Final Report

Peer Reviewed

Australian suburban house building: industry organisation, practices and constraints

authored by

Tony Dalton, Joe Hurley, Ehsan Gharaie, Ron Wakefield and Ralph Horne

for the

Australian Housing and Urban Research Institute

RMIT Research Centre

October 2013

AHURI Final Report No. 213

ISSN: 1834-7223

ISBN: 978-1-922075-41-3

AHURI

Australian Housing and Urban Research Institute

Authors	Dalton, Tony	RMIT University
	Hurley, Joe	RMIT University
	Gharaie, Ehsan	RMIT University
	Wakefield, Ron	RMIT University
	Horne, Ralph	RMIT University
Title	Australian suburban house building: industry organisation, practices and constraints	
ISBN	978-1-922075-41-3	
Format	PDF	
Key words	housing, building, suburban, construction, industry	
Editor	Anne Badenhorst	AHURI National Office
Publisher	Australian Housing and Urban Research Institute Melbourne, Australia	
Series	AHURI Final Report; no. 213	
ISSN	1834-7223	
Preferred citation	Dalton, T., Hurley, J., Gharaie, E., Wakefield, R. and Horne, R. (2013) *Australian suburban house building: industry organisation, practices and constraints*, AHURI Final Report No.213. Melbourne: Australian Housing and Urban Research Institute.	

ACKNOWLEDGEMENTS

This material was produced with funding from the Australian Government and the Australian state and territory governments. AHURI Limited gratefully acknowledges the financial and other support it has received from these governments, without which this work would not have been possible.

AHURI comprises a network of universities clustered into Research Centres across Australia. Research Centre contributions, both financial and in-kind, have made the completion of this report possible.

AHURI FINAL REPORT SERIES

AHURI Final Reports is a refereed series presenting the results of original research to a diverse readership of policy-makers, researchers and practitioners.

PEER REVIEW STATEMENT

An objective assessment of all reports published in the AHURI Final Report Series by carefully selected experts in the field ensures that material of the highest quality is published. The AHURI Final Report Series employs a double-blind peer review of the full Final Report where anonymity is strictly observed between authors and referees.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ABS	Australian Bureau of Statistics
AHURI	Australian Housing and Urban Research Institute Limited
BAPs	Building Approvals
BDAA	Building Designers Association of Australia
BPIC	Building Products Innovation Council
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industry Research Organisation
FaCSIA	Australian Government Department of Families, Community Services and Indigenous Affairs
FTMA	Frame and Truss Manufacturers Association
HCSM	Housing Construction Simulation Model
HIA	Housing Industry Association
ICT	Information and communication technologies
NRAS	National Rental Affordability Scheme
OECD	Organisation of Economic Cooperation and Development
SME	Small to medium sized enterprise

EXECUTIVE SUMMARY

This report presents the outcomes of a research project conducted by the Australian Housing and Urban Research Institute (AHURI) RMIT Research Centre on the way a significant proportion of new suburban detached housing is built in Australia. The report examines the 'volume building' housing industry that supplies detached housing, the dominant form of contemporary new housing.

The aim of this project was to critically review the scant literature on the volume housing construction industry in Australia and to undertake qualitative research and modelling to explore issues of innovation and practice. The research explored the characteristics of this industry, including the context within which average construction times for new housing have lengthened over the previous decade.

There is limited research on volume housing construction in Australia, and this report provides a much needed insight into the industry and the difficulties it faces in delivering housing through economic cycles of fluctuating demand. It provides the basis for ongoing research in a context where questions of industry responsiveness, housing affordability and prospects for industry innovation are pressing.

Interim findings were presented in the Positioning Paper *Australian suburban house building: industry organisation, practices and constraints* (Dalton et al. 2011b). The paper outlined the way that house building was organised and presented an analysis of the industry within which there are increasing construction times. It described the organisation of house building based on three types of contracts: supply contracting; supply and install contracting; and labour subcontracting. Each house is built through the careful sequencing of contractors and subcontractors who provide products and services. Three features of the industry were identified that are associated with increasing construction times: changes in dwelling design and the increase in diversity of design options; the capacity and performance of supervisors as organisers; and problems with the quality of on-site work.

This report extends the analysis of suburban house building presented in the Positioning Paper by examining house building as a production process consisting of sequenced activities. Supervisors, the front line of volume house building companies, organise multiple, sequenced discrete activities for multiple houses at the same time to deliver housing. All supervisors draw on the same pool of subcontractors, contractors and supply and install contractors, hence the need to transcend house-by-house analysis and see house building as a production process.

Research questions

Based upon institutional analysis, the research explores patterns and practices of suburban house building by identifying the norms and routines of those who make up the volume detached housing construction industry. This is the context for posing the following principal research question:

> How is the work of new suburban house building organised and what practices and constraints may contribute to delays in building completion times?

Four secondary research questions guided the research program that responded to the principal research question.

- What are the trends in the time taken to build new housing, measured through commencements and completions?
- How do builders typically organise work on new housing projects from commencement to completion through a system of contracts?

- What are the main issues identified by industry participants managing new house building that may relate to and assist in explaining lengthening construction times?
- In what ways might house building arrangements and practices be changed so as to reduce building completion times?

The following research methods were used to respond to the research questions: secondary data analysis; literature review; semi-structured interviewing; focus group discussion; and simulation modelling.

The secondary data used in this report is drawn primarily from the ABS and HIA industry data. The literature review for this research was constrained because there is little earlier research on Australian suburban house building. The literature examined in this report was used to understand innovation and the limits to innovation in suburban house building. It was also used to establish a framework for understanding suburban house building as a production process. And, as a response to the lack of research in this area, this research used interviews with industry participants to develop a detailed understanding of the house building industry. This interviewing comprised of 25 semi-structured interviews and informed the analysis presented in the Positioning Paper and this Final Report. A focus group comprised of senior industry participants supplemented the interview. The simulation modelling was designed to simulate aspects of the volume housing production system in order to further examine issues of production management and the effects of resource constraints raised in the literature and the interviews.

Key findings

Chapter 2 presents an analysis of innovation in the volume building housing industry and considers the limits of innovation. A distinctive characteristic of the industry framing the consideration of innovation is that it is subject to cycles of high and relatively low demand. This pattern is likely to be a factor in shaping the dominant form of the industry today. The prevalence and proliferation of specialisation evident in contracts and scheduling is both a scene of innovation, and an obdurate and enduring mode of organisation. It is notable that innovation is evident in both marketing, leading to a diversification of offerings, and in subcontracting itself, leading to growth in the number of contracts for each dwelling. This results in increasing complexity on one hand, and increasing entrenchment of the subcontract mode of production on the other.

In Chapter 3 we explore subcontracting and specifically the process of scheduling of materials and labour. The research is focused on two contrasting volume housing construction firms, each using a variant of a system of construction management scheduling. Company A and B exhibit distinct differences in the nature and use of their systems. Company A schedules are used largely as guides and checklists by supervisors, whereas in Company B the schedules have been tailored to more accurately reflect what is being built and are used to record work done. The analysis describes the scheduling system of each company; the way that supervisors and construction managers use their system; and the utility of the data that is produced by their system. The two companies represent significant difference in the practice of scheduling, with company B using a more sophisticated approach that provides more dynamic feedback to system users. However, we find in both cases scheduling practices are limited in terms of revising building schedules in response to changes in project delivery. As such, questions remain regarding the costs and benefits of each system to the companies, purchasers, and overall efficiency.

In Chapter 4, we extend the scheduling inquiry by developing a Housing Construction Simulation Model (HCSM) to explore the effects of time delays on parts of the process due to material or labour delays. Through this study, the inter-relatedness of activities for a portfolio of houses being produced at the same time becomes clear. For example, it enables an assessment to be made of the logical consequences for the broader production process if the completion of the plumbing 'rough-in' is delayed in one or a few houses. It can also assist in investigating the effects of bad weather on the timely completion of houses and the effects of increasing the size of the portfolio of houses under construction at any one time. It therefore assists in understanding how a delay in one or a few activities is transmitted through the production process by many interdependencies. We find that, in periods of relatively high demand, the system is likely to be unable to cope and will produce significant and extensive delays in completion times across the industry.

Policy implications

The analysis presented in the previous three chapters is brought together in Chapter 5 and possible policy implications considered. Policy discussion in this area has been limited and often assumes that the sub-contract system is dysfunctional and that movement towards off-site manufacturing is both desirable and inevitable. However, there has been little movement towards off-site manufacturing in the industry. The analysis presented in this research of the Australian suburban house building industry suggests that this is not likely in the near future either. There is a long history of discussion about the industrialisation of suburban housing production and some experimentation with off-site factor production, but there is no real prospect of systematic movement from on-site to off-site production.

Instead, it is suggested that analysis of suburban volume house building should be extended in two ways. First, consideration could be given to a program of research undertaken with companies on their construction processes in ways that stimulates debate about best practice housing production. Second, there is a need to review programs that are designed to stimulate demand for new housing (including 'affordable' housing) and consider how they might also encourage product, process and organisational innovation leading to reduced completion times.

Finally, it is important to note long-term trends that suggest that volume housing is a declining proportion of housing industry output. This observation about the changing mix in residential house types suggests that it is important to relate the production of houses to the broader housing industry. Housing policy formation in Australia is not informed by a deep understanding of housing production and supply. In this context, if housing policy-makers are to gain a deeper understanding of the way housing is produced, there is a case for further applied research into the production of all forms of housing. This could lead to the development of a 'housing industry policy' endorsed by industry and government about goals for the industry based on a better knowledge of the residential development industry.

1 INTRODUCTION

This project presents research on the way that suburban detached housing is built. This built form continues overwhelmingly to be the dominant housing type produced by the housing industry in Australia. It is housing largely located on newly subdivided land on the fringe of cities on what are often described as master planned estates. These are the areas in which some house building companies increased the scale of their operations during the 1990s and became what are now commonly referred to as 'volume builders' (Dowling 2005). Alongside the volume builders there are many more builders who build a smaller number of houses each year. The Australian housing industry is overwhelmingly a small business industry (Dalton et al. 2011a, ch 3). This is the context within which new problems in new housing supply have emerged and are attracting policy attention.

This chapter proceeds by:

- Identifying the two issues that stimulated this research.
- Stating the research questions that have guided the research.
- Describing the methods used to undertake the research.
- Summarising the initial research presented in the Positioning Paper.
- Outlining the structure of the Final Report in the following three chapters.

1.1 The issues

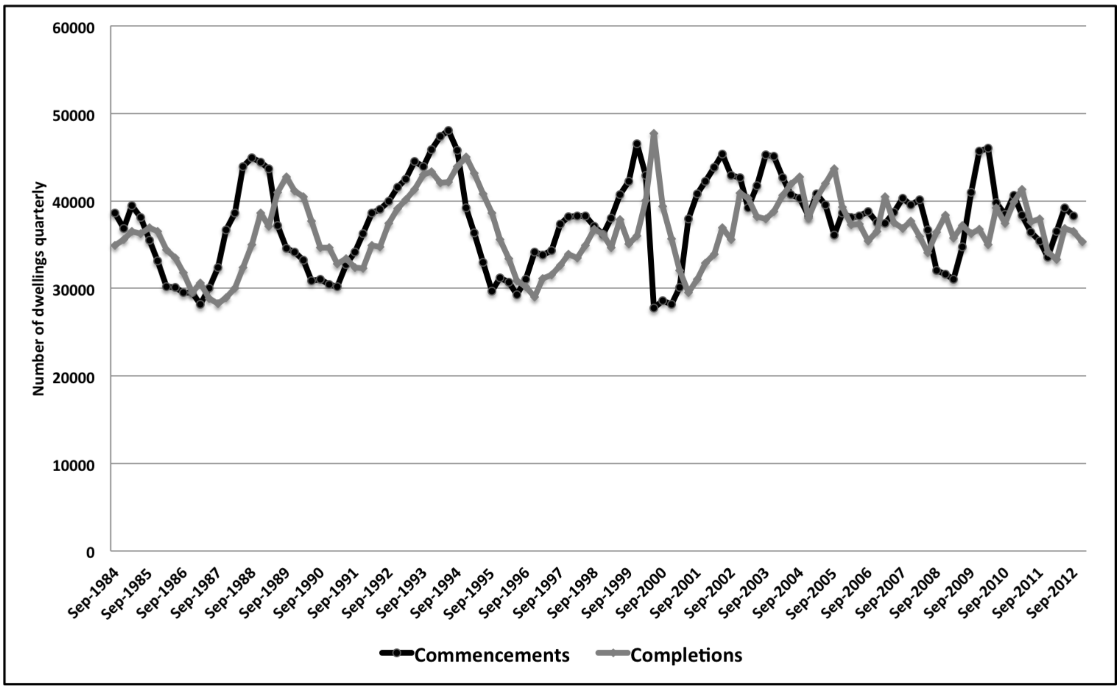
Two policy problems provide a focus for this research. The first is the continuing undersupply of new residential dwellings. This is a well-recognised issue and well-documented by the National Housing Supply Council. The second is that the average time taken to build new houses has been increasing for more than a decade. This is significant because houses continue to form the largest proportion of total new residential dwelling supply. This lengthening time is a less recognised issue and forms the principal focus of the research presented in the Positioning Paper and this Final Report. This section further outlines these two issues.

1.1.1 The undersupply issue

The long-term trend data for the production of new dwelling supply is presented using a moving quarterly average for both commencements and completions in Figure 1. Broadly these data indicate that the production of new dwellings has remained steady over the past three decades.

This history of supply is viewed as a problem. When it is matched to demand estimates, based on demographic modelling, this broadly constant level of new supply is evidence of growing undersupply (National Housing Supply Council 2009, 2010, 2012). In the most recent report, the National Housing Supply Council (2012, p.23) estimated that 'underlying demand growth outstripped adjusted net supply by 28 000 over the year, taking the cumulative gap to 228 000 dwellings'. Further, the Council of Australian Governments (COAG) (2009) has confirmed that this undersupply is a policy issue for federal and state governments.

Figure 1: Dwelling unit commencements and completions, moving quarterly average 1984–2012



Source: Australian Bureau of Statistics 2013a, 2013b

The main response to the undersupply issue has been to focus on the impediments to the land development industry and the housing industry and how they might be removed. For example, COAG (Housing Supply and Affordability Reform Working Party 2012, p.2) focused on what are broadly described as 'supply-side impediments'. They included 'land supply, infrastructure cost recovery, and land use planning and approval processes'. The recommendations of this COAG report focused on 'regulatory impediments that may prevent land from being allocated to its highest value use'; 'regulatory arrangements that determine the allocation of land for development purposes'; 'charges imposed on developers and homeowners'; and 'government housing programs'. These factors are undoubtedly important. This COAG report and other research (e.g. Goodman et al. 2009; Urban Development Institute of Australia 2012; and URBIS 2009) identify factors restricting the supply of land and, through these restrictions, constraints on housing construction starts. Further, research by Coiacetto (2006, p.438) suggests that concentration of the land development industry might also 'pose obstacles to achieving sustainable development'.

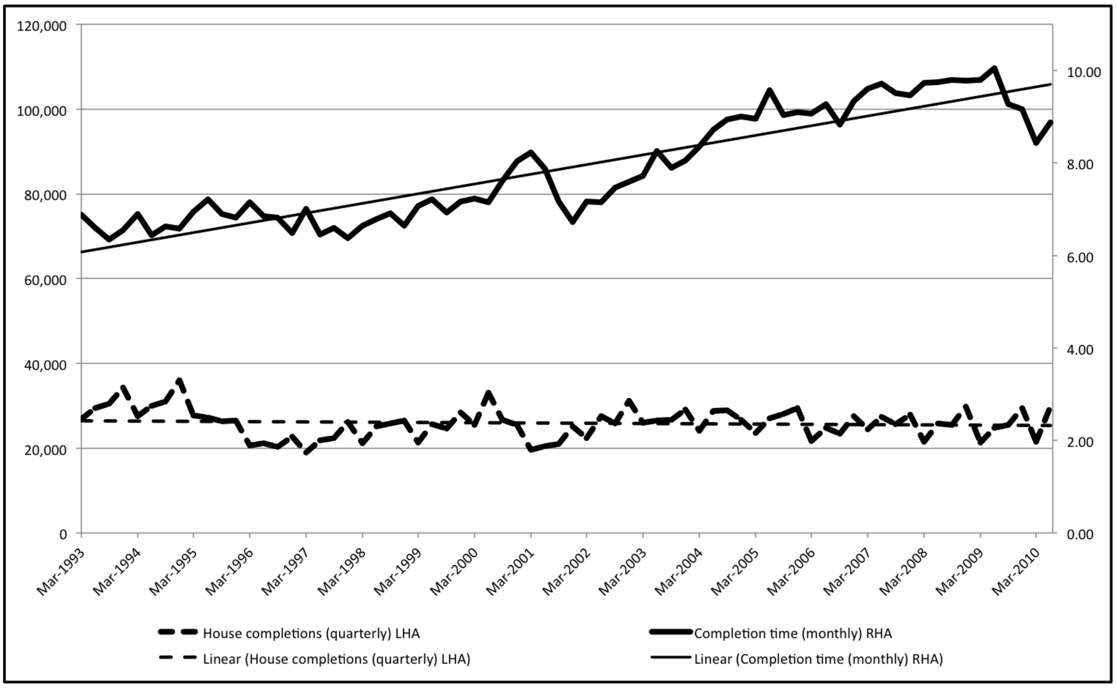
1.1.2 Housing production time taken

This research takes a different approach by focusing specifically on the construction of housing after commencement up until completion. It puts to one side all the issues about land use planning, the adequacy or otherwise of land developer charges and government demand side programs. Instead this research focuses on housing construction as a production process and analyses the arrangements used to construct housing and how these arrangements might contribute to undersupply. It does this because there is *prima facie* evidence that the time taken to construct detached houses has increased (Australian Bureau of Statistics 2008a; Gharaie 2011). The simple proposition underscoring this research is that if the time taken to construct houses, which continue to constitute more than 60 per cent of new dwellings, has increased, then this increase contributes to undersupply.

