs (e.g. high volume project builders). As for consumers, the initial cost was perceived as the driving factor behind many government decisions, with little consideration of long-term effects.

> *"People always make the decision on price. They might wish they made the other choice 5 years later, but it's too late, the choice job's gone."*

A number of other issues were raised regarding the differential treatment of certain factory-built, transportable housing products. Despite an acknowledged requirement for all offsite constructed products to be built to the National Construction Code standards if they are to be placed permanently on a site, the Queensland Building and Construction Commission (QBCC, formerly the Building Services Authority), has not historically offered home warranty insurance for such builds. With this now being addressed, this was seen as lifting a significant burden on these businesses and will bring a greater level of scrutiny to the workmanship of prefabricated builders.

> *"The Queensland Home Warranty Insurance system: that finally is actually being addressed. And that will also help our industry, because there are, like in many different industries, the backyarders and the shonkies that have done a bad job over the years and that will clean them up as well, so it's good for the whole industry."*

Improvements and streamlining of development processes was also seen as a potential advantage to the prefabricated industry. One interviewee who had invested substantially in establishing a factory and other infrastructure spoke of the impacts of cancelled or stalled projects on both their immediate business and contracted employees.

> *"It's a real trickle down. In all of those cases we had guys lined up to do work. Probably 20 to 30 guys that we had to turn around and say 'sorry guys I know you've been knocking back other jobs to keep yourself available but there's nothing to do.'"*

Another factory builder pointed to misconceptions with some Queensland regional councils that interpreted new transportable or modular homes as removable, temporary installations. Addressing this issue was noted as a slowly developing issue assisted by a developing relationship between the builder and councils. A Western Australian based modular builder noted a similar set of concerns:

> *"I think it's councils not so much moving with the times. Some councils will allow a development to build modular, and they will segment modular from traditional build. If you're still ticking the boxes that the traditional build is it shouldn't matter if it's come on the back of a truck in a week or if it's been built over a period of 9 months."*

Overall economic conditions

In light of the recent global financial crisis (GFC) and competitive Australian housing market respondents pointed to tightening of costs as being an advantage either through encouraging smaller, modular products or by forcing more efficient operations. One of the panellised builders conversely noted the challenges of introducing an innovative product in a slow market.

> *"…trying to promote a new wall system, in probably the most severely depressed housing market, they did say since the second world war, was quite a challenge. But bit by bit by bit we're getting repeated business and referral business. It* [GFC] *was a negative for us."*

While the GFC negatively impacted the overall housing and construction sector in Australia, another factory-based builder pointed to the negative interaction between the economic decline and an already difficult relationship with banks and other lenders. Likewise, those prefabricated house-building companies which were also reliant income from their expertise in the temporary or transportable housing market were suggested to have suffered in the recent decline in the output of the mineral resources sector. Three participants noted the international pressures on the housing market, noting that Australian-based companies may soon face increased pressure from imported, prefabricated products. There were two conflicting reports given concerning the competition that cheaper imports pose. While one panellised builder noted that local consumers were willing to pay more for a better finish, another drew attention to the increasing quality of import products. Each of these interviewees noted that trade agreements and the global market may result in high-quality, yet comparatively inexpensive goods being imported which may reduce the long-term profitability of local prefabricated products.

> *"It's the same with cars or anything else. There's no great moral issue there. That's just the global market place we've created for ourselves thinking that cheap imports was a long term benefit. Personally I don't think so."*

Energy efficiency requirements and climate change

Four of the builders drew attention to the potentially supportive effect of better assessing the environmental costs in both house building and operation. Each of these interviewees pointed to the relatively inefficient insulation performance of traditional build methods, as compared to the strong performance of their own prefabricated products, whether insulated panels or well-sealed transportable houses. Increased performance targets, such as a further increase from a 6 to 7 star energy requirement in the National Construction Code, were seen as drivers to making several prefabricated systems more cost competitive.

> *"I think if we are genuinely going to reduce, loosely termed, the carbon footprint, we are going to look at sustainability and reduce power bills. All around Australia, power bills are going nuts and I think they will just continue to do that. In my opinion we have to get up to seven stars, and seven stars has to be calculated correctly. So, if we got to seven stars, systems like this* [prefabricated buildings] *would dominate. Traditional, old fashioned, brick construction, to genuinely get to seven stars, would not be cost effective and would highlight the lack of sustainability."*

Aside from the potential supporting effect of stricter energy efficiency regulations, attention was also directed by two respondents to the role that increasingly more extreme weather and climate change may have in encouraging the uptake of prefabrication.

