



## Adoption of prefabricated housing—the role of country context



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### ABSTRACT

This exploratory paper examines secondary sources to develop hypotheses for future testing in quantitative research, around the question ‘How do housing industry contexts in different countries influence the adoption of prefabricated housing construction?’ This is a management study of innovation adoption. Prefabricated housing has been routinely promoted as a means to improve the efficiency, quality and environmental performance of house construction, use and demolition. The uptake of prefabrication internationally has not however been consistent, with a clear division between leading and laggard countries. The role of the national housing industry in developing and maintaining a jurisdiction’s prefabrication industry has not been previously explored comprehensively. This gap in knowledge is addressed in the current paper. A focus is given to collecting verifiable data to expose the differences between jurisdictions with both high and low levels of prefabrication adoption. Adoption is measured using data on prefabrication use. Based on content analysis, the main determinants of adoption are revealed to be (1) annual number of housing completions, (2) rates of new building versus renovation, (3) new housing ownership models, and (4) types of housing constructed. Analyses revealed the complexity of interacting factors and their potential influences on the uptake of prefabricated housing. The academic contribution of the paper is in providing a robust basis for more refined investigations of this emerging topic. The practical value of the paper is in providing guidance for policy makers to help them improve adoption of prefabrication, through demonstration projects for example. A limitation of this paper is that the data available is insufficient to facilitate more comprehensive analysis. Future quantitative, theory-driven research is needed to formalise the hypothesised relationships and conduct thorough statistical testing.

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### 1. Introduction

Prefabricated housing involves the manufacturing and assembly of components offsite, before their final installation at a chosen location (Goodier & Gibb, 2007). While traditional onsite construction routinely employs some manufactured products such as plasterboard sheets or finished doors, the term ‘prefabrication’ is generally reserved for more comprehensive products, comprising manufacture of structural volumetric spaces (e.g., enclosed modules or whole houses); non-structural volumetric spaces (e.g., bathroom pods); and significant assemblies that do not alone define space (e.g., wall panels). Various overlapping terms have been used to describe prefabrication. For example, ‘modular housing’ has typically been synonymous with

volumetric construction, while more inclusive terms such as ‘industrialised building systems’ and ‘modern methods of construction’ have included volumetric and non-volumetric prefabrication, along with advanced onsite construction methodologies like tunnel-form construction. This paper specifically focuses on the use of volumetric and non-volumetric/panellised prefabrication, in line with the particular advantages they offer over traditional construction (Walker, Harley, & Mills, 2015).

Prefabrication represents a new way of doing business. In this sense, the paper is about innovation. The OECD provides the most authoritative overview of innovation activity in the world. Their most recent manual defines innovation as implementation of a new or significantly improved product or process, including changes to marketing and organisational methods (2005). Prefabrication results in a superior housing product through the implementation of new processes. Prefabrication would also be considered a ‘radical’ innovation according to the seminal Schumpeterian definition (Schumpeter, 1934), as it causes a major disruptive change to the operation of supply chains, with the move from on-site to

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off-site production. The paper is concerned with the adoption of this innovation (Rogers, 1962) and its diffusion throughout the housing industry, given its benefits.

Prefabrication has been promoted in recent academic and industry literature as a means to improve the efficiency, quality and environmental performance of house construction, use and demolition (Eastman & Sacks, 2008; Elnaas, Ashton, & Gidado, 2009; Goodier & Pan, 2010; McIntosh & Guthrie, 2008; Monahan & Powell, 2011; Pan & Goodier, 2011). For example, research from Hong Kong shows a 52% reduction in waste generation across all building types with the application of prefabrication (Jaillon, Poon, & Chiang, 2009). The factory-precision of prefabricated housing panels has also been associated with superior insulation performance (Pan, 2010), reducing household energy demands and improving occupant comfort. Prefabrication aligns with several strategies for the creation of a sustainable urban environment including improved waste management, minimisation of onsite work and community disturbances, and simplified reuse and recycling of products at the end of a building's lifecycle (Sev, 2009). Despite strong calls for change in construction methods, backed by growing evidence of sustainability improvements, prefabrication uptake has lagged in many jurisdictions.