Figure 2 below presents trend data for the number of house completions and the monthly average taken to complete them. This figure shows that during the period 1993–2010 there has been a marginal decline in quarterly completions of houses from approximately 27 000 to 25 000. During this same period, the average completion time has increased from approximately six to ten months. One factor that helps to explain this increase in time is the increase in house size. However, as Gharaie et al. (2010) show, this increase in time cannot be fully explained by increasing house size. The increase in average house size plateaued out in the early 2000s, yet the time taken from start to completion continued to increase.

Further, as shown in Figure 2, although fluctuations in completion time and completions appear to be synchronised, completion times steadily increased from approximately 4.5 to 7.5 months in the period 1993–2010. In other words, it is only possible to explain short term increases in completion times by referring to labour shortages associated with increased house building activity. There is, therefore, a case for going beyond a focus on point-in-time industry conditions and builder experience in recruiting sub-contractors, and examining more closely the arrangements used to build detached suburban houses.

Figure 2: House completion numbers and time taken 1993–2010



Source: Australian Bureau of Statistics 2010b, 2013b

This growth in build times raises an issue about how this has been reflected in the economics of house building. At the level of formal contracts this has been reflected in an increase in the standard contract time. A senior manager in a volume building company noted that the standard contract time for single-storey houses had increased:

> … from back in the '80s of building single stories … you know it would have pushed out probably two months I'd imagine in contract times for those days.

However, the limited evidence that compares the cost of Australian suburban house construction with other comparable countries suggests that this lengthening construction time is not radically affecting the comparative cost of construction in Australia. The first reported comparison was undertaken in the 1970s by Blakey

(1977) from CSIRO who examined labour productivity. More recently, the international quantity surveying company, Turner and Townsend (2012), compared cost data for various types of buildings including medium standard house construction. A summary of both comparisons is presented in Appendix 2. In summary, they both indicated that in housing construction cost terms Australia is middle ranking.

1.2 Research questions

The research approach adopted for this project can be broadly described as institutional analysis. This type of analysis is one that focuses on the relationships and ways of producing goods and services. We seek to identify and analyse what we describe as the customary ways in which suburban houses are built by identifying the norms and routines of the various actors who do the building work. This is the context for posing the following principal research question:

> How is the work of new suburban house building organised and what practices and constraints may contribute to delays in building completion times?

Four secondary research questions guided the research program that responded to the principal research question.

- → What are the trends in the time taken to build new housing, measured through commencements and completions?
- → How do builders typically organise work on new housing projects from commencement to completion through a system of contracts?
- → What are the main issues identified by industry participants managing new house building that may relate to and assist in explaining lengthening construction times?
- → In what ways might house building arrangements and practices be changed so as to reduce building completion times?

1.3 Undertaking the research

The research for this project was undertaken using secondary data analysis, literature review, semi-structured interviewing, focus group discussion and modelling. Research ethics approval was obtained from the RMIT Research Ethics Committee prior to any interviewing or the conduct of the focus group. All interviewees and focus group participants were given a plain language statement and signed a consent form. This consent permitted the research team to record interviews and use the transcripts in a way that maintained research participant confidentiality.

1.3.1 Secondary data

Secondary data used in this report is drawn primarily from the ABS and the HIA. The ABS data on house building is generated through two collection processes. The monthly Building Approvals (BAPS) collects data relating to residential and non-residential building work above value limits that have been approved within the reference month. The Building Activity Survey collects data relating to all stages (commenced, under construction, completed) of residential and non-residential building activity undertaken in the reference quarter. The HIA data used is from the Housing 100 series. It presents data on the largest 100 housing construction companies and their annual production of all types of dwellings.

1.3.2 Literature review

The initial literature review for this research was necessarily constrained because there is little extant research focusing on suburban house building. This lacuna became evident during the preparation of the Positioning Paper that typically reviews the academic and policy literature. Because of this absence, earlier research interviews were undertaken for the Positioning Paper and were used to build a description of volume builder house building processes. The literature about contracting systems was then used to provide an initial analysis of the contractual system used to build suburban house building.

In this report, the literature has been used in two principal ways. First, it has been used to understand innovation and the limits to innovation in suburban house building. Second, it has been used to establish a framework for understanding suburban house building as a production process similar to that used to analyse production processes in other mass production industries.

1.3.3 Interviews

Semi-structured interviews have been used extensively in the conduct of this research. Prior to each interview a set of thematic questions were prepared. Typically between seven and ten questions were prepared and given to the interviewee prior to the interview. They were used to provide the interviewee with a clear idea of the key themes and issues to be explored during the course of the interview. This format also allowed for supplementary questions to be asked. An example of the type of questions put to interviewees is provided in Appendix 1. In the main, the interviews were between one and one-and-a-half hours in duration. Each interview was digitally recorded and then transcribed using a professional and confidential transcription service. These transcripts were then read and key words searched during the analysis and writing.

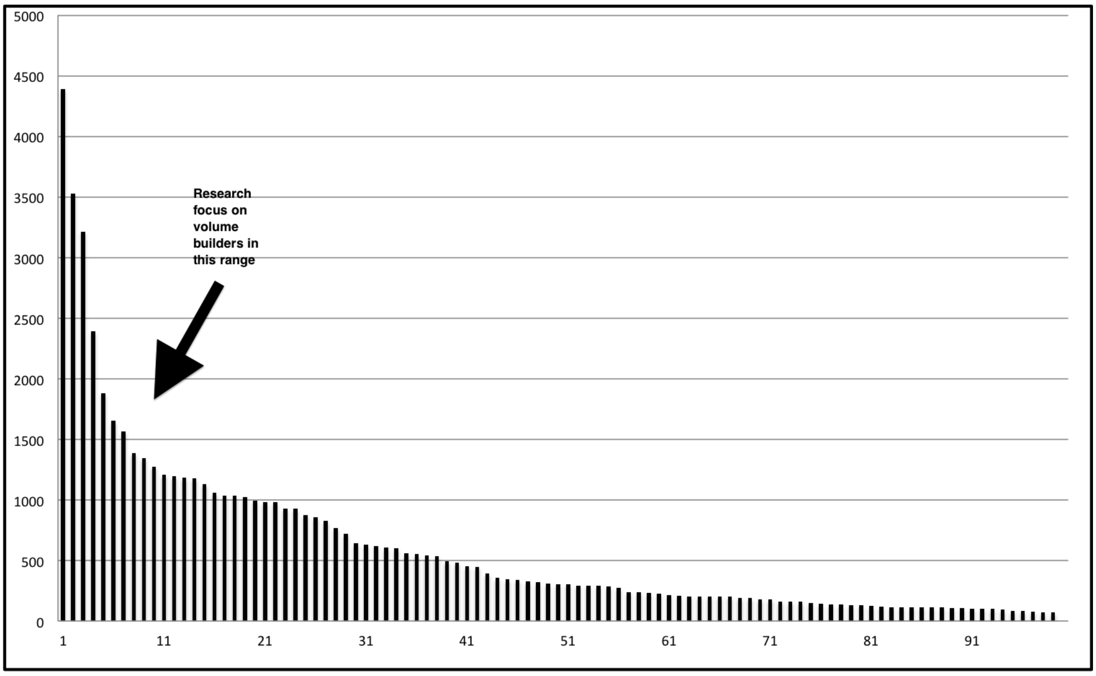
Twenty-five interviews were undertaken in the period July 2011 to July 2012. Three of these interviews were undertaken with two research participants who jointly responded to the questions and prompted each other. The interview categories and the number of interviews in each category are presented in Table 1 as follows:

Table 1: Summary of interviews

Category	No
Volume builder managers	13
Volume builder retired manager	1
Volume builder sub-contractors	3
Small residential builder	1
Building surveyors	2
Residential engineering consultant	1
Residential land developers	2
Materials and component manufacturers	2

The category with the largest number of interviewees was managers working in volume building companies. Managers in this context were people who held senior general and specialist positions through to supervisors who directly supervised sub-contractors. These 14 interviewees, including the retired manager, were distributed across five companies that can be described as volume builders. This is the term generally used to describe house building businesses that are included in the annual HIA Top 100 series (Housing Industry Association 2010). Figure 3 below indicates broadly where these companies are located in the distribution of companies from largest to smallest within the Top 100 series.

Figure 3: Number of dwellings completed by HIA top 100 companies 2010



Source: Housing Industry Association 2010

It became clear through initial interviews that the systems these companies used to design, build and market houses were similar. It was on this basis that it was decided to select two companies and investigate their construction scheduling practices through further interviewing. These are the two companies identified as companies A and B in Chapter 3 of this report. Further, other interviews, in particular interviews with sub-contractors, building surveyors, a residential engineering consultant and material and component manufacturers also confirmed that volume builders were similar in the way they designed, built and marketed houses. In other words, volume builders have developed similar systems for producing housing.

It also became clear during the interviews that contemporary volume builder systems had a common origin in the system developed by AV Jennings in the early post-war period described by Garden (1992). It was a system that spread through the industry as senior people left AV Jennings and started their own companies. As one interviewee, with long-term experience in the housing industry, noted:

> … there's a lot of the builders, a lot of the people who are running building companies, housing companies these days, went through the AV Jennings university of housing … in the 1970s, '80s and '90s

1.3.4 Focus group

In December 2011 a focus group was held at RMIT. Twelve participants comprised of builders, a building surveyor, a land developer, a building materials supplier, housing industry association representatives and a housing industry policy analyst participated in the focus group. It began with a presentation of the context of the undersupply issue and evidence of lengthening completion times. The focus of the round table discussion were the tentative conclusions that lengthening production times of new suburban detached housing were in part explained by product change and consequential increase in the complexity of building processes, supervisor skill deficits and problems with the quality of on-site trade work requiring significant remediation. The focus group, like the interviews, were digitally recorded and transcribed. Also, similar to the interviews, this transcript was read and key words searched during the analysis and writing.

The research team concluded that they had established a good understanding of the way in which volume builders design, build and market new suburban houses through the interviews and focus group. In other words, we had achieved data saturation where no new substantial information would result from additional interviews or focus groups (Morse & Richards 2002).

1.3.5 Modelling

General-purpose simulation software called Simul8 was used to model the construction process. It contains default components such as work entry, workstation, inventory and resources and allows modelling of a specific situation through programing. This was used for controlling the workflow and variability, and for reporting house completion time, idle time and resource utilisation.

1.4 The Positioning Paper

The initial response to this primary research question and the secondary research questions were presented in the Positioning Paper, *Australian suburban house building: industry organisation, practices and constraints* (Dalton et al. 2011b). The paper outlined the way that house building was organised and presented an analysis of three features of the industry associated with increasing construction times.

The organisation of house building is based on three types of contracts—supply contracting, supply and install contracting, and labour subcontracting. Each house is built through the careful sequencing of contractors and subcontractors who provide products and services. These contractors and subcontractors, brought together and organised by building company supervisor, constitute what Bresnen et al. (1985) describe as a 'temporary organisation'. Further, it is customary for these contractors and subcontractors to be members of multiple 'temporary organisations' at the same time as they move from building site to building site undertaking separate discrete tasks at each site.

Three features of the industry were identified as being associated with increasing construction times. First, more complex dwelling design and greater purchaser choice. Changes in dwelling design including the growth in the number of house models offered by companies, complexity of house design (especially facades) and the increasing proportion of two-storey houses. Second, the capacity and performance of supervisors as organisers. Supervisors must coordinate the subcontractors who build these more complex houses and some supervisors struggle with this coordination work, which has consequences for the timely sequencing of contractor and subcontractor tasks. Third, problems with the quality of on-site work. Building surveyors and in-house company quality assurance people find deficits in the quality of work undertaken by tradespeople, which requires rework, further inspections and rescheduling of subsequent tasks.

This report extends the analysis of suburban house building presented in the Positioning Paper by examining housing building as a production process. This represents a shift from the identification and discussion of the actor groups, such as supervisors and subcontractors and contractual arrangements. Instead, house building is viewed as a production process consisting of sequenced activities. Contractual relationships are placed into the background, as activities become the primary unit of analysis within a broader production process.

A starting point is recognising that houses are built by sequencing discrete activities. However, each house is but one house in a larger portfolio of houses being built at the same time. An individual supervisor will typically be responsible for between 10 and 15 houses at the same time and other supervisors will be supervising similar numbers of houses. All supervisors will be drawing on the same pool of subcontractors, contractors and supply and install contractors. It is therefore important to go beyond a house-by-house analysis and see house building as a production process.

1.5 Structure of the Final Report

The report that follows contains three substantive chapters. Following this introduction, Chapter 2 describes the development of the Australian suburban house. It is the outcome of a history of innovation that has produced a number of recognisable housing forms with distinct structural features and use of products. The most prominent housing form is the brick veneer house that is built primarily on-site. It is also an industry that is characterised by considerable ongoing innovation in the use of products, design and the way that work is done. However, throughout this history of innovation, suburban house building has remained resolutely an on-site process.

Chapter 3 presents an analysis of the time management and construction scheduling methods used in the industry by examining the way this work is done within two volume building companies. Company A and Company B exhibit distinct differences in the way they have developed and use their systems. The analysis presents an account of the scheduling system developed by each company; the way supervisors and construction managers use their system; and the usefulness of the data that is produced by their system, based upon interviews and reviews of system reports.

Chapter 4 extends the analysis regarding the inter-relatedness of activities for a portfolio of houses being produced at the same time. It does this by presenting the results of a simulation of production processes, based on the many discrete activities that result in a complete house, for a portfolio of houses at different stages of construction. This simulation supports the investigation of the disruption or delay of particular activities to the overall production process.

For example, it is possible to explore the logical consequences for the broader production process if the completion of the plumbing ‘rough-in’ is delayed in one or a few houses. It can also assist in investigating the effects of bad weather on the timely completion of houses. The chapter assists in understanding how a delay in one or a few activities is transmitted through the production process through the interdependencies across many temporary organisations and the more permanent supply chains.

Chapter 5 brings the analysis presented in the previous three chapters together and considers possible policy implications. These possibilities are considered along a continuum from minimal change, through incremental change, to radical change in production process. At one end of the continuum is the radical idea that there could be significant growth in off-site manufacturing. However, available analysis of the Australian suburban house building industry, and a similar industry in North America, suggests that this is not likely. There is now a long history of discussion and experimentation with very little movement to off-site construction. Instead, there is scope for considering incremental changes and how this might be encouraged.

2 SUBURBAN HOUSES AND INNOVATION

In this chapter the design and materiality houses represented in the ABS trend data presented in Figure 2 is examined further. In the Positioning Paper the focus was on house design and increasing levels of complexity. An aspect of this increased complexity was the large number of house models offered by volume builders. Another was the opportunity for purchasers to vary standard designs and the opportunity to purchase optional extras. Further, the proportion of two-storey dwellings has increased as average house size has increased and average land size has decreased. The trend has been towards both double-storey and increasing customisation.

This chapter responds to the principal research question: 'How is the work of new suburban house building organised and what practices and constraints may contribute to delays in building completion times?' by describing the materiality of houses and an analysis of the dwelling structure. It also presents an analysis of the way in which this has changed through innovation and the limits to innovation in house building. This provides the context for the single house activity analysis presented in Chapter 3, and the analysis of the production system in Chapter 4 where many houses are assumed to be under construction at the same time.

This chapter has three sections addressing the following issues:

- There are three main types of Australian suburban houses—the timber house, the solid brick house and the brick veneer house. In recent decades, it is the brick veneer house that has become the main type in new house production.
- There is continuing innovation in suburban house building evident in the continuing change in the use of products, work processes, the marketing of houses and organisational practices.
- Larger scale innovations that could reduce the time taken to construct new dwellings have been considered over the years. However, prospects for their up-take are limited and the current model appears to be entrenched.

2.1 Suburban house structures

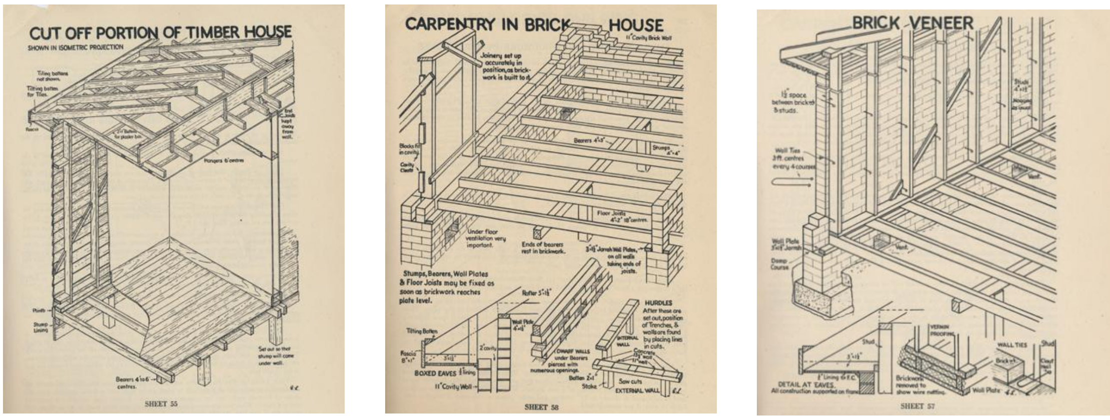
The structure of the contemporary suburban house evolved in the late 19th century. This was a time when there were significant changes in the building materials industry and in methods of construction. Together these changes 'widened the field of men within whose competence the building trade lay' (Frost 1991, p.120). The changes that Frost notes are cheaper milling of frame, floor and weatherboard cladding timbers and the manufacture of mortised frames for windows and doors. He sums up these changes in the use of timber for the structure of houses:

> The balloon frame construction method, which joined light studs, joists, and rafters by simple nailing, was quicker, easier, and cheaper than the former method of mortise and tenoning heavier timbers.