> *"There are things coming – this environmental stuff – if I'm right. I think I am and most of the scientists in the world think I am. … You know, we talk about insulation. We don't seal our houses in Australia because we have a mild, well a relatively mild climate. If we started to have to seal our houses, then of course brick houses just disappear in to the sunset."*

This was not only limited to consumer post-occupancy benefits, but also to the improvement of workers conditions if they can be brought into an undercover factory environment.

Labour and skills availability

The challenges of a reducing and ageing workforce and the pressure this will place on finding suitably qualified tradespeople was raised as a potential advantage for centralisation of tasks

through prefabricated factory work. This was highlighted as particularly pertinent to those outside of the largest urban centres.

> *"one of the problems that the building industry at large is going to have to face as the market increases is … a distinct shortage of tradespeople. Because the tradespeople that we have are ageing, and the tradespeople that we have are not in the rural or remote, or not even the regional areas. And it's much easier if you can get a lot more production on one site rather than wasting all the time and energy, and all the extra costs of running to and from different sites."*

The current lack of training specific to all types of prefabricated or innovative building was noted as a burden for small start-ups to fund and administer without high-level support from government departments or industry bodies. Supporting this training was seen as a method for securing the future of new building methods.

> *"If you can get an apprenticeship as a painter then you should be able to get an apprenticeship as a thermal panel carpenter. It's that specific. And I'd like to be able to work with someone to set that up. But it's the sort of thing you just can't constantly personally fund. When you're dealing with prototype products, you're educating trades, you're educating staff, and you're marketing it to a potential client base."*

Conclusions

The current paper provides in-depth information on the state of the Australian prefabricated housing industry sourced from interviews with small and medium innovative builders already using prefabrication. A theoretical structure based on the TPB and TAM models was used to direct the data collection. In line with the earlier stated aims, a large range of belief factors across the theoretical predictors of prefabrication uptake were identified and tabulated to give an indication of their relative importance. Key illustrative quotes were also presented to provide further meaning to this numerical data and highlight important nuances. Several key conclusions can be drawn regarding the current state of prefabrication in Australia and the challenges that must be met to improve uptake.

Current state of prefabrication

The current state of the prefabrication in Australian housing could be described as promising, but ultimately stagnant. The overall message to be taken from the discussion of the TAM/Attitudes variables is that a number of conflicting dichotomies need to be resolved to instil a widespread intention to adopt prefabrication. Each of these dichotomies is shown in Figure 2.