## 2. Approach to international comparison

There are limitations to definitively cataloguing how national industries develop and operate on the basis of a small, interpretable set of factors. The end goal of this management study of radical innovation adoption is thus not to describe an 'ideal' system of determinants through highly structured theory, but rather to establish a broad framework to identify national differences and generate hypotheses for future validation (Edquist, 2005). This exposing of the 'national peculiarities' (Ive, 1990) of a construction industry allows for the particular outcome of prefabrication uptake to be separated from the unique circumstances in which it arose and continues to exist (Lundvall, 2010).

There is a risk of invoking the 'ecological fallacy,' or inferring reasons for individual business decisions through aggregate data. Nevertheless, the approach taken provides a valuable starting point for further discussion (Phua, 2004). This is particularly relevant to the context of prefabrication uptake, where even national data to initiate debate is not always readily available (Blismas & Wakefield, 2009; Taylor, 2010). National administrative datasets on construction industries have known issues of inconsistent reporting and categorisation. International comparisons completed with a frank acknowledgement of these limitations however remain valuable to understanding the housing construction industry (Ruddock, 2002). The quality of any jurisdiction's data as measured by its coverage (completeness of topics covered), reliability (stability over time and consistency with other measures), and accuracy (a true representation of factual occurrences) will all affect the ability to make meaningful comparisons (Yitmen, Akiner, & Marar, 2012).

This paper presents compiled data on the varying uptake of prefabricated housing across selected international jurisdictions. A core set of quantitative data was collected at the housing industry level for each jurisdiction, to examine possible determinants of prefabricated housing uptake. Consistent trends and lessons for emerging markets were identified to address the research question: 'How do housing industry contexts in selected countries influence the adoption of prefabricated housing construction?' The following broad strategy for addressing the research question is utilised:

(1) collect data about prefabricated housing and broader housing trends;

- (2) compare this data between jurisdictions with varying uptake, and
- (3) critically assess the findings through content analysis, to identify drivers of uptake.

## 3. Scope and methodology

This section presents a rationale for the scoping of this investigation, the types of data collected, and the methodology for their analysis.

### 3.1. Selected jurisdictions

The jurisdictions profiled as part of this study were chosen specifically to encompass those that have an acknowledged high application of prefabricated housing such as Japan and Sweden (Barlow et al., 2003), those that have been identified as having both relatively high levels of prefabrication and highly efficient traditional or 'craft based' house-building industries such as Germany and the Netherlands (Clarke & Wall, 2000) and major economies that have an infrequent application of prefabricated housing such as the United States, United Kingdom, and Australia. This range of countries allows identification of both how successful prefabrication industries have arisen, as well as highlighting the circumstances which may have limited reform (Fernie, Leiringer, & Thorpe, 2006). The appropriateness of comparing these countries was reinforced by each being a developed nation, with a strong economy, and membership of the Organisation for Economic Cooperation and Development (OECD, 2013).

### 3.2. Data sources and methodology

This paper focuses on accessible, empirical, and referenced evidence from housing industries. This drastically limits the range of potential determinants that can be examined. There are other important determinants which are not covered as they fall outside this clearly defined scope, such as policy directions, approval processes, financing arrangements, purchase intentions, and workforce skills (Daly, 2009). Regardless, the housing industry context in each country provides important pre-conditions for demand, and these are yet to be comprehensively investigated in the literature.

The available robust evidence related to country context was subjected to content analysis (Krippendorff, 2004) and thematic codes were extracted independently by the two authors and then cross-referenced to result in the validated country-context prefabrication determinants shown in Table 1. At this point in the exploratory research, the search for coding categories was driven by empirics, rather than a particular theory, as the current investigation seeks only to identify key determinants, while future theory-driven research will explore the strength and mediators of proposed relationships.

This selection of determinants follows Pries and Janszen, 1995 broad conceptualisation of changes in the building industry being driven by a combination of market demand, product and process influences. They draw particular attention to the dual role of consumers and government building programs encouraging new works, and how a focus on narrow building types can entrench traditional processes. Stanilov's (2007) review of post-socialist housing development similarly took into account total housing output, how the mix of private and public housing affected attitudes, the relative success of multi-residential versus detached building, and the benefits and disadvantages of renovation of existing stock versus new construction. These previous reports provide a general justification for the importance of this set of variables for understanding prefabrication adoption internationally.

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