Further, galvanised iron became more available for use as a roofing material instead of slate. Machine-made bricks, which were quicker and cheaper to lay than hand-made bricks, became available for the building of middle class houses during the 1880s. Joinery and plasterwork which had been 'painstakingly fabricated on site was now imported ready-made or turned out to standard patterns at a steam joinery or plaster works' (Davison 1981, p.86). It is in this context that suburban detached houses were built in the new subdivisions beyond city centres. Increasingly this housing was being built for owner-occupiers.

Two main types of housing were built in the late 19th century for different market segments—the timber frame and weatherboard clad house; and the solid brick house. In the 1920s a third type of house structure was developed—the brick veneer house. It was a form of construction where a wood frame held up the roof and was covered with plaster on the inside and had a skin of bricks on the outside. In practice it was a compromise between the timber house and the more expensive solid brick house and provided purchasers with the status of a brick house (Australian Bureau of Statistics 2013b). Figure 4 below presents cutaway diagrams of these three different construction types from a 1950s instructional book used to teach apprentice carpenters their trade (Lloyd 1950).

Figure 4: Twentieth century Australian house structures



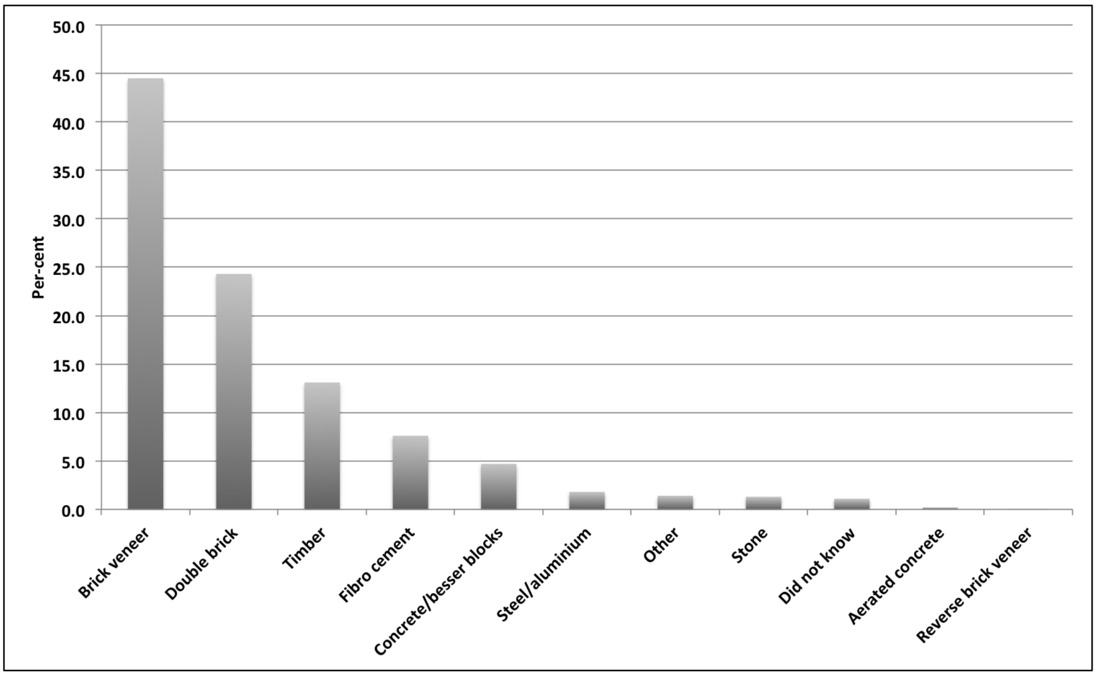
Source: Lloyd 1950

By the post WW II period when the housing industry was being re-established there were three main structural forms. However, by the end of the 20th century, the brick veneer house had become the dominant form.

Figure 5 below presents the proportions of the main material of outside walls for Australian housing in 2008. It shows that the national average for brick veneer at nearly 45 per cent; solid brick nearly 25 per cent; and timber 13 per cent. However, it should be noted that this average conceals considerable differences across the states and territories. In particular the ACT, at 74 per cent, had the highest proportion of brick veneer houses and Victoria had 61 per cent. Western Australia had the highest proportion of solid brick houses, at 79 per cent, followed by South Australia with 39 per cent and New South Wales with 25 per cent. Tasmania has the highest proportion of timber houses, at 27 per cent, followed by Queensland, with 25 per cent (Australian Bureau of Statistics 2008b).

This indicates that there are considerable differences across the states and territories around the national averages in the design and construction of suburban houses. It suggests that different preferences for materials and development of capacities by companies and trade groups have been institutionalised at the sub-national level.

Figure 5: Main material of outside walls (2008)



Source: Australian Bureau of Statistics 2008b

2.2 Innovation in suburban house building

Although the structure of suburban houses has remained largely unaltered since the brick veneer house became the dominant form, there is nevertheless evidence of considerable ongoing innovation. As Thorpe et al. (2009, p.196) conclude, based on their research in 11 small firms that design and construct houses:

> … the research shows that emphasis on new or improved products and processes, in addition to a clear focus on the use of innovative design and sustainable construction methods and materials, is prevalent among smaller construction industry firms in Australia.

However, innovation is not a straightforward linear process as research on the uptake of sustainability measures in Australian housing aimed at improving the energy and water efficiency of new housing shows (Crabtree & Hes 2009; Robinson & Edwards 2009). Crabtree and Hes (2009, p.222) observe that 'the Australian housing sector brings together multiple, often conflicting, perceptions of the common good, the technologies which best serve this, their costs and legality'. Consequently innovation is iterative, partial, sometimes contested and not always easily observed and described.

In the innovation literature it is acknowledged that defining and identifying innovations is not straightforward (Blayse & Manley 2004; Manley 2003; Thorpe et al. 2009; OECD 2005). As the OECD (2005) notes, their work over two decades in promoting innovation surveys has led them to redefine innovation and include linkages, marketing and organisational change. They now propose a definition that distinguishes between four forms of innovation:

> An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations. (p.46)

These innovations can be developed endogenously, either within particular firms or more broadly within institutions, or they can be acquired exogenously from other firms or institutions through diffusion processes.

In the house building industry the idea that innovation can be acquired through the process of diffusion is important given the nature of the industry. It is an industry dominated by small businesses, often unincorporated partnerships, providing goods and services coordinated through multiple contracts (Dalton et al. 2011a). In other words, it is an industry dominated by small to medium-sized enterprises (SMEs) that devotes very few resources to endogenous innovation. Instead, businesses rely on largely informal networks for learning about new products and ways of doing things differently (Thorpe et al. 2009).

In the house building industry there are three sources of learning in these networks that stand out.

First, there is the manufacturing industry. As Manley (2008) notes, manufacturing firms operate in larger and more standardised markets and have research and development programs. They become sources for innovation by providing innovative components and building products that builders use.

Second, there are many trade, professional and peak associations that are associated with accreditation and standard setting processes that are constantly communicating with their members and transferring knowledge between members (Thorpe et al. 2009; Manley 2008).

Third, regulation, particularly performance-based regulation, can encourage innovation (Gann 2000; Manley 2003). The formation of the Building Products Innovation Council (BPIC) by product associations in 2003 is evidence of this through its coupling innovation support for performance regulation. It seeks a 'nationally harmonised building code; ensuring regulatory impact statements look at real-world cost impacts on the whole supply chain; and ensuring access to responsive product certification systems to support continuous innovation in the industry' (Morschel 2003).

What innovation results from these types of innovation processes? The following discussion responds to this question by providing an overview of innovation using the four OECD categories. They are categories that have been developed through analysis and repeated surveys of innovation in many industry sectors since the 1990s (OECD 2005, p.3). They provide a means for organising this discussion of innovation in the housing industry. It is not a comprehensive account of innovation in house building, but it does present key features sufficient to demonstrate that there has been innovation over the past three or four decades in suburban house building.

2.2.1 Product innovation

Product innovation is found in the introduction of goods and services that are new or significantly improved, including components, materials, software and functionality (OECD 2005, p.48). In suburban house building there is abundant evidence of this type of innovation. Table 2 below presents examples of innovation for each of the main stages in the construction of the typical suburban house set out in Dalton et al. (2011b). These examples indicate that innovation is extensive and is associated with all stages of suburban house construction.

Table 2: Suburban house construction product innovation

Building site preparation	→ Stainless steel mesh for termite control → Geo-fabrics in silt fencing
Building envelope	→ Waffle slab design and construction → Steel reinforced aerated concrete wall cladding → Caulking compounds → Rendering mesh and compounds → Tapes → Glues → Energy efficient glazing and double glazed units → Manufactured roof trusses → Manufactured wall frames → Steel web and timber flange beams → Waterproof membranes
Dwelling service systems	→ Plastic plumbing → Photo-voltaics → Solar hot water systems → Smart wiring for IT → Wireless control systems
Dwelling fixtures and fittings	→ Water efficient taps, showers and cisterns → Energy efficient lighting → Plastic water tanks → Manufactured modular kitchens → Seals
Finishing and furnishings	→ Low emission paints and floor coverings → Smart blinds
External living and landscaping	→ Shade sails → Porous paving

In volume building companies there is a deliberative process that centres on houses being built in display villages, which is used to identify and consider new products that could be used in houses. An executive of a volume builder outlined their 'R&D process' in response to a question about 'where is this done in the company?'

> It's done in our R&D area … the Research and Development team are the team that does all the new display home designs. So they research all the new materials and if they think [they are] worthy they'll try them in a display home. Obviously there's a committee that looks at new materials, it includes our purchasing manager and … building managers, as well as design managers and—and then they'll implement it and see how it goes, you know.

In these deliberative processes consideration of change appears to be driven by factors that staff identify as exogenous challenges to their customary ways of building houses. Two types of challenges can be identified.

First, builders encounter endogenous problems. Two examples illustrate this process—the shift from framed floors to concrete raft slabs and then to the waffle slab; and reduction in the use of bricks and increasing use of lightweight external wall claddings.

Raft concrete floor slabs began to replace framed timber floors for brick veneer construction, shown in Figure 4 above. They were introduced because of quality control issues in framed timber floors, especially those built with green hardwood, even though they were more expensive. However, they quickly became the norm. A supervisor explained:

> We used to build most of the houses on stumps. So it's footings, brickwork, base brickwork, stumps, floor joists, and then flooring, and away we went. But now it's … [slabs]. So it was a lot harder to get out of the ground than what it is now.

The waffle floor slab developed soon after. It is a concrete floor slab with reinforcement formed up and cast as a grid of deep ribs around coffers that are formed with polystyrene pods. A volume builder who was seeking to reduce costs through the more efficient use of concrete and develop a slab that performed better on reactive soils developed it in the early 1980s in Adelaide. By the mid-1980s it was being tested and considered by professional associations and standards authorities and being used nationally. There was a process of diffusion across companies as 'more and more companies started to re-invent the innovation to market as their own product' (London & Siva 2012, p.8). This diffusion happened despite the attempts by some of the innovators to patent aspects of the design and specially manufactured components.

Over the last decade, builders have been experiencing difficulty in finding bricklayers, which is driving the search for alternative and less labour-intensive wall claddings. An executive outlined the problem: 'bricklaying is a risk because there's not that many [bricklayers] around these days'. Another executive corroborated: 'they're one of the trades that we are exceedingly short of in this country and their prices are going up and … we're all looking for different ways of substituting for brickwork'. A bricklayer suggested a reason for the shortage of bricklayers in the current labour market context: 'to get an apprentice to start off with, you've got to have somebody with the right attitude. A lot of them want the top dollar from day one. … I don't think I'll ever train another apprentice'. A response by volume builders has been to find substitutes. A volume builder notes that they are putting in a 'lot of work … into lightweight solutions and also with those solutions, like Hebel, to get the work [done] as 'supply and fix' … as opposed to brickwork, where we've got to worry about the bricklayer'.

Second, builders also respond to regulation. An example of this is energy efficiency regulation and associated increased demand for improved energy efficiency which is stimulating considerable product innovation. An executive explains: 'a lot of the work that we've done over the last few years, in terms of innovation, centres around energy efficiency'. These have been in the areas of 'different wall cladding systems that insulate a lot better' and 'a monitoring system to be able to assess different areas of the house's load and usage of energy … that will get to market within the next couple of years'. An executive in another company describes a similar process of innovation: 'we've actually got an in-house guy who's an expert in sustainability and energy ratings and he's constantly looking at products to lift that sort of bar'. Overall, house builders have responded to the introduction of energy and water efficiency performance regulation and have developed new capacities for choosing materials and designing more energy-efficient houses.

In addition to the exogenous challenges, there is in-house product innovation. As Johnson (2006) observed in her research on changes in the design of outer suburban detached houses, more than a decade after her first project (Johnson 1993), there has been substantial change in house design.

> Occurring over the last 20 years, there have been fundamental shifts in household form as well as in the planning, politics and sociology of the suburb, such that a new look has emerged. Now located on smaller allotments and serving a more diverse population, house designers have embraced space like never before—adding rooms, opening the home to a newly tamed garden and offered new ways and spaces to display affluence, entertain others, and actively pursue leisure at home.

The volume building companies have largely been responsible for the development of this 'new look' in house design. In these companies in-house designers are constantly observing what other builders are doing, responding to regulatory change, reacting to developers and their subdivision designs and formulating ideas based on what they think customers and prospective customers are seeking. At a broader level there is the circulation of ideas through a professional association, the Building Designers Association of Australia (BDAA), that brings together housing designers.

An executive in a volume building company spoke about the process in this company in the following terms:

> Really, all the innovation has been in design, you know, use of stone, use of cabinetry, look, feel, that kind of thing, which has all added complexity to … the home. And the detail of how you flash something, how you don't let it leak, how the two materials come together, that type of detailing. Is it innovation? I guess it is. It's fashion.

At the same time there is a process of balancing design and the practicality of building, what the builders call 'buildability':

> I think design integrity is [as much] about how to put a building together as it is with the final aesthetic … we have to be clever in how we put the building together.

In sum, the design of suburban houses, both in terms of product choice and the design aesthetics, is constantly changing. Builders design, build and sell these houses within a competitive market. They also do this design work in a context where they are assessing and responding to industry conditions, such as labour supply, and policy driven regulation, such as requirements for more energy efficient structures.

2.2.2 Process innovation

Process innovation is found in the implementation of new and significantly improved production and delivery methods. This type of innovation is also evident in changes in techniques, equipment and software (OECD 2005, p.49). In other words, the focus is on the way things are done. Evidence of this type of innovation in suburban house building processes can be divided into three types.

First, there has been extensive growth in the development of specialist on-site mechanical equipment on suburban house building sites. Initially much of this equipment was first used on large civil engineering sites and then later diffused across the construction sector (Gann 2000, p.141). The use of this equipment by the contractors who work on site has increased the productivity of the workforce. Types of equipment include access equipment such as mobile hydraulic platforms; air compressors and tools including nail guns; power saws for cutting many different types of materials; earthmoving equipment; lifting equipment; nailing, stapling and fastening guns; pressure cleaners; grinders and planers; waste disposal equipment;

painting and rendering spray guns; drills; and electronic measuring and levelling devices. There is continuing development of this equipment and with many items supplied by hire companies that are able, because of the scale of their businesses, to offer new and more capital intensive items into the house building industry.

The second change is in the form of personal communication that followed the use of mobile telephony from the early 1990s. The spread of mobile phones revolutionised the way that all the actors constituting the temporary organisations involved in constructing dwellings, supplying materials and equipment interacted. No longer was communication about future arrangements for scheduling work restricted to after-hours phone calling, faxes and mail. Arrangements could constantly be made, unmade and remade by all the players. There is a suggestion that this led some supervisors to be less methodical in the way they organised their work and recording what they did. An executive with many years in the industry observed:

> What I've seen over the years is that [the] mobile phone was a killer because it stopped supervisors having to organise because they could simply arrive at a job, make a phone call and then go onto the next one, phone call. They didn't have to record everything, they didn't have to be organised in terms of getting their trades, making sure things were done because they couldn't just make a phone call.

The third area of change is the introduction of information and communication technologies (ICT). In the ancillary support activities, such as accounting and personnel, it has become standard either used directly in the larger business or by the remote use of systems provided by specialist services, for example, business services provided by the HIA. However, some builders, especially the volume builders, have also installed ICT systems that directly support house building by aiding house design and the scheduling of activities in the construction process.