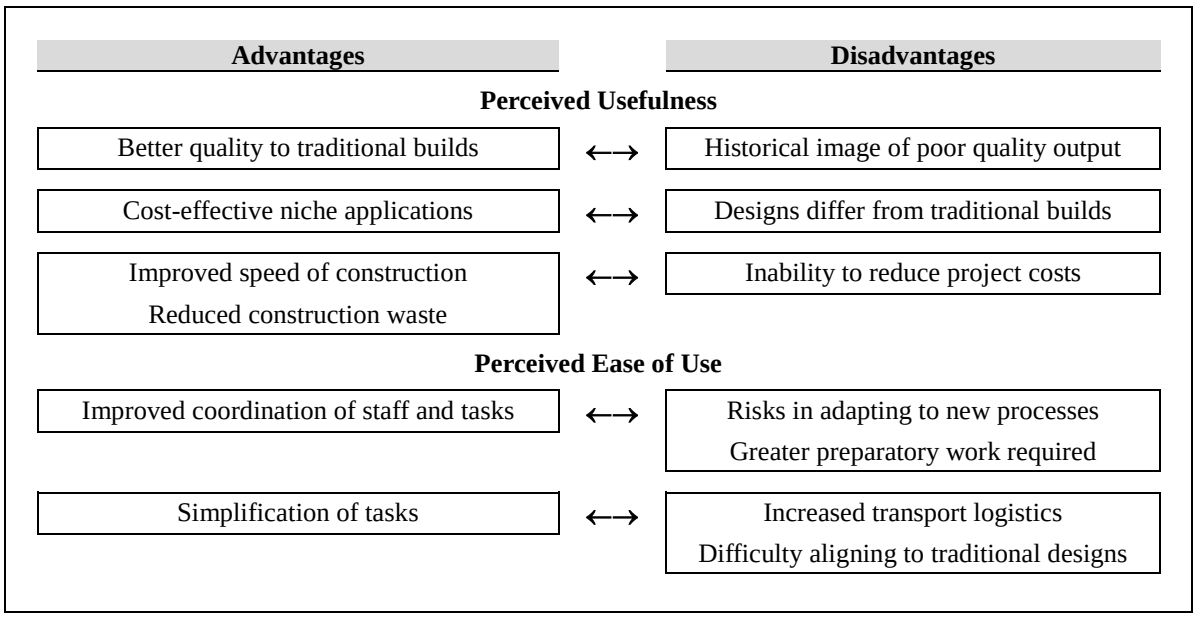

Figure 2. *List of TAM dichotomies influencing prefabrication uptake*

The interview data suggests that only isolated success has been achieved in shifting these dichotomies so that the advantages outweigh the disadvantages. While prefabrication has the potential to improve the quality of houses, this conflicts with a resonating historical image of poorer quality builds that has as yet not been challenged widely. The advantages of niche applications are inherently limited because the houses often don't follow traditional styles that are favoured in the current market. Improved construction speed alone cannot reduce per project costs and is reliant on a currently non-existent high demand to reduce costs overall. Reductions in construction waste are similarly not matched by significant cost savings. Advantages arising from improved coordination and simplification are eroded by costly upfront investments, shifting of complexities from building to transport, and efforts to maintain traditional design flexibility.

The remaining TAM factors from Table 3 not present in Figure 2's dichotomies are unlikely to be major 'game changers' affecting adoption. Improved energy efficiency or greater maintenance demands post-occupation may sway some consumers, but they provide little direct encouragement to builders to change their methods. Workplace safety is also already highly regulated in Australia and there are no strong threats to the onsite construction industry's credibility in managing such risks.

Further, there is also no strong normative influence from key persons or groups in support of Australian prefabrication. On the other hand, resistance to changing traditional methods, whether from tradespeople, finance institutions, consumers or government departments was frequently highlighted in the current study. The building industry and the consumer housing market in Australia are known for their conservatism in most matters (The C. I. E., 2013). While there are glimmers of hope in the applicability of prefabrication to rural areas and its alignment with greater environmental consciousness, explicit support for prefabrication has not yet reached a critical mass.

Australian contextual factors also continue to limit the potential of prefabrication. A population distribution not conducive to large-scale house production, a disinterested financing industry, and a lack of dedicated governmental support for prefabrication all contribute to a negative outlook. The

weak assessment of energy efficiency in housing was singled out as a particular example of regulation failing those producing high-performing prefabricated houses. Other factors which may promote prefabrication such as climate change and a shifting labour market are not currently having a profound effect. It appears likely that prefabrication will continue to be a fringe element of the Australian housing construction market until the above discussed challenges are resolved.

Meeting the challenge of improving prefabrication uptake

What then are the key areas which can be targeted to improve prefabrication uptake? Eight recommendations for action across the prefabricated housing innovation system are put forward. The respondents in the current study all reported that the houses they produce are of a better quality than what can be achieved with traditional build methods. If this is indeed the case, why then do negative perceptions and a lack of consumer demand persist? As Chandler (2014) recently stated at the prefabNZ 2014 Conference, most prefabrication innovations '*don't materially lower the end cost of projects and do not create a compelling case for [adoption]'* (p5). Inciting population-level behavioural change is difficult, and relies on there being an initial spark to encourage contemplation of change (Burnes, 2004; Prochaska & Diclemente, 1986). With estimates that less than 5% of the Australian construction market is prefabricated (Hampson & Brandon, 2004), it is unlikely that exposure to prefabricated housing is common among consumers. The consumer market, largely uninterested in the technicalities of building, needs to be further convinced of the advantages of prefabrication. Further research to inform targeted marketing is required into how prefabrication meets consumer demands for flexibility and alignment with traditional build requests. This future research should additionally take into account consumers' state of residence, rurality and whether their purchase is a first or subsequent home.

> **Recommendation 1:** Successful Australian prefabricated housing projects must be promoted heavily, and wherever possible prioritise the highlighting of advantages for consumers rather than builders.

> **Recommendation 2:** A mapping of how prefabrication can meet consumer demands should be completed, taking into account varying contextual influences.

It may be ambitious to believe that there is space for many small, successful prefabrication operators. The early innovators in the current study are mostly smaller operators '*low in the food chain'* of housing businesses. As such, they do not have the resources to play a lead role in driving change in the housing market (Chandler, 2014). Those businesses serving low demand niche markets with higher margins are likely to remain viable, but will continue to operate on the fringes of the mainstream housing construction sector. Harnessing the economies of scale that prefabricated housing promises may only be possible if sufficiently large, well-funded, well connected, factory-based operations establish themselves in Australia's heavily populated urban centres. Size and turnover of a business should not however be the sole determining factor in assessing their potential efficiency. Smaller prefabrication providers that can demonstrate substantial innovation and improved construction outcomes should not be discouraged or disadvantaged. While the decision to invest in such operations would be at the behest of company owners, efforts should be directed at incentivising this change.