The first use of ICT in house construction came with the introduction of manufactured trusses in the mid-1980s. The manufacture of trusses became possible following the development of nail plates, sometimes referred to as connector plates, which have spikes or teeth projecting from the plate. When pressed into adjoining timber members they form a strong joint. When manufactured trusses first began to replace on-site roof framing in the 1970s, the nail plate manufacturers, such as Gang Nail, also supplied structural design knowledge to truss manufactures in a book of engineer-designed truss templates. However, by the mid-1980s the nail plate manufacturers began to design and licence software that truss manufacturers could use to custom design trusses for each and every house. An engineer from a connector plate company described this innovation:

> So by the mid-1980's we started producing software that could design any shape of roof truss. No longer was it standard. Now [the truss manufacturer] had a piece of software that said, 'Well that's a roof, and that's got a hip end here and a hip end here. I can push a button, and well, all the trusses go there. Now I push another button … and I've got all the costing and the production details'.

More recently, the connector plate manufacturers have been extending the scope of the software and it is progressively being introduced into the structural design of houses.

> Now … we're not just dealing with trusses, we're doing … frames … trusses, floors, components that are not nail plated tech. So we can put in steelwork and all sorts of things for lightweight construction. And we are all [connector plate manufacturers] racing madly to the point where you don't put in a roof,

> you put in a house or a building, and you push a button and … everything's taken care of, the whole lot, top to bottom.

The truss manufacturing industry that has developed from this process has a distinctive structure. At its apex there are three companies that manufacture and supply connector plates, machinery for truss and frame manufacture and structural design software. Two of these companies, Pryda and MiTek, are international companies, and a third, Mulitnail, is an Australian owned company. Between them they supply connector plates, manufacturing equipment and software to approximately 300 SMEs that manufacture the trusses. These companies are located in and around metropolitan areas and provincial centres where house builders create demand for trusses, floor trusses and prefabricated wall frames. The truss manufacturers have developed an association, the Frame and Truss Manufacturers Association (FTMA) that represents the fabricators of and suppliers to the pre-fabricated timber truss and wall frame industry.

A second and more recent ICT innovation is the use of scheduling software. This connects supervisors' scheduling work for each house with the ordering, or 'call-ups' as they are referred to in the housing industry, and the payments system. In other words, it connects the day-to-day build process for each house to multiple labour and materials supply chains. There are two main proprietary systems, Framework and Clickhome. A manager in one of the volume building companies described the introduction of one of these systems:

> [This] was the first bit of software I ran into that actually had automated the process, or it set up basically a framework that allowed the company to decide how they wanted to build. … So we've been … going six years with it.

However, introducing this system required considerable effort to build commitment among supervisors by demonstrating that using software in house building could produce rewards.

> Well, supervisors have improved. Out of sight. When they first released this six years ago, 90 per cent of them had never even sent an e-mail before in their life. So you know, it was a steep learning curve for them … we spent three days to a week with every supervisor, where we actually just went out in the car with them and just helped them. One on one … the key to it was basically following up all the issues. … It was like resolve, resolve, within 24 hours, so that people had the confidence in the system, that they think this is working.

The use of ICT systems in the sector in analysed in more detail in Chapter 3 through the examination of current practice in two volume building companies.

2.2.3 Marketing innovation

Marketing innovation is associated with the implementation of new marketing methods involving changes in product design or packaging, product placement, product promotion or pricing (OECD 2005, p.49). The focus is on what is presented to prospective purchasers of new housing and how the presentation of new housing is shaped.

A framework for analysing marketing innovation in housing construction is found in the three categories proposed by Kriese and Scholz (2011) and their analysis of sustainability in residential property marketing. They start with the socio-environmental dimension of residential property and divide it into two parts 'the building itself and its location'. They then add an explicit social dimension, the 'people or intended inhabitants and community'. These three categories of location, building and people provide a useful way of reporting on and analysing the marketing of new suburban housing by volume builders.

The marketing of suburban housing includes all the means usually used to market other commodities—print materials, television, radio and Internet sites. This type of marketing forms a part of what Leonard et al. (2004) describe as the 'building and trade 'media' representations of house and home'. However, for the housing commodity in the Australian setting, there is one further means used by builders to advertise—display houses in display villages. Burke and Hulse (2010) describe the display village arrangement and the importance of display houses.

> In Australia, the developers acquire land, obtain the necessary zoning, clear the land, subdivide and provide the appropriate infrastructure. The land is then sold to individual builders or, much more commonly, to households for subsequent construction. A consumer shops around the display village on a new estate (there may be up to 50 houses on display), chooses one and gets the builder to construct it on their own piece of land.

Advertising is directed towards encouraging prospective purchasers to inspect houses in display villages. Responsibility for this advertising is broadly divided between the land developers and the builders. The land developers advertise locations and convey ideas about the people who will come to live in these locations and comprise the community. The volume builders focus primarily on the house including its design features and amenity.

Typically the developers are offering a wide choice of locations, albeit on the fringe of metropolitan cities. For example, a large land developer presents a choice of nine locations around the fringe of metropolitan Melbourne. The advertising for all the estates presents variations on the theme of nature, parklands and open space. However, there is also local infrastructure, which is listed, such as schools, medical facilities and shopping.

An example is Mernda where there is 'life surrounded by nature with over 70 hectares of parklands and open space, and all the convenience of having a Town Centre at your doorstep, featuring a shopping centre, medical centre, two primary schools and a kindergarten'. Arbourlea in the southeast is where residents can 'escape the hustle and bustle in your own private hideaway, nestled between stunning waterways and natural woodlands in Melbourne's flourishing South East' (Stockland 2012). This illustrates a strong 'exurban' narrative where potential new residents are offered an escape from the 'urban'.

It is in this context that the volume builders make the display home central to their advertising strategies. A volume builder marketing manager explains the approach:

> Our major objective is to drive the person in terms of foot traffic to our display home and that interest is sparked via advertising, largely, for us, print advertising, advertising on our website and all the other smaller marketing activities that we do in terms of communicating with the market. … We also like to get the customer emotively involved in the product, which is the display home. Not only does it sell the product the best, but it also gives an opportunity to explain things to the customer, hands on.

The process starts with developer invitations to volume builders to come into a display village and is followed up with negotiations about which sites are on offer. There is considerable competition between the builders for sites that have the most passing traffic and avoid the sites 'at the back of the village'. Other conditions are also negotiated. Some builders have sought to influence the subdivision design in a context where average lot sizes have decreased and added new constraints to the way houses are designed. A volume builder manager noted:

> We're taking it on the other way and we're actually developing new lot types to suit new house ideas that are going out to the developers and trying to, trying to work with them to get those lots … into their [developer] matrix.

There can also be some negotiation over who pays for the display homes depending on the status of the builder and market conditions. If the developer wants a particular builder enough, then the developer will contribute by paying for the cost of construction or not requiring settlement on the land until the display house is no longer needed for marketing and is sold.

Display house design and construction typically has a time frame of about three years, two years for the design and construction and another year before it becomes clear whether the house model is popular in the market and will continue to be offered. As a volume builder executive notes, 'you want to get it right because you're making a lot of investment for those display homes'. However, the display models can also evolve over time. A marketing manager explains how the models continue to evolve:

> We may have had feedback from customers. We may have had feedback from our design team. We may have found a better way of building it. … Therefore the product changes and where the product changes is … at the level of display home. So the first [display] might have been built at …, the second one was built in …, the third one was built in …. So the product has evolved over time. But all those three display homes are still open at any one point in time. So therefore we still offer all three products.

Not surprisingly, in the context of the display village where competitors have their display houses alongside each other, there is a process of reviewing each other's designs and appropriating ideas. An executive of one company describes the process of review and appropriation:

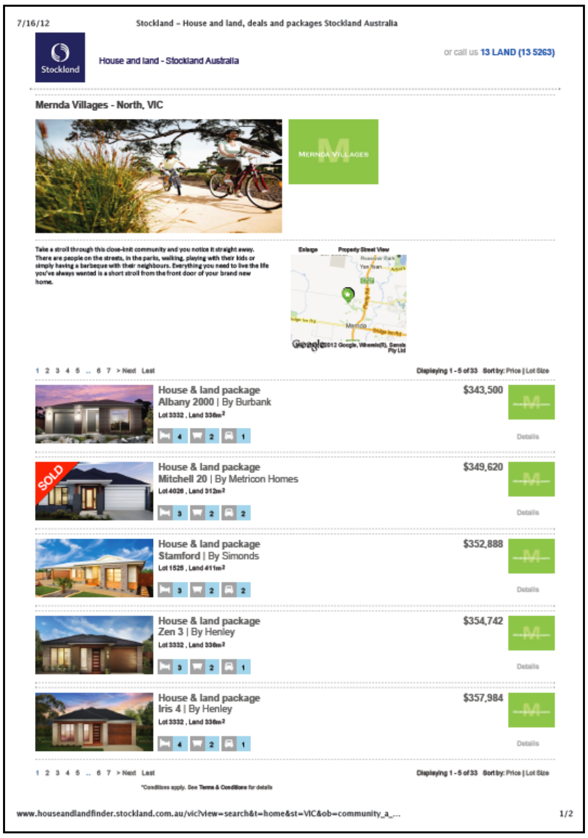
> We'll open up a display centre, then [another volume builder] will go out and look at ours and they'll open up theirs, or they might pull it apart a bit and open up theirs, and it's all very competitive for the customer out there.

Typically, in each village a number of volume builders will each build a small number of houses that will be open for inspection for a year or more. Further, these builders will have a presence in multiple display villages around the fringe of metropolitan cities in the growth areas.

Unsurprisingly, volume builders devote considerable resources to the design and building of the display houses, given that they are central to its advertising and sales strategy. One volume builder operating in two states was planning to build more than fifty new display houses in the next twelve months. This considerable investment was 'because of what's happened in the past, we've found that sales have sort of followed displays'. They are also assessing and responding to the market analysis of the land developers who 'pride themselves on … knowing their customers inside out'.

Prospective purchasers are shown a collection of houses designed and built by a volume builder. They may then move onto inspect the display homes of other builders. Typically each builder using the village as a sales point has between three and five different house models on display. Figure 6 below illustrates the nature of this choice in Mernda. In this estate the developer has established a display village where six volume builders have built houses. The developer web site presents 33 houses for the six volume builders. Prospective purchasers can therefore make initial comparisons before travelling to the display village to inspect houses and talk to the sales people.

Figure 6: Display village web advertising



Extra care is taken in the presentation of these display houses. Typically the builder seeks to maximise the attractiveness of houses by including features and finishes not included in the base model presented in print or web advertising. An executive described the practice:

> Displays, we often put in timber windows or double-glazing throughout, no matter what range it's in. You know the tiles are the best that you can get out of our catalogues. Bricks as well, you, you just up-spec everything.

An executive from another company described this same approach to marketing houses:

> Our philosophy is to really trick-up the display home to wow people and show them the dream, but then we start from, well here's the base specification and then here's all, what we call standard options, that they can upgrade to.

The house, its design, its features and finishing are constantly being reviewed and recreated by the volume house builders. The designers within these companies are constantly making comparisons and picking up and 'borrowing' ideas. As a housing building company director describes:

> It comes down to competition … we all compete for the same buyer and we're out there rationing out our display homes. We hold onto display homes for a couple of years now, whereas back in the Jennings days, you'd have them open for five years wouldn't you, the same model. Pumping them out. Now, as soon as we open one, [our competitors] will be out there looking at it and ratcheting it up and it's just being ratcheted up all the time.

The land developers convey the broader ideas about the people or intended inhabitants of the houses being built on the new estates. In this advertising the houses are in the background. The dominant images are people outdoors relaxing, exercising and playing. Through this imagery and accompanying text there is the message that purchasers will, with other newcomers, constitute what McGuirk and Dowling (2007, p.24) describe as 'life style communities' where there is the possibility of a 'broadly common identity forged around lifestyle preference and/or life cycle stage'. For example, the text that accompanies the advertisement of display village houses reads:

> As you walk through the close-knit community that is Mernda Villages, there is something very special about it. It's all about balance—balance between work and family, the peace of being surrounded by nature and the convenience of having everything you need on your doorstep. It's the kind of place where your neighbours grow into friends and your kids discover it's more fun to play outside than it is to watch TV.

The land developers and the builders therefore share the advertising for new suburban housing on the fringe of metropolitan cities. Land developers advertise the locations and present ideas about the people who will live in these future communities. The builders on the other hand focus on advertising the houses through various media with their display houses located in display villages central to their advertising efforts, encouraging prospective purchasers to spend time in their houses and possibly experience the 'wow' factor. Marketing innovation is thus active and competition driven, with market strategies constantly being reviewed and recreated.

2.2.4 Innovation in organisation

Innovation is evident across three areas of organisational change: workplace organisation, business practices, and external relations with other firms (OECD 2005, p.51). In context of the volume building industry, the focus is on the way companies are structured and manage the work of building houses. An initial account was presented in the Positioning Paper (Dalton et al. 2011b).

This study found no evidence of significant innovation or change in the three main forms of contract—supplier contracts, supply and install contracts, and subcontracts. These three types of contracts are used to supply materials and to use them in building houses on-site. The management front line is comprised of supervisors who organise and schedule the many contracts resulting in finished houses. Typically they organise and schedule work for between 10 and 15 houses.

Construction managers in turn lead supervisors, monitor workflows and quality, and coordinate subcontract labour supply across groups of supervisors. Typically five supervisors will report to a construction manager. There is then a head office with groups that are responsible for house design and documentation, sales, and accounts. This form of workplace organisation has been consistent in recent decades and there are no indications of change.

In the area of business practices there is some evidence of incremental change, which primarily focuses on the way in which supervisors address construction delays and quality. Two examples are provided. The first extends the account of a volume builder that introduced the ICT process innovation based on the Clickhome scheduling software. This can be used to review supervisor practices through its capacity to generate reports on the timely completion of milestones for each house under construction. The responsible manager described the approach to performance management based on achievement of milestones:

> Everything is all about, 'How are you meeting your time frames?' Your stages are behind schedule, and I'll show you the reports. We're managing it at milestone level. So therefore yes, we can go in and see that they're not

> managing the individual tasks appropriately, but we don't need to be throwing that in their face. We say you haven't met the timeframe. What are you doing?

Overall it provides the basis for performance appraisal and an accompanying reward system.

> And as it's turned out, you know, you can see on the KPI reports and you can see it in the bonuses at the end of each year, good supervisors make good on all, the majority of the jobs, irrespective or whether there's a little bit extra or a little bit less [for each house], they're making it.

The second relies on the strengthening of relations with an external partner and the development of a new ICT system by at least one major company providing a statutory building permit and surveying service. As noted in the Positioning Paper (Dalton et al. 2011b) all dwellings must be inspected and passed by a building surveyor at set points in the construction process. It was also noted that building surveyor inspections typically reveal poor quality work and this leads to the need for significant rework. The innovation being developed by one building surveying company is to record the results of the inspection system in a way that supports the evaluation of firm performance and individual supervisor performance.

> So we can track a performance on a first time pass or fail for a particular mandatory inspection. So if I take this client for example, and I run a report in … their overall first time pass rate for … this region here … is 70 per cent. So, in other words, we've done 142 inspections of which 100 were approved the first time and … 42 sorry were failed, give them 70 per cent. When we break that down, they're hovering around 61 per cent for first time passes on their final inspections, 60 per cent of their frame inspections, 95 per cent on their slab steel, 83 per cent on their pre-slab, 66 per cent on their piers. Now I can further break that down to individual site managers [supervisors].

On the basis of these types of reports, the building surveying company plan for the future is to develop a simple analysis of the failures and go back to the volume builders and offer training to the supervisors.

> So if we work out that the top … failure categories happen to be … trusses, connection details, bracing etc. We … go on site, pick a job that basically has got it all wrong, sit there with them and say guys have a look at this, this is what we're expecting.

In these two ways there is a basis for assessing the performance of supervisors in organising and supervising the work of the subcontractors. Of course, the improvements may ultimately be limited because of the state of skill development within the trade workforce. As a building surveyor observed, the level of skill formation within the trades, especially carpentry, is an issue. For example, there is:

> … the guy that's doing the single-storey isn't really a chippie … a carpenter, he isn't a master of his trade. He's a person that's been taught for about a year, a year and a half and is now on his own making a buck and just knows how to do very simple things in that trade … our reports go from you know, one or two pages to five, six-page reports, and you just know that this bloke's got no idea what he's doing.

The development of better business practices by supervisors will help, but ultimately there is an issue of skill formation within the trades.

2.3 Limits to innovation

This section considers the prospects for further innovation and raises the question of possible limits to innovation. As the discussion above demonstrates, there has been considerable innovation in house building evident in: the products used in building housing structures; processes, especially ICT supported processes, used by builders and their contractors; advertising, especially display houses in display villages, used to sell houses in the fringe areas of metropolitan cities; and organisational changes. However, so far this innovation in suburban house building has not resulted in any significant movement of on-site construction work, undertaken by a trade workforce coordinated by builders and their supervisors, to off-site manufacturing in factories.

This continuing preference for on-site work is in contrast to much that has been said and written about what should happen. Throughout the post-WWII decades arguments were made that Australian house building should be moved off-site and industrialised and manufactured in factories. This was based on the idea that the production of houses, relying on craft based trades, was inefficient and that it is an industry that has been left behind (Australian Bureau of Statistics 2010a). The critique has continued, for example, the Australian Centre for Innovation and International Competitiveness (1992, p.52) described the problem:

> By practice and organisation the housing industry is rather more like a manufacturing industry, with its emphasis on the production of material artefacts, i.e. houses. But as a manufacturing industry it has been strongly resistant to the pressures and opportunities for industrialisation. … Moreover, the high level of fragmentation in the industry, a consequence of the many small firms and the sub-contractor system has maintained it in an essentially 'cottage industry' form of organisation'.