> **Recommendation 3:** Future policy directives should incentivise the establishment of factory based prefabrication operations in Australia's urban centres that can demonstrate improved efficiencies and economies of scale.

Driving down the costs of prefabrication is likely to both attract a consumer base and influence businesses to shift from traditional onsite processes. Accurately assessing the cost impacts of changing to prefabrication is complicated by the need to consider factors as diverse as materials, labour, certainty of timelines and delays (Blismas, 2007; Gibb, 2001; Miller, Buys, & Bell, 2012). Better advice regarding the realities of prefabricated cost savings must be made available to guide housing construction companies' decision making.

> **Recommendation 4:** Better cost assessment data for prefabricated housing must be collected against a variety of measures and contexts.

Effort should also be expanded to breaking down the barriers in transport industries which compromise the delivery of bulky, prefabricated units. Legal size restrictions on the transport of oversize items are common and are likely to be maintained for the foreseeable future (Main Roads Western Australia, 2013; Queensland Department of Transport and Main Roads, 2012). The focus should therefore be on solutions given the legal constraints. The implications of these restrictions to those businesses delivering pods, modules or complete houses to a building site are far-reaching, such as the limits they impose on housing designs.

> **Recommendation 5:** Further consideration should be given to how the transport industry can interface with builders using volumetric prefabrication innovations.

Supplanting the traditional housing industry mindset with one more supportive of prefabrication should be a key focus for government intervention. This conservatism spreads across multiple segments of the industry, though it is particularly prevalent among the traditional trades and subcontractors. Drawing on knowledge outside of the traditional onsite construction sector, as has been done with other major innovations in modern construction such as lean production (Womack, Jones, & Roos, 2007) and Building Information Modelling (Eastman, Teicholz, Sacks, & Liston, 2011), may be one part of the solution. Toyota, as the last remaining Australian-based manufacturer of motor vehicles, has announced it will join Holden and Ford in ceasing local operations by 2017. This skilled population of soon to be unemployed car manufacturers may be readily adapted to working on prefabricated housing with minimal re-training (Green & Newman, 2014), and may not harbour the same level of resistance as traditional builders. Similarly, the use of more efficient panellised building products that can be incorporated into traditional offsite building may be better received than a shift to factory-based operations.

> **Recommendation 6:** Strategies should be put in place to harness displaced manufacturing staff to grow the prefabricated housing industry.
>
> **Recommendation 7:** Onsite, panellised building methods should be promoted wherever possible to those builders wishing to maintain onsite processes.

The conservatism in the financing of prefabricated housing in Australia has not been sufficiently addressed in Australian research (Blismas & Wakefield, 2009; Boyd, Khalfan, & Maqsood, 2012). The Australian banking sector is very powerful, and would only be responsive to a strong financial argument for financing prefabrication. Both federal and state governments are also strongly driven by budget considerations and the need to keep costs low when awarding contracts. Ultimately, a convincing business case must be developed setting out the likelihood of success in the prefabrication industry both now and in the future. Such a case should include a thorough statement of the current prefabrication industry; an outlining of future opportunities; assessment of risks, benefits and key stakeholders as outlined in the current paper; proposed timelines for returning a profit on investment; and an outlining of the risks of maintaining traditional construction methods

(see Hastings (2010) for a complete description of potential business case inclusions).

> **Recommendation 8:** A detailed business case should be completed for prefabricated housing in Australia, with a view to taking this case to finance and government departments.

Future considerations

The TPB/TAM model employed in the current study covered a range of influences from immediate technical advantages and disadvantages, to the influence of ‘important others’, to contextual factors limiting possible courses of action. The breadth of the theory is both a weakness and a strength. It allows identification of a wide range of important influences but these may not necessarily form a coherent model without further quantification and testing. The generalizability of results is known to be improved by the use of multiple forms of data collection (Hesse-Biber, 2010; Jick, 1979). As such, the results of the interviews reported here serve as a starting point for the next stage of wider and more structured survey research currently being undertaken by the authors. This survey will quantitatively assess the opinions of all types of housing builders in the Australian states of Queensland and Western Australia. The proposed relationship between the predictors identified in this study and intentions to adopt prefabricated housing innovations will be statistically modelled and compared.

The use of a predetermined and well-established behavioural model allows further research to build and refine the current work, with a shared understanding of common input variables. The identified advantages and disadvantages aligned well with the Perceived Usefulness and Perceived Ease of Use groupings proposed by the Technology Acceptance Model as precursor predictors of builders’ attitudes. A range of normative and control influences were also readily identified be participants, supporting the usefulness of the overall Theory of Planned Behaviour model. Future research should continue to refine the theoretical basis to better explain the underlying factors influencing prefabrication uptake.

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