The policy argument based on this conception of the problem is to decrease the industry fragmentation, industrialise the industry based on new ICT technologies, and increase off-site manufacture and fabrication. The Cooperative Research Centre for Construction Innovation, in an industry vision setting project by Hampson and Brandon (2004, p.24), issued a similar call for the further industrialisation of building, including for housing construction. One element of this vision is that by 2020:

> A majority of construction products will be manufactured in factories off-site and brought to site for assembly. This will enable better quality control, improved and more efficient site processes, better health and safety control, more environmentally friendly manufacture and possible reductions in cost. The goal is to establish the economic viability of off-site manufacture to ensure a major improvement in the quality of components.

What are the prospects for the growth of manufactured housing off-site and less on-site craft-based building work? Three issues are identified and discussed below as a response to this question.

First, it is important to re-examine the nature of contracts used in house building, especially the supply-and-install form of contract, because the development and extension of these contracts seems to have stalled. Second, there are continuing fluctuations in house building, which shapes industry structure and tends to reinforce the current mode of production. Third, there is the suburban house and its design development and an absence of standardisation. This discussion is presented as a basis for further inquiry and debate rather than as a firm answer to the question. Further, it is suggested that all three factors together may assist in the persistence of the on-site craft-based form of construction.

2.3.1 Contracts

Supply and install contracts, as discussed in the position paper (Dalton et al. 2011b), are contracts between the house building company and another company for the supply of material and components and their use, installation and fixing on site. In recent years these types of contracts have been extended. Underlying this extension, the volume builders have been strengthening their connection with the larger highly capitalised building materials manufacturers. This has been driven by their interest in gaining the price advantage that can be negotiated for the supply of higher volumes of material. However, the development and extension of this form of contract, which would replace a combination of separate ‘supply contracts’ and ‘subcontracts’, has stalled. This is despite interest in extending this form of contract by volume builders. It indicates that the larger highly capitalised manufacturing companies are willing to negotiate on the price of materials, but are not interested in extending their role into suburban house building by increasing their on-site role. Three examples indicate this.

First, it is useful to return to the story of roof trusses and the arrangements that have developed. In summary, three large firms supply connector plates, equipment and software necessary for the manufacture of trusses. It is important to note that these companies do not manufacture the trusses themselves. Instead these three companies have supported the development of more than 300 truss manufacturers that are SMEs just like the rest of the house building industry. Further, the SME truss manufacturers make their trusses in factories using the latest equipment and ICT, yet have not extended their role to installing their trusses on site. Installation is still done by a sub-contract carpenter employed by the builder.

Second, in recent decades the volume builders have reorganised arrangements with a number of their ‘supply and install’ contractors. Initially these contractors, such as concreters, plasterers, plumbers and tilers were contracted to both supply and install their materials. Where they obtained their materials was up to them. These contractors negotiated with material suppliers before agreeing on a price with the volume builders. The shift that has occurred is that volume builders now negotiate directly with the material manufacturers over price and establish multi-year supply contracts. Certainly some of these ‘supply and install’ contractors organise the delivery of materials to the site. Indeed plumbers will bring pipes and fittings to the site on their trucks. However, payment for these materials is made directly by the volume builder. An executive from a volume building company explains their logic:

> So we’ve split it up to get buying power to, 'cause all of a sudden, you know your plumber was controlling the, or probably benefiting from the buying power and if there was a decrease [in] the market with some concrete, with the concreter you’d never hear about it, but if there was an increase, they’d be all over you like a rash. So, we decided then I guess that if we were the ones that were creating the volume, we should be benefiting from it in our buying power.

Third, it is useful to return to arrangements used for the supply and fixing of plasterboard and roof tiles. In summary, most plasterboard and roof tiles used in new suburban housing are supplied and fixed by large building materials manufacturers. However, two points can be made about ‘supply and install’ contracts for these two elements of the suburban house. One is that the ‘fixers’ continue to be sub-contractors. The material manufacturer organises and pays the sub-contractors, plasterers or roof tilers, instead of the builder.

The other and more important point is that this type of supply and install contract has not been extended to other elements of the building, despite interest in its extension by builders. For example, a volume builder is keen to extend this arrangement to the supply and install of concrete floor slabs and bricks:

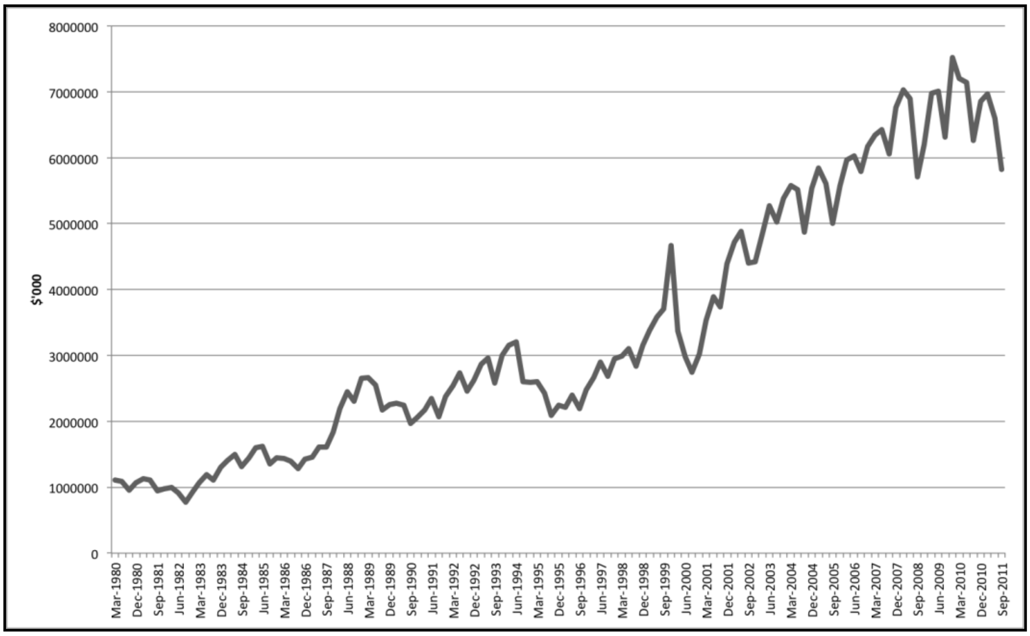
> … the crazy thing is that we, with our slabs, we buy the concrete and we use contractors to put the slab down and the steel and that's the foundations of a house and if we have a problem with the slab, it's us. There's no accountability. We've been trying to get manufacturers to do the supply and install, but they'll want to charge so much because of all the overheads they've got to employ. But the accountability they don't want either, so it's like the shortage of bricklayers. Utopia for us is to get [the manufacturer] to supply and install the bricks—your problem, you make the bricks, but there's no way they'll go near that.

In sum, the large building materials manufacturers supply materials to volume builders. For a few building elements, notably plaster board and roof tiles, they have extended their involvement beyond 'supply contracts' to 'supply and install contracts'. However, the extension of the supply and install type of contract to other building elements, such as bricks and concrete slabs, has not proceeded, despite builders pressing for the extension of 'supply and install contracts'. It seems that the building materials manufacturers have identified too many risks for them in ensuring sufficient timeliness and cost efficiency of installation.

2.3.2 Fluctuations in house building activity

Fluctuation in the level of activity is an entrenched feature of the housing industry. As the Bureau of Industry Economics (1990, p.1) noted at the end of the 1980s, 'housing markets have long been characterised by a high degree of cyclical variability both in output and prices'. This cyclical variability or fluctuation remains a persistent feature of the industry. Figure 7 below presents a trend line for the value of work done on new houses for the period 1980–2011. Indeed, the extent of the fluctuations in the level of housing industry activity has increased since the Bureau of Industry Economics (1990) conducted its review at the end of the 1980s. These fluctuations have an impact on the level and nature of innovation in house building, especially movement towards off-site manufactured construction.

Figure 7: Value of work done on new private sector residential building (houses)



Source: Dalton et al. 2011b

The starting point for making this argument is that fluctuations in housing production are strongly connected to a private housing market where house prices rise. Price increases will produce increased demand for new housing as producers, land developers and builders respond to unsatisfied demand. However, because new housing supply constitutes such a small proportion of total supply, it is sensitive to small fluctuations in total housing demand. As Australian Bureau of Statistics (2010b, p.147) notes, 'changes in overall housing demand tend to induce large variations in the demand for newly built housing'.

The question then becomes what type of industry structure can best accommodate large variations in demand? A follow up question is what is the capacity of this type of industry to innovate at the level necessary for a shift towards off-site manufacture?

In response to the first question about what type of industry structure can best accommodate large variations in demand, it is important to note the Bureau of Industry Economics (1990, p.23) findings that came from their survey of large and small builders:

> As intermediaries who negotiate for the materials and the skills necessary to complete their contract with a purchaser, building firms do not face any major impediments to expansion or contraction. As long as the inputs are available, a building firm can in theory vary its output over a very wide range at little cost.

The Bureau of Industry Economics also noted that 'the very competitive nature of the industry means that errors by one building firm will quickly see its market share taken by another' (1990, p.23). 'Another' in this context can be an existing business, or new businesses because of the low capital requirements required to become a building contractor. In other words, the current industry structure, comprised of firms with low capital to labour ratios able to expand and contract their building activity, is well-suited to variations in demand. This type of industry is not one that has the capacity to set up the factories necessary for large-scale off-site manufacture of building components.

This dynamic and consequence has been demonstrated over time. As Australian Bureau of Statistics (2010b, p.147) argues, large capital intensive builders have found it difficult to accommodate large variations in demand. In periods where prices are depressed, large house builders face competition both from existing owners selling into the market and small builders with low capitalisation. These larger highly-capitalised house builders are not in a position to control the market by simply lowering output and waiting out the market down turn. Instead these larger builders have tended to depend on public sector social housing programs, which supported their development but when funding ceased have disappeared (Ball 2006, p.148).

In Australia this was the case in some states where governments supported the development of concrete slab production in factories. In Victoria this was done through a Housing Commission Prefabricated Concrete Housing Factory at Holmesglen in Melbourne. It mass produced concrete panels that were used to build high-rise and medium density flats and fully detached concrete houses (Tibbits 1988; Eather 1988). However, from the mid-1980s the additions to this public housing stock declined significantly. Correspondingly there has been a growth in the stigma experienced by people living in public housing estates (Palmer et al. 2004) and a collapse in policy capacity for sustaining the existing system let alone its expansion (Jacobs et al. 2013).

2.3.3 Suburban house design and variation

The approach to suburban house design is the third factor mitigating against movement towards less on-site building and more off-site manufacture of dwelling components or whole dwellings. The design approach is characterised by considerable choice of models, choice of options, and provision for purchaser modifications. This approach to house design does not provide the basis for easily moving on-site production off-site into factories. This difficulty in increasing the proportion of off-site production can be appreciated by noting the basic characteristics of mass production. The argument is that the characteristics of factory-based manufacturing production and on-site suburban housing are fundamentally different.

In factory-based manufacturing, labour makes products by assembling standardised parts and this process is often referred to as mass production. More recently there has been the development of production arrangements that seek to incorporate customised features into mass production. 'Mass customisation' (Salvador et al. 2009; Zipkin 2001) is the term that is used to describe this development. However, it nevertheless remains the case that in the manufacturing process the underlying product remains the same but is overlayed with some features that reflect customer choice.

In the case of the Australian suburban house design and builder, there has been little initial standardisation. As described above, the volume builders are constantly developing their house designs. This is usually done when preparing designs for new houses that will be included in display villages. Consequently in a new display village with multiple builders there may be up to 50 houses where all the houses are different. Further, each house design is offered with a choice of façade, there are lists of optional extras and some customisation of the floor plan is also possible. In sum, there is little standardisation of house design.

The full extent of the absence of standardisation is demonstrated by the fact that each house is documented separately. The design process will start with a model selected from the catalogue. However, the variations and additions and subtractions mean that each house is distinctive and will be documented separately in a set of drawings and a specification. Typically engineering consultants will design the footings for each house and then rework the structural design for the chosen façade and other structural changes.

There is therefore no standard product, even within one house building company. Further, the difference in product design increases as builder numbers in the industry increases. The basis for manufacturing, based on repetitive production of the same items is missing. Any move towards off-site manufacturing of the type envisaged by Hampson and Brandon (2004) in housing production would require the development of a very different paradigm for house design, and/or an approach to a 'bespoke' form of offsite manufacturing.

2.4 Summary

The principal question guiding this research asks: 'How is the work of new suburban house building organised and what practices and constraints may contribute to delays in building completion times?' This chapter responded to this question by analysing the materiality of suburban houses and how this has changed. It did this on the basis that house-building practices by industry participants shape the design and building materials and techniques. Expressed in other terms, suburban housing design and building can be regarded as a socio-technical process. It is a technology which, to use Wajcman's (2002, p.542) formulation, is 'a socio-technical product, patterned by the conditions of its creation and use'. Further, because this is a socio-technical process, it is important to recognise the history of suburban housing design and continuing change in design and building practices.

The first section identified the three main types of Australian suburban house structures that form a very significant proportion of the detached suburban housing stock. They are the timber house, the solid brick house and the brick veneer house. In recent decades, it is the brick veneer house on a concrete slab that has become the main type in new house production. However, the proportion of brick veneer houses in new housing production varies across the states and territories. This variance in materials and construction techniques indicates differences in the housing industry across the states and territories.

The second section examined innovation in suburban house building. Product and service innovation is driven both by the exogenous conditions, such as regulation and labour supply, and the continuous redesign of dwellings in a competitive market. It is evident in new products and services in all stages of housing construction. Innovation in processes is evident through increased use of on-site mechanical equipment, mobile telephony and ICT. Marketing innovation is apparent through the way in which the housing industry focuses on ideas in association with particular locations, the buildings, and the people who will live in them. Display villages are central to the way that volume builders create marketing ideas. Innovation in organisation has centred largely on delays and quality by focusing on performance reviews of supervisors and increasing use of building surveyor analyses of building quality.

The third section considered limits to innovation in residential house building. Three limits were identified against the background of a long-term argument for moving housing construction off-site into factories. First, efforts by builders to get the larger building materials companies, such as brick and concrete suppliers, to take responsibility for organising the on-site installation of the products have stalled. Second, the continuing fluctuations in levels of house building make the high level capital investment required to build factories too risky for investors. Third, the multiplication of designs and customisation results in the absence of a standard product that might be produced in factories. In combination, these issues significantly limit the potential for off-site housing production.

There will continue to be considerable innovation in Australian suburban house building of the four types—products and services, processes, marketing, and organisation. However, larger-scale innovation of the type envisaged by the proponents of industrialisation, where components are manufactured off-site in factories and are then brought to sites for assembly, is unlikely. Product components would require standardisation and companies, the existing materials suppliers or others, with access to capital would have to be prepared to invest. The continuing fluctuations in demand for new housing make this type of investment risky.

3 CURRENT PRACTICE IN CONSTRUCTION SCHEDULING

Following the analysis of innovation in suburban house building in Chapter 2, the focus in this chapter is on time management and construction scheduling in the suburban house building industry. It responds to the principal research question: ‘How is the work of new suburban house building organised and what practices and constraints may contribute to delays in building completion times?’ by focusing directly on the practices of time management and scheduling and their strengths and weaknesses. This goes beyond the conventional approaches to the study of scheduling, which is based on a detailed description of the activities required to complete a project and their associated use of resources. The research method used to gather the data for this chapter was to examine time management and scheduling in two large volume building companies. We call these companies, Company A and Company B.

This chapter has two main sections:

1. An account is presented of the methods used to schedule housing building activities for the construction of houses within the two companies and the approach taken to responding to resource requirements and constraints.
2. An analysis is presented of supervisor and construction manager scheduling practices used to deliver completed houses with a particular focus on the practice of recording actual time taken to complete activities in the schedule.

The analysis draws primarily on interviews with supervisors and middle management in the two companies and sub-contractors, service providers and suppliers. It is supplemented with an analysis of production data, management tools and reports made available to the research team.

3.1 Establishing a schedule for house building

Effective house building supervisors manage the sequencing and timing of the activities that are required to deliver housing. They respond to ‘how’, ‘when’, and ‘by whom’ type of questions. A well-developed construction schedule provides answers to these questions. It will include a list of activities that need to be done in order to complete a project; indicate the duration of activities; identify the sequence of activities and the start date and end date of each activity; and identify the material and skills needed for each activity.

A construction schedule helps the builder and the house purchaser know what the completion date of the house will be. Using the schedule, builders can arrange for the supplies and subcontractors to be available at a specific time. Further, the cash flow of the building process can be predicted, monitored and controlled using the schedule. Also, the effect of any changes in the project or any interruption in the construction can be evaluated and rectified (Mubarak 2010).

In this chapter, the term ‘task’ refers to any action required during building construction. It may be an activity with duration or an action with no specified duration, such as filling in a checklist, calling the client or booking a subcontractor. Activities within the schedule have a start and finish date and normally there are resources associated with them. Most of the activities in house building are also related to cost centres in the builder’s accounting system in order to facilitate cash flow management. This section examines how two different house building companies establish a construction schedule for a house building project.

3.1.1 Activity definitions and durations—Company A

Company A has established a 'master' event route to describe the process of building houses. The event route consists of an ordered list of all standard tasks that may be required in the production of a Company A house. There are 196 tasks listed, which include both activities required to deliver a house as well as procedural actions to aid job management. The event route starts with 'file to supervisor' and it ends with 'utilities connections and hand over to the clients'. Every activity in the event route has an associated duration specified in days. For example, 'painting' is allocated seven days; and 'tiling' is allocated five days. The event route also includes actions that are in fact reminders for the supervisors to keep in contact with the client, or to evaluate progress. Despite this, they have durations associated with them. This duration is one day in most cases. The relationships between activities are determined through prerequisite activities. This 'master' event route is used across all housing products delivered by Company A, and thus provides a generic construction plan to assist supervisors in the building of houses.

Although the event route provides a practical platform for supervisors to undertake the tasks associated with building a house, its generic nature presents limitations. In reality, different houses require a different set of activities for completion. As one supervisor recounts, there is a considerable difference between the activities required to build a double-storey house and a single-storey:

> … In the way our critical path is set up it goes frame up, bricklayer or frame and roof cover, bricklayer and then start on the inside with rough-ins. But it doesn't allow for the fact that it's double-storey and scaffold has got to go up … That's where that delay is coming from there … whether you're building a single or a double you just basically have to know … we've got to just juggle when things happen. (Company A, Supervisor)

While a critical component in the delivery of a two-storey house is the erection of scaffolding, the 'master' event route for Company A does not include an activity for this as it has been developed based on single-storey construction. It therefore relies on the job supervisor to ensure scaffolding is erected onsite at the appropriate time. Given that scaffolding is a prerequisite for a number of tasks in the construction of a two-storey house, delay in this task can have a significant impact on construction time. Yet this delay would not be reflected in the schedule. There are many more activities that are particular to two-storey construction, that are not reflected in Company A's event route. Timely completion of jobs is very much dependent on supervisor knowledge and project management skills.

Another issue in construction scheduling are activity durations. Theoretically, the duration of many activities required to deliver a house should vary according to the specific features of the house. For example, we would expect the duration for the 'framework' task in a 130 square metres house to be less than that for the same activity in a 230 square metres house. Such differences in expected activity durations would be considerable when considering the difference between single and double-storey houses. However, in the Company A scheduling system these differences are not recognised. The same length of time is set for each activity regardless of the type or size of the house. One supervisor, when reflecting on the activity duration for rendering exterior walls stated:

> … I'm pretty sure they only allow … like one day for base coat one day for top coat. To do a double-storey house it takes a week, a week and a half. (Company A, Supervisor)

Consequently, supervisors pay little attention to the duration of activities in the schedule and rely instead on their knowledge of activity durations based on particular job characteristics.

In the example of wall rendering, it was reported that the completion time for the activity is frequently greater than the time allowed, especially for double-storey houses. However, other activity durations do allow for significant contingency and do accommodate differences in features and other potential causes of delay. For example, laying a concrete slab is an activity that is critical in the first phase of house production, and is prone to weather delay. As a manager at Company A puts it, 'I call a slab two weeks but I could get it in five days' (Company A, Building Manager).

Ignoring the differences between different houses in the task list affects the utility of the schedule in managing construction. The generic nature of the event route used in Company A means that in practice it is a flexible checklist of sequenced activities rather than an accurate schedule of required activities. Supervisors choose the activities in the checklist that they judge to be appropriate for a given house and ignore the others. The event route at Company A therefore provides limited capacity to support supervisors in scheduling the activities required to build and complete houses on time.

3.1.2 Activity definitions and durations—Company B

As with Company A, Company B has generic lists of all tasks potentially required to build one of Company B's houses. However, an important difference is that Company B has two generic lists, one for single-storey, and one for double-storey production, recognising the significant difference between the two. The two lists consist of different tasks (although the majority are the same); and also different standard durations for each task. There are 214 tasks within the single-storey template and 234 tasks for double-storey template.

Unlike Company A, Company B allows for the customisation of these generic task lists to match specific jobs. In Company B, the scheduling process flows from the design documentation for each house. After the design is completed for a specific house, the bill of quantities is produced, and all the required purchase orders are listed. When a job is allocated to a supervisor, the system generates a task list based on the specific purchase orders that have been raised. It does this by matching purchase orders with the relevant generic task list (single or double-storey), and relates tasks to purchase orders. The supervisor thus ends up with a customised task list for the specific house.

The scheduling system in Company B has a capacity to accommodate new tasks and new construction methods. Since the tasks are derived from the bill of quantities, if there is a new item without a task associated, the system flags this item and asks for a new task to be defined. The Business Analyst Manager provides an example:

> … we used to have a separate company do the flashing and guttering and then we brought them in to line, so we had to adjust the matching rules, because now we're ordering it in a different way. (Company B, Business Analyst Manager)

In Company B this finer grained analysis of tasks required to build single and double-storey houses has been extended to recognise different build times for single and double-storey houses. This recognition has been established by acknowledging that the time required to complete tasks in a double-storey house will take longer than in a single-storey house. For example, the 'framer' activity is allocated six days for a single and 12 days for a double. The 'bricklayer' activity for a single is 12 days, while for double there are two separate activities: 'bricklayer—ground floor' is allocated six days; and ‘bricklayer—first floor’ is allocated 13 days. This recognition of the different activities and the time required to build double and single-storey houses means that the supervisor schedule in Company B provides more guidance on job management than in Company A.

In Company B, recognising the different amounts of time required to complete tasks in house building has been deliberately limited to distinguishing between single and double-storey houses. Different house characteristics, such as size or design features are not reflected in build times set down for different tasks. Although the ICT system does have the capacity to reflect different house characteristics in schedules, a decision has nevertheless been made that this would overly complicate schedules and not aid project delivery. The Business Analyst Manager at Company B describes this functionality and notes the management decision:

> For example … we can look at the purchase order, the system will look at the purchase order and say it’s 60 square metres of ceramic floor tiles to be done. And the standard allowance is three days for that work to get done. It can look and say well, hey, for every 20 square metres above 60, add an extra day on that, on to that tradesperson and add it to the timeframe for the job. So you can set up those rules for anything in there. And, in discussion with the building manager, his point of view was, no, you’re trying to be too fancy now. (Company B, Business Analyst Manager)

The first step in scheduling a construction project is to list activities needed for the project to be completed. Activity lists in Company B are compiled by producing a customised list that is house specific derived from the bill of quantities and purchase orders. This is a more accurate representation of what is required for particular houses than the generic activities list produced in Company A. The difference between Company A and Company B is further evident in the Company B practice of recognising the different time required for the same activity in single and double-storey houses. However, Company B has not extended its recognition of actual time taken for activities to include the differences between different house designs. This ultimately limits finer grained scheduling of particular jobs and scheduling of workflows associated with the production of multiple houses.

3.1.3 Establishing resources

An important aspect of scheduling in any project is identifying resource requirements and constraints. In residential housing construction, these resources are supplied to each site through three forms of contract—labour only sub-contracts, supply contracts and supply and install contracts. If the completion of any of these contracts is delayed either through difficulty in obtaining materials that arrive on site through supply and install contracts and supply contracts, or delayed arrival of sub-contractors then the timely completion of on-site tasks can be delayed. This possibility is not recognised in the scheduling practices of Company A and B. Both companies assume that subcontractors and materials supplies are always available or that the construction manager or supervisor will find a way of overcoming resource constraints.

Although it is assumed in the scheduling that there are no resource constraints in the schedules it is also common knowledge at times that there are both materials and sub-contractor constraints that can affect job delivery. For example, in Company A, before construction starts, a supervisor usually contacts the concreter and checks their availability. One supervisor explained that he sets the date for the commencement of a house only when he has agreed a date for laying the slab:

> … So basically when we get a file one of our first phone calls is to skip half of these things and go to your concreter and go, okay, when are you available

> because then you go, right, okay, I'll work from that date backwards. (Company A, Supervisor)

However, this availability check is limited to concreters. Once the concreter is locked in, all other activities are scheduled without checking for resource constraints. Checking the availability of other subcontractors becomes the supervisor's 'on the job' responsibility in conjunction with their construction manager.

Despite this limited engagement with resource availability, there is evidence that resource constraints do affect job delivery times. The timely supply of bricks supply is a well-known issue in the industry. This stems from purchasers choosing from brick manufacturer catalogues presenting many styles where the stocks of some of these styles are limited. As a Company A supervisor noted:

> We do have issues with brick supplies as far as the availability of bricks. The client might say I want this brick here but they're unavailable. Now the client has the option to wait for those bricks or re-select basically. So that plays a big part in the critical process of late as well. That's probably the only major supplier issue.

Also the availability of bricklayers is well known as an issue. A construction manager from Company B noted:

> I know again over the years where there's been bricklayer shortages which generally if it's affecting us, it's affecting everyone else in the industry, from the smallest builder to the largest.

Then there are constraints that appear when there is a high level of demand in the industry. An example of this is in the supply of roof trusses. A Group Technology Director for a truss manufacturer described how the timely supply of trusses can become constrained in periods of high demand:

> … the normal lead time is two to three weeks, and during very frantic periods of construction, like two years ago, it could be six to eight weeks. (Group Technology Director)

In summary, in the volume building industry the general practice is to assume that there are no constraints in the supply of resources. For much of the time this appears to be a reasonable assumption to make. However, it is clear that in some labour and material areas, and especially in times of high demand, resources are constrained. At present there appear to be no mechanisms in the industry to systematically anticipate and respond to resource constraints via job scheduling.

3.2 Scheduling in management jobs and improving practice

Construction planning is not limited to scheduling at the beginning of the project. Normally it continues throughout the project by using it to benchmark construction progress. The initial schedule determines the completion date for a particular house building project. However, there may be changes required during construction and changing the schedule can help in reorganising tasks and times in order to meet pre-set completion target dates.

In day-to-day house building operations in volume building companies, construction schedules form the basis for conversations between construction managers and the supervisors who report to them. Further, these schedules for individual houses can be drawn together to establish an overall operation schedule. This overall schedule can be analysed in ways that gives construction managers and senior managers greater insight into their operations. However, if operational schedules are to be used in this way by managers, a precondition is that there must be accurate data entry that records the actual construction process. Performance analysis can only be done by analysing data that records tasks and time taken for all jobs that are underway. This section examines how the two different house building companies actually use construction schedules in the process of delivering house building projects.

3.2.1 Scheduling at Company A

The Company A scheduling system is based on the 'master' event route which is translated into a schedule for each house. When the construction manager receives a construction order, the construction commencement date is entered into the system and all activity completion dates are automatically forecasted based on the information contained in the 'master' event route. This schedule is given to the supervisor and forms the basis for the progress meetings where supervisors report to their construction manager.

Because the schedule at Company A is generic in nature, supervisors use the schedule more as a checklist than as an active scheduling tool. The supervisor determines which tasks to implement and when. They check off activities when they are completed and enter a completion date into the system. This process supports overall monitoring of the job against the generic event route. As a Company A supervisor noted:

> … we have like a critical path which … it basically says when each stage or when everything is supposed to be completed … Now me staying ahead of schedule, behind schedule, is whether I'm ahead of what this is saying is the perfect model. … each week we get basically, it's sort of a review of each job that we're running at the moment against that perfect model.

In other words the schedule is used as a general indicator of progress, rather than providing targeted assistance. In practice, supervisors tick off activities as they progress, rather than accurately recording commencement and completion times. Supervisors will frequently reorder the sequencing of activities without changing the schedule. In explaining an apparent delay in the recorded details of a particular project, a Company A supervisor provides an example:

> … depending on the block we may get … we assess the block whether sediment control is going to be required before the slab can be poured or not. So, in this instance, here the sediment control was installed after the slab was poured … So it's just where it's come up in the order of the way things are done.
>
> *Interviewer*: So there was no delay whatsoever?
>
> No, no delay, as far as the job went ….

Also supervisors in Company A will frequently record completion dates for activities well after they were completed. Typically this was done just prior to a meeting with their construction manager. A Company A supervisor explained:

> Some of the things in here won't have been critical to the build, so I could have just not ticked them off as being completed because they weren't actually relevant and I just sort of let them sit there until whatever.

Also supervisors will often mark activities as complete before they have been completed in instances where the activity is judged to be 'non-critical'. A Company A supervisor explained this approach to data recording:

> [The recorded completion date against 'Cross over to driveway'] … that is just data entries looking at it now. I've ticked off that it's completed before it

actually was completed. I mean there's a … the way we run the call forwards sometimes there's things that aren't really critical.

In sum, the fact that the activity list, durations and schedule are not customised to particular jobs appears to support this practice of ‘checking off’ activities rather than detailed recording of activity progress.

As noted above, house schedules can be aggregated into an operational schedule and be used to improve company operations. For example, the work of one sub-contractor performance across a number of houses can be assessed. In this way operational schedules can be used to identify where there are systemic problems and provide the basis for considering options for improvement. However, this type of analysis does need accurate data that is an accurate reflection of what happened on construction sites.

The practices of recording job progress at Company A mean that evaluation of job progress at the activity level is difficult. Table 3 below presents data from analysis conducted on scheduling data for 35 houses at Company A. The analysis sought to determine the average completion time for each activity in the event route, and through this identify the activities that were frequently in excess of their scheduled duration. The table shows the top 10 activities for delay, based on scheduling data. As shown in this table, the most frequent delays have happened in the ‘lock-up’ and ‘heat and cooling rough in’ activities. All these ten activities have been delayed in more than 50 per cent of cases. The highest average delay has been evidenced in the delivery of ‘early brick or tile’.

Table 3: Top 10 activities for delay based on scheduling data (Company A)

Activity name	Frequency of delay (%)	Average delay (days)
Lock Up—Carpenter	76	9
Heat & Cooling Rough In	75	7
Brick Hardware	74	5
Lock Up—Materials	70	6
Temporary Fencing	66	9
Slab Preparation	63	5
1st Brick Sand Delivery	63	5
Roof Truss—Schedule In	53	8
Fascia & Gutter	52	4
Early Brick/tile delivery	52	12

According to this analysis, improvement in the delivery of these activities would significantly improve the timeliness of operations in Company A. However, supervisors and managers at Company A confirmed that many items on this list of delayed activities are there because of the way supervisors use the schedule. That is, supervisors use the schedule more as a checklist for calling up resources and completing activities, and not for accurately documenting the building process. While on the ground this may not affect the ability for experienced supervisors to deliver individual houses, it limits the ability for any analysis of the company’s operation-wide production system.

This approach to scheduling in Company A indicates that emphasis is placed on the ability of supervisors to manage jobs using tacit skills, rather than formal systems. In this context, 'tacit skills' is the intangible 'know-how' of workers that is often taken for granted, but is essential in successful businesses (Bowman 2001). In the case of Company A, supervisors have acquired these skills initially as carpenters and then by being mentored on the job by their construction manager. A Company A supervisor describes the process and demonstrates how he relies on know-how gained through 'on the job experience' as he describes the call-forward he will do early in the construction of a house:

> … much of it was put on the computer, and I can look on the screen and go through all my jobs on the screen … But generally, from my experience, I know exactly what I need to do. … So I know, I know when I've got the concreter booked, I know, well, basically, I program, you follow a job, and the concrete is starting, say, tomorrow, which is Thursday, I know in my mind who's going to do the frame on that next Tuesday/Wednesday, and at that stage I'm thinking about who is going to brick it up the following week. So I can program in my own head and say, right, okay, you're going to finish that job, from there that framer will finish that job, you can brick that up after he finishes that, and that's the way I try and coordinate …. (Company A, Supervisor)

A senior manager from Company A endorses this approach.

> Every supervisor has a tablet or a laptop and they manage their jobs off a laptop … you can't manage your job off a laptop. It's a great information source, it's a great back-up, but they wait for their computer to tell them what they should be doing next, not thinking and planning what they should be doing next … the system that Jennings implemented was the system that … that I grew up with, and that I now push into all of my construction teams. And it was a simple basic call forward, a simple diary to run … You know how to run a call forward, you know how to be somebody who can manage people, you're going to get results.

Thus the approach adopted by Company A is on the importance of having engaged, knowledgeable and skilled supervisors, rather than using formal ICT systems to manage house building. Supervisors regard the schedule they use as the 'ideal'. It provides them with a starting point for each job, an event route, which is then used iteratively to track and plan the job.

3.2.2 Scheduling at Company B

Company B has in place a scheduling system that establishes a custom schedule for each house derived from the bill of quantities for each house. The duration, however, is a standardised time for either a single or a double-storey house. The full duration is set based upon standard time durations for the different building elements and does not allow for any variation for size or design features. Therefore, the schedule accurately sets out all the tasks for each job, but with standardised durations.

Each schedule includes expected completion dates for the five main stages of house construction: slab; frame; lock-up; fix; and final. Construction managers and supervisors use these dates to track job progress at weekly meetings and the supervisor sets times for individual activities within the five stages. Supervisors forecast ahead for a period of at least one week and two weeks where possible by entering a call forward date for each activity, which is the date that an activity should start based on the customised schedule. When an activity has been completed supervisors are required to log a completion date.

In Company B, this process of logging a call forward date activates a purchase order. The exception is when activities require a 'varied supplier'—that is, suppliers that may vary from supervisor to supervisor. These varied suppliers are sub-contractors such as concreters, frame carpenters, lock-up carpenters, bricklayers and painters. A Company B, construction manager explains:

> … we call those contractors a 'varied supplier', because the supervisor will actually engage the required contractor to do those works, so he'll have a bricklayers' order, a concreters' order for the slab and just the typical, I don't know, I suppose the contractors that would float from builder to builder … Most of our supervisors again they'll have a steady concreter, a steady carpenter….

Most of the other contractors are automatically engaged via the scheduling system. They are the larger subcontractors, in particular electricians and plumbers, and other supply and install subcontractors. The Company B business analyst manager explains:

> … here, when a supervisor says deliver the bricks, doesn't need to know what bricks. We don't actually send the purchase order information again. Okay? Purchase orders have already been e-mailed out to all suppliers. So we've already distributed all the orders to all suppliers before the job goes to site … We're just basically saying now, hey, deliver that order ….

A further level of automation of the call forward process has been implemented at Company B by identifying key activities in the schedule and linking them to other related activities. In other words, the relationships between activities has been determined and built into the call forward process. Supervisors can elect to automate the call up of linked activities based on the call up of one key activity. The Company B business analyst manager explained:

> … when the supervisor calls up earthworks, he has the opportunity to say yes, all the linked tasks, call them up for me. So he just puts in earthworks, the system says, okay, well, two days after that start, I need a steel fence. Three days after I need the waste cage, four days after I need the temporary fencing. And he can automatically call all of them up and add those extra days automatically to them.

Company B uses ICT to support scheduling by supervisors based on three components. First, use of the scheduling system is required and supported by senior management. Second, it relies on continuous development of the functionality of the system so that it incorporates changes in activities comprising the schedule; interfaces with other internal systems and external provider systems; and supports data recording. Third, considerable effort is made to develop the skills and confidence of supervisors to use the ICT system. The Company B business analyst manager explained the importance of supervisor skill development:

> When we rolled it out, I was, myself and one other guy, we spent three days to a week with every supervisor, where we actually just went out in the car with them and just helped them. One-on-one … the key to it was basically following up all the issues and everything, every template issue I had, every supplier issue I had, they were number one for me. It was like resolve, resolve, within 24 hours, so that people had the confidence in the system that they think this is working.

The detailed nature of the system and requirement to record call forwards and completion dates now supports detailed reporting on company-wide practice. Company B now generates regular reports that are used by supervisors, construction managers and senior managers to reflect on the efficacy of the system in the context of continuing changes in designs and building technologies.

One means to evaluate the efficacy of the system is to focus on non-standard purchase orders. Every time a non-standard purchase order is raised, an 'auto' task is generated with the purchase order name. This means that the number of non-standard tasks can be tracked and if a non-standard task appears regularly it can be reviewed and possibly added to the generic task list. In this way, the generic task list evolves to reflect new construction methods, materials use and designs.

The weekly meetings between a supervisor and construction manager centre on a 'progress report'. A supervisor's progress report summarises the stage reached on all jobs against the five main stages of house construction. This enables the construction manager to know whether a job is ahead or behind the time allowed in the schedule for either a single or double-storey house. If a job is significantly behind schedule, a construction manager can examine the call forward and completion dates for each task and ask the supervisor to explain any delays. As the Company A business analyst manager explained, the system does provide for call-forward automation but this should not lead supervisors to 'set and forget':

> … When they come in on the, on a Wednesday and go through it, [the supervisor has] actually got to tell the construction manager what work they're expecting to get done. It's not a set and forget, it's not a, 'oh, just put it in the system and' … no. He needs to know what's going on.

As well as assisting in the management of individual jobs, the scheduling system is used to generate regular reports to aid construction managers and senior managers in other ways. The 'labour allocation report' presents data on the broader use of the Company B subcontracting labour pool. This enables construction managers to analyse how the pool of subcontractors is being used—to what extent, in what locations—which in turn helps construction managers assist supervisors to use 'varied suppliers' in future work. This report becomes particularly important in periods of high demand for housing and labour shortages.

A 'supplier call-back report' summarises the number and nature of call-backs for each subcontractor being used by the company. Supervisors are required to log supervisor call-backs which happen when a supervisor contacts a supplier because a task has not been completed. This results from a supplier not meeting purchase order obligations, such as incorrect delivery of materials, or a delay in getting materials or labour to site. Supervisors are always required to document a call-back. This data then enables company managers to identify and evaluate the performance of suppliers across all jobs.

At the senior management level, the most important report generated by the scheduling system is the 'aggregate workflow' report. This report provides a snapshot of aggregate construction activity. It displays for each construction manager the number of houses and associated progress claims for each of the five construction stages. It enables the senior managers to assess cash flow and to determine the balance of jobs across the five production stages. A business analyst manager at Company B describes how senior managers value this report.

> … this is something they look at if not daily, all the time … to see where we're at. And how many jobs that we've got at a particular point … one of the, the issues that we've been having over the last 12 months is that we've had too many jobs at the final stage. … it's the worst in terms of dollars and it's the longest time frame in the whole process.

In summary, supervisors at Company B are relied upon to coordinate the build, and manage the 'varied suppliers' and quality of their work. Their know-how built up through years of on-the-job experience is central to their capacity to do this work.

However, Company B, in contrast to Company A, requires supervisors to use ICT systems that provide detailed guidance on when to call-up resources, record when the work has been done and record when work is not complete and requires a call-back. The data that is generated through this process is now used extensively within the company to review performance and make management decisions.

3.3 Summary

This chapter presented an analysis of construction scheduling and time management in suburban house building. It did this by comparing two case study volume house building companies of similar size that we call Company A and Company B. Both Company A and Company B use the traditional approach to volume building that places supervisors and their managers at the centre of managing individual house builds. The supervisor coordinates supply, supply and install and labour only sub-contractors that are used to build each house. These supervisors are supported by head office support functions including tendering, design documentation, materials selection, labour procurement and production management systems support.

The systems used to support the scheduling and time management of house production were the focus of this chapter. The resulting analysis was organised around two dimensions of scheduling. The first dimension is the type of system adopted by each company to schedule housing building activities used to construct houses. The second dimension is the nature of the supervisor and construction manager practices used in each company on a daily basis to schedule activities used to deliver completed houses.

The analysis showed that these two companies have developed quite different approaches to the challenge of scheduling and coordinating the building of increasingly complex suburban houses.

Company A has developed a generic scheduling system that is not customised at all to its different products. It is a ‘one size fits all’ checklist of activities that guides supervisors on the nature and sequence of activities required to deliver a house. This company emphasises supervisor responsibility to know what work has been done on-site and when to issue call-forwards. This approach rests on the tacit skills of supervisors and construction managers to manage the build process. This is a well-established method of construction management in the industry. However, in the context of increasing complexity and the increasing number of discrete activities required to build a standard suburban house, the question remains whether this is sufficient. Further, limitations in the documentation of progress on each project limit the ability for company-wide analysis, and thus make identifying efficiency gains that might be revealed by a production system perspective hard to identify.

Company B has developed its scheduling system and it now stands in contrast to the system used in Company A. It distinguishes between single and double-storey houses and produces a house specific schedule based on all the activities required by the bill of quantities. The schedules can also be modified to reflect changes in house design and building practices. Supervisors are required to record call-forward and completion dates for all activities and the system provides a semi-automated call-forwards process in an effort to automate some supervisor work. The system is then used to produce a series of reports, which are used by managers at all levels to review performance and make decisions.

In an effort to better understand delays in the volume building industry, this chapter has presented an analysis of the scheduling of house building by contrasting the approach of two companies. However, it is not possible to say based on this research how the scheduling approach of each company affected the build times of each company during the period of high demand during the late 2000s or reduced demand since then. Research data that would support this more extensive analysis was not sought nor could it be expected that private volume building companies would provide data of this nature in a highly competitive market. Instead, it is sufficient to demonstrate for purposes of this research that senior managers in both companies pay considerable attention to scheduling and improving the coordination process. However, the way they go about it is quite different.

There are efficiency gains to be made on volume house building by incorporating production system ideas into management processes. Production system thinking goes beyond management arrangements that approach house building on a house-by-house basis. Instead it recognises interrelated dependencies and knock-on effects and seeks to respond to them. Innovation in construction scheduling and related ICT in many parts of the industry is limited, but it is occurring and there is potential for considerable extension. Further research could explore the barriers and enablers for the greater use of scheduling that is able to support more sophisticated and integrated construction management in volume building.

4 HOUSING PRODUCTION MODELLING AND ANALYSIS

In order to extend an understanding of housing production systems, this chapter reports on the development and application of a simulation model designed to simulate aspects of the volume housing production system. It draws on research undertaken in the Virginia Centre for Housing at Virginia Polytechnic Institute and State University (O'Brien et al. 2002; Wakefield & O'Brien 2004; Wakefield et al. 2001) and in the RMIT School of Project Construction and Project Management (Gharaie 2011; Gharaie et al. 2010).

In the Australian context, it presents further evidence that applying production modelling thinking to the analysis of on-site building of suburban detached houses can produce important new insights about why the time taken to build suburban houses has increased. In particular, it assists in understanding the operations of volume builders that construct between 35 and 40 per cent share each year of the total supply of detached suburban housing.

The chapter explores the usefulness of production modelling ideas to suburban housing production. It begins by making a link between the current context of undersupply and increasing build times and interest in production system ideas. The chapter then presents a discussion of housing production that focuses on what can happen when production conditions change. This is discussed through:

- An outline of housing construction simulation modelling (HCSM) and a discussion of the effect that the day-to-day can have on the builder operations.
- Exploration of the effect of change in the availability of resources on production processes.
- Exploration of the effect of increases in the number of houses under construction at any one time.

The conclusion is that production system thinking does assist in identifying and analysing the issues that confront volume house building companies and the capacity of the housing industry more broadly.

4.1 The production system idea

In the most recent housing construction boom, it became clear that there have been systemic changes in the industry that have implications for the capacity of the industry to meet demand. Three endogenous changes found within the operations of the volume building companies themselves were identified and discussed in the position paper (Dalton et al. 2011b). They were:

- The number of contracts used to build suburban detached housing has grown significantly in recent decades. This growth has resulted in making the job of coordinating house building undertaken by supervisors more complex.
- Volume house builders now offer purchasers more variety and choice. This choice is evident in the growth of model numbers and options for 'customising' each model resulting in decreased product standardisation.
- Poor quality of work identified by building surveyors and volume builder quality systems requires call-backs for the rework necessary to bring components of the building up to the required standard.

In addition, there has been pressure on the housing industry from shortages of skilled labour particularly during the late 2000s. This shortage of skilled trade labour has a number of sources including in the weakening of the apprenticeship and training system and the movement of workers into other parts of the construction industry (Dalton et al. 2011a, ch 4). These changes in the industry have affected the ability of the industry to meet housing demand in peak periods. Gharaie (2011) presents evidence of the limited capacity of the industry to respond to demand in the most recent period and shows how build times have increased.

This is the context for focusing on the idea of production systems used in manufacturing industries and considering how this idea might help identify structural limitations of the current system. It follows an earlier application of these ideas both in the USA and Australia. A previous period is the one stemming from the demand from baby boomers in the 1960s and 1970s in the USA that led to the Operation Breakthrough program in the USA (O'Brien et al. 2000). In the Australian context, it assists in explaining the large scale post-war public housing program in Australian capital cities and provincial centres (Berry 1999).

A feature of these responses was the increased interest in the way that housing is produced and the possibilities for greater use of mass production techniques developed by manufacturing industries. It is important to note that this interest was being expressed when there was more tract type building of houses and where there was little variation in floor plans and styles. In the Australian context, this is evident in the traditional public housing suburbs of both Sydney and Melbourne from the 1950s through to the 1970s.

It is well known in operations research that constrained resources, random entries to the production process, variable activity times and interruptions to the production process due to rework, inclement weather or equipment breakdown result in delays and instability in the production process (Gharaie 2011). A response has been to develop and use simulation models that can help understand the behaviour of production systems (Hopp & Spearman 2008; Mubarak 2010). This in turn has led to the development of management approaches that aim to improve efficiency and reliability of those systems.

This approach to house building has informed the development of a model that takes all the constituent production activities required to build a detached suburban house—for example, slab construction, framing, roof tiling etc.—and put them into a sequence. Further, knowledge of how houses are built has guided the sequencing of these activities that ensures that activities are linked and logically follow preceding activities. For example, a frame cannot be constructed until the floor slab has been cast; roof trusses cannot be fixed until the wall framing has been completed; and the plaster board internal wall sheets cannot be fixed until the plumber has finished the pipe work and the electrician has finished the electrical wiring.

In other words, this model represents the necessary sequencing of many activities. It is then used to assist in comprehending the complexity and interdependency of the production system used by volume builders who work with many subcontractors to build a house on-site.

The model has been developed so that it has the capacity to explore how resource constraints can influence the time taken to complete basic work tasks brought into the on-site building process through the contract system. The particular work tasks included in this model are those contributed by the concreter, the plumber, the carpenter undertaking wall framing and the plasterer. Below various scenarios are explored by making assumptions about the availability of these four types of contractors and the increase in completion times if the builders have to wait for one or more of them to complete their component. While the model simplifies the production process, it nevertheless assists in comprehending the implications of resource constraints; and it can inform consideration of strategies that might improve the performance of builders.

4.2 Housing construction simulation modelling: the HCSM

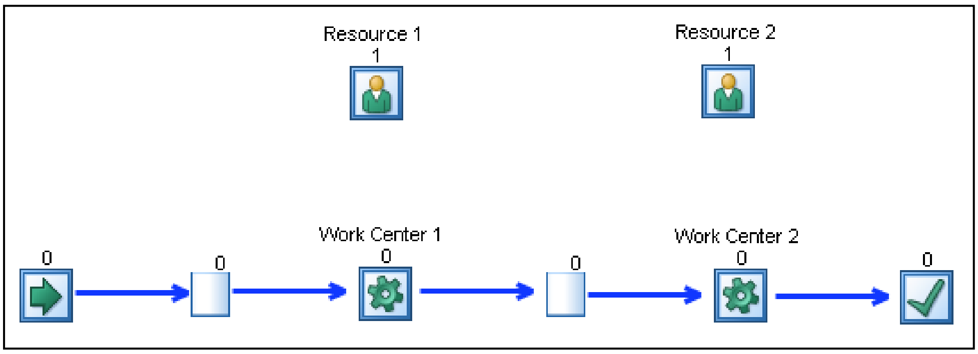
The following section uses the House Construction Simulation Model (HCSM) to investigate how variations that occur in day-to-day operations of builders affect the efficiency of the volume housing operations of one builder. Assumptions that are made in the development of various scenarios are the following:

- *Infinite resources*, which can be described as the ideal operating environment that ensures that one or many houses are completed in the minimum time.
- *Constrained resources*, where the supply of resources, including materials and labour, is constrained either by the market or through use on other projects in the organisation.
- *Rework and call-backs* which are necessary when the job is not ready because the preceding trade has not finished or has made a mistake that requires rectification.
- *Different time durations for particular production activities* that relate to the size of each trade crew and their efficiency.

The HSCM model uses representations of resources and work activities that combine resources to represent the construction process.

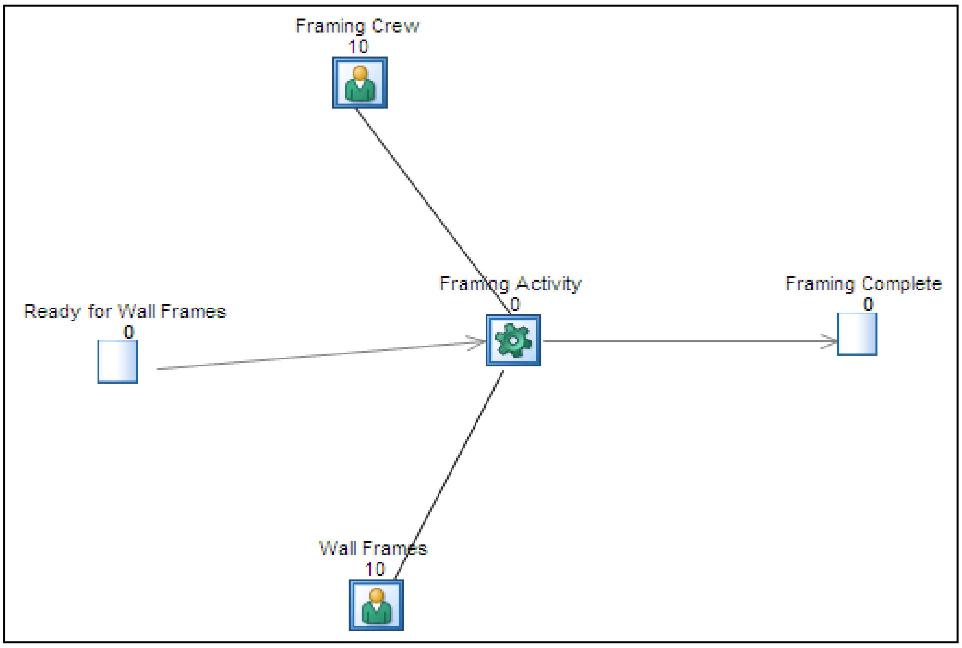
Figure 8 below shows a very simple system model with two work centres, where each work centre can only undertake work when a resource is available and the previous activity is complete. If we use housing construction as an example, the arrow graphic represents a customer signing a contract for a particular house, a house is in the production queue (represented by the tank icon), Resource 1 is then the plumbing crew who will trench the underslab plumbing before the slab is poured. When a house is in the queue and a plumbing crew is available, the underslab plumbing can take place, depicted as 'Work Center 1'. Once the underslab plumbing is complete, the completed underslab plumbing enters the next queue. When Resource 2, the concreting crew, is available, the slab concrete can be poured and finished.

Figure 8: Representation of a simple simulation model



The graphical representation of the later wall framing activity is illustrated in Figure 9 below. The tank icon 'ready for framing' indicates that the previous activities have been completed. This means that when the resources, 'wall frames' and 'framing crew', are available the 'wall framing' activity can begin. When that activity is complete the house under construction is ready for the next activity such as brick veneer walls and roof trusses. In this way a simulation model of the whole construction process for a suburban house has been developed.

Figure 9: Wall framing in the simulation model



The full model is based on the list of 180 work tasks supplied by Company A, referred to in the previous chapter. Company A has developed this list of work tasks, which supervisors use as a checklist and guide for sequencing call-forwards and sign-offs. As is evident from the discussion in the previous chapter, Company A supervisors do not use this list as critical path documentation. Instead they use their knowledge of housing construction and their tacit skills in organising subcontractors, supply contractors and supply and install contractors. They use this list of work tasks to check and record activities that have been completed. In this context, the HCSM has been developed based on the activity list and descriptions of house building by supervisors and the research team's own knowledge of housing construction.

The HCSM has been calibrated using the activity times from Company A that sets a house completion time of 160 days. This completion time assumes that all resources are available when required and each activity takes the specified time. Further, each supervisor employed by a production builder is likely to be supervising between 10 and 15 houses that are at different stages of construction. As shown in Chapter 3, the supervisors are the primary schedulers and managers of resources, the materials and sub-contractors, which are the heart of the house building process. Supervisors are in turn organised into groups that report to a construction manager who coordinates the flow of resources between supervisors, especially sub-contractors.

4.3 Production process dynamics

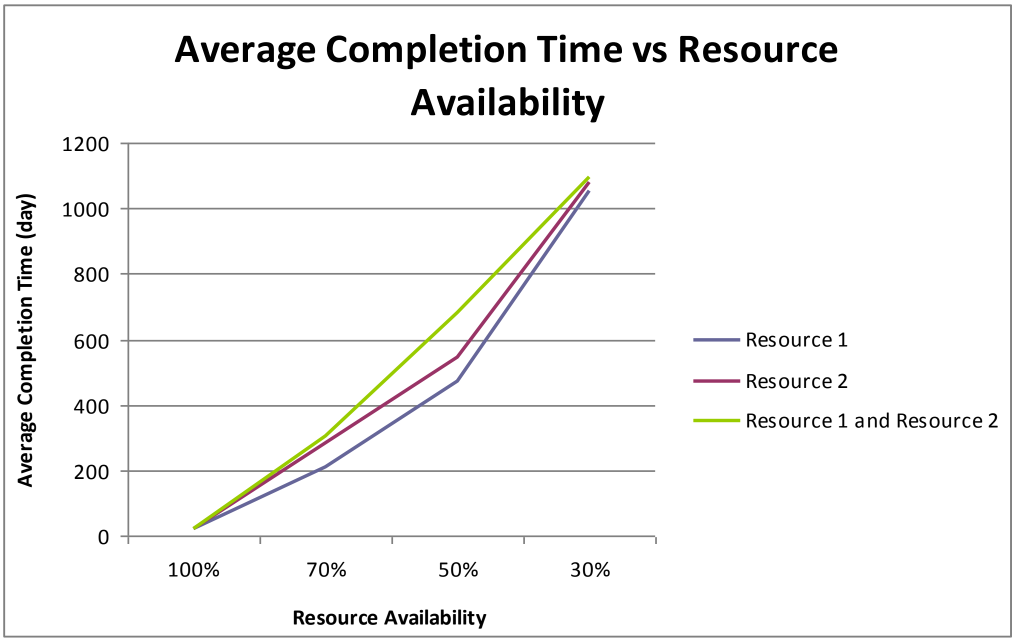
In this section the dynamics of the production process under different resource scenarios is explored using the HCSM for just two resources. In this example we assume that a contract for the purchase of a new house is signed every 10 days, that is, for three houses per month. This is not dissimilar to the situation for a supervisor working for a volume builder when housing demand is relatively low. For the purposes of this illustration, the two resources are the underslab pipe work and placement of the reinforcement for the waffle slab that takes 10 days to complete; and slab concreting that is completed within 10 days. This approach is illustrated first for 10 different combinations of resource availability for just two resources in Table 4 below. Figure 10 below shows the effect of constrained resources.

When the resources are always available, that is, there are infinite resources; the two tasks are completed in 20 days with no delays in the system. Work using the two resources on the 100 houses is completed in an average time of 20 days per house. In run number 2, the first resource is only available 70 per cent of the time, that is, for 30 per cent of the time that the plumbing crew is working on other sites. The second resource remains available. Work on the 100 houses using the two resources is now completed in an average time of 207 days per house. Another eight runs using different levels of availability for these two resources are calculated. This demonstrates how quickly a resource-constrained system can become relatively unstable and delivery times extend rapidly.

Table 4: Results of simple HCSM tests

Run No.	Resource availability scenario		Work complete: average no. of days in system	Queue for work centre 1: average queue size	Queue for work centre 1: average queuing time	Queue for work centre 2: average queue size	Queue for work centre 2: average queuing time
	Resource 1	Resource 2					
1	100%	100%	20.0	0.0	0.0	0.0	0.0
2	70%	100%	207.2	1.8	187.2	0.0	0.0
3	50%	100%	471.1	4.5	451.1	0.0	0.0
4	30%	100%	1051.1	10.3	1031.1	0.0	0.0
5	100%	70%	285.3	0.0	0.0	2.7	265.3
6	100%	50%	544.9	0.0	0.0	5.3	524.9
7	100%	30%	1079.3	0.0	0.0	10.6	1059.3
8	70%	70%	302.8	2.1	215.5	0.7	67.3
9	50%	50%	680.4	6.3	629.2	0.3	31.2
10	30%	30%	1092.9	10.3	1032.2	0.4	40.7

Figure 10: Results of simple HCSM tests



4.4 Extending the HCSM analysis

In this section the analysis using the HCSM is expanded using different numbers of new houses commenced each month and the inclusion of four resources. In the absence of accurate real time data from Company A, assumptions have been made about the availability of resources. The assumptions are then varied as shown in Table 5 below.

First, the number of contracts for new houses signed off every month is varied: one house every 20 days, 15 days, 10 days and every five days. The frequency of house starts represents the level of customer demand in the system. For instance, in busy periods it would be reasonable to assume that a production builder may start a house every five days or begin six houses per month. In slower demand periods they may only start one to two houses per month. The simulation model can be assumed to represent one construction manager's work, where a construction manager may be responsible for five to 10 supervisors, who are supervising the construction of 10 to 20 houses.

Second, resource constraints are introduced in the model for four of the major subcontracted resources, concreting, plumbing, wall framing and plastering at levels of 100 per cent, 70 per cent, 50 per cent and 30 per cent availability. The 70 per cent availability figure means that the resource is only available 70 per cent of the time throughout the simulation. In other words, when the resource is required there is a 70 per cent chance it is available and a 30 per cent chance that it is otherwise engaged, for example. working at another site.

The model was run with constraints applied to each resource in turn as shown in the first four sections of Table 5. If all resources in the system were subject to constraints at the same time which from the interview data it appears is often the case in periods of housing construction boom, the effects on system output would be more extreme. The last section of Table 5 presents results based on constraints from all four sub-contract areas applying at the same time.

The complexity of the HCSM is reduced for the purposes of this presentation by making the following assumptions:

→ Times to complete work activities are fixed.

→ There are no interruptions to the work other than waiting for the constrained resource.

→ There are no delays caused by wet weather.

→ There is no rework because every activity is completed correctly in the time allocated.

All of these extra sources of possible variation could be included in the model. However, they have been excluded because this would unnecessarily complicate the analysis and further extend the average house completion times.

Table 5 below presents a summary of the results for all runs and indicates construction system behaviour. The following discussion illustrates the results for particular runs with specified constraints.

In the unlimited resource case, presented in Figure 11 below, a house takes 163 days to complete and there are no delays.

Figure 11: Average completion time per house for 100 days at varying commencement times with unlimited resources

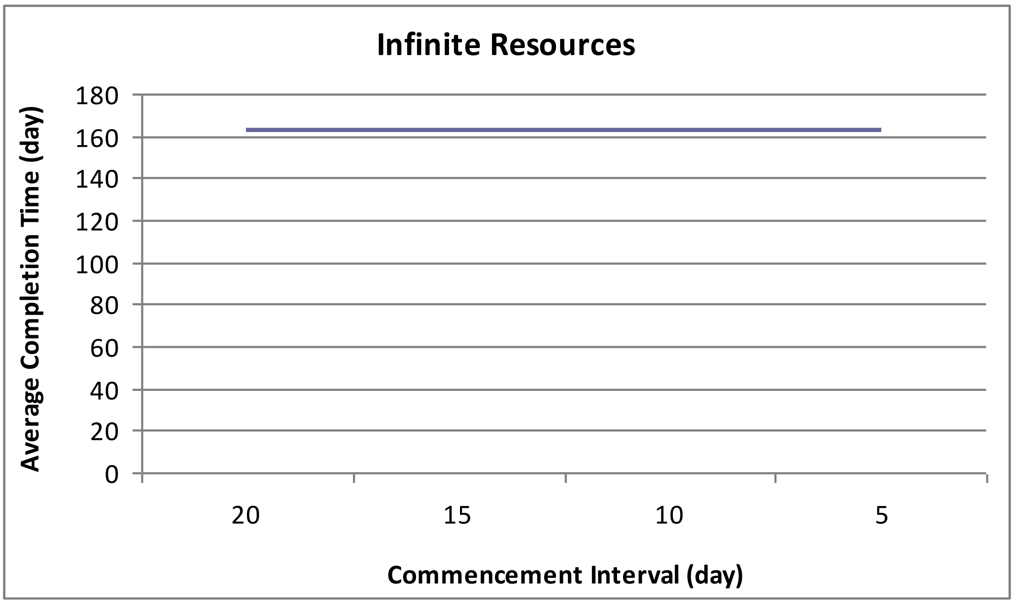
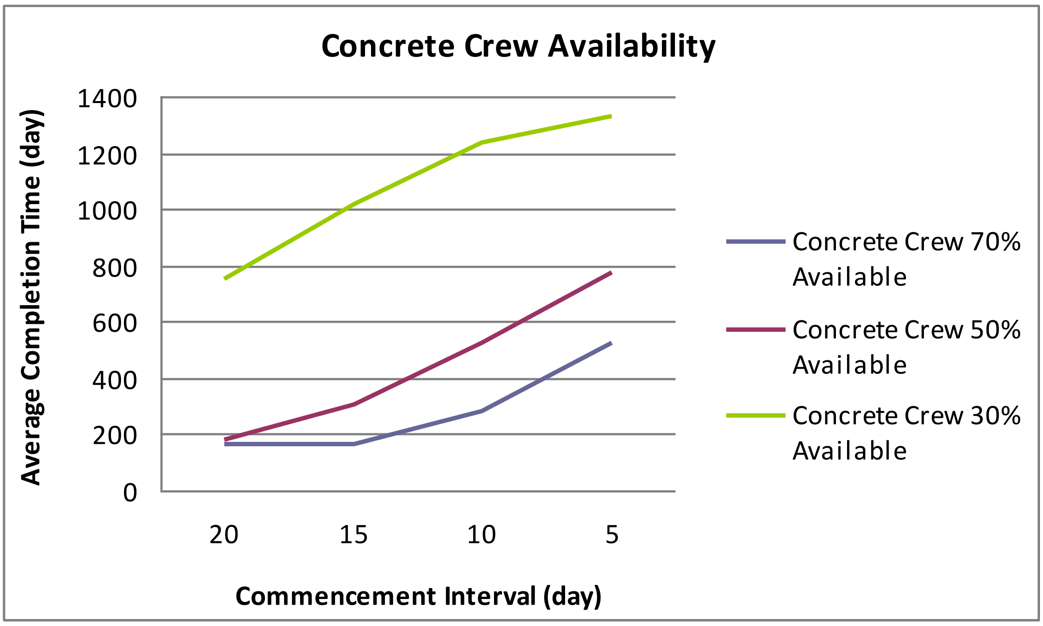


Figure 12 below shows what happens when a resource constraint of 70 per cent availability for the concreting crew is introduced. The average house completion time grows from 163 days to 166 days for starting a house every 20 days and to 527 days when a house is started every five days.

Figure 12: Average completion time per house for 100 days at varying commencement times with limited Concrete Crew availability



This illustrates how house construction sites can become idle in periods of high demand as builders wait for a concrete crew to pour the slab. Starting a house every five days is quite extreme in this model and illustrates a construction system that relies on discrete resources, such as a concrete crew, that is being pushed to operate well past its capacity.

The average completion times with 30 per cent availability are 754 days and 1325 days respectively. These, of course, are extremely long completion times and no builder could allow this to happen. At some point the builder would seek to supplement the number of crews available by trying to engage concreting crews used by other builders or newly formed crews. The results of the HCSM indicate that the current arrangements with the housing construction industry are a potential source of vulnerability in completion times during periods of high activity/high demand.

Similar resource constrained analysis is carried out for plumbing, framing and plastering crews with somewhat similar results but different average completion times. The average completion times vary with the duration of each crew's work task and where in the construction system the activity occurs. The results of these simulations are also shown in Table 5 below and then illustrated in Figures 13 and 14 and below.

The final piece of analysis assumes that all four resources are constrained at some level and, as expected, average house completion times become much longer as house construction is delayed by insufficient resources for all four work tasks. The result of this simulation is shown in the last section of Table 5 and in Figure 16 below.

Table 5: Results of HCSM run for Company A construction process

Time taken in days				Crew utilisation (%)				Crew availability (%)			
House start intervals	Minimum house completion	Average house completion	Maximum house completion	Concrete	Plumbing	Wall framing	Plastering	Concrete	Plumbing	Wall framing	Plastering
All crews fully utilised and available											
20	163.0	163.0	163.0	41.6	9.2	27.7	32.4	100%	100%	100%	100%
15	163.0	163.0	163.0	54.1	12.0	36.1	42.1	100%	100%	100%	100%
10	163.0	163.0	163.0	77.4	17.2	51.6	60.2	100%	100%	100%	100%
5	163.0	163.0	163.0	84.5	18.8	56.3	65.7	100%	100%	100%	100%
Constraints on concrete crew utilisation and availability											
20	163.0	166.9	187.4	70.2	9.2	27.7	32.3	70%	100%	100%	100%
15	163.0	168.1	194.1	81.3	12.0	36.1	42.1	70%	100%	100%	100%
10	169.0	282.4	372.4	92.6	14.6	43.8	51.1	70%	100%	100%	100%
5	175.1	527.5	864.2	92.4	14.7	44.0	51.3	70%	100%	100%	100%
20	164.8	178.0	207.8	91.0	9.2	27.7	32.3	50%	100%	100%	100%
15	164.9	307.7	401.8	95.4	10.6	31.9	37.2	50%	100%	100%	100%
10	173.9	522.5	881.6	95.6	10.6	31.9	37.3	50%	100%	100%	100%
5	174.3	775.1	1365.3	95.3	10.7	32.2	37.5	50%	100%	100%	100%
20	226.5	754.0	1353.8	99.2	6.0	18.0	21.0	30%	100%	100%	100%
15	232.3	1013.9	1830.3	99.1	6.0	18.1	21.1	30%	100%	100%	100%
10	231.0	1238.0	2268.7	98.5	6.1	18.4	21.4	30%	100%	100%	100%
5	301.1	1325.8	2474.0	97.8	6.7	20.2	23.5	30%	100%	100%	100%

Time taken in days				Crew utilisation (%)				Crew availability (%)			
House start intervals	Minimum house completion	Average house completion	Maximum house completion	Concrete	Plumbing	Wall framing	Plastering	Concrete	Plumbing	Wall framing	Plastering
Constraints on plumbing crew utilisation and availability											
20	163.0	163.4	169.7	41.6	40.7	27.7	32.4	100%	70%	100%	100%
15	163.0	163.5	168.9	54.1	43.1	36.1	42.1	100%	70%	100%	100%
10	163.0	163.4	169.7	41.6	40.7	27.7	32.4	100%	70%	100%	100%
5	171.0	369.1	565.0	84.5	51.1	56.3	65.7	100%	70%	100%	100%
20	163.0	164.2	178.8	41.6	59.4	27.7	32.4	100%	50%	100%	100%
15	163.0	165.9	194.5	54.1	63.0	36.1	42.1	100%	50%	100%	100%
10	163.0	177.6	206.3	77.3	71.7	51.5	60.1	100%	50%	100%	100%
5	171.4	374.6	565.4	84.5	72.4	56.3	65.7	100%	50%	100%	100%
20	163.0	170.2	230.8	41.6	77.6	27.7	32.4	100%	30%	100%	100%
15	163.0	180.4	250.8	53.6	83.9	35.7	41.7	100%	30%	100%	100%
10	166.5	227.7	291.4	73.4	90.3	49.0	57.1	100%	30%	100%	100%
5	169.1	412.1	605.5	81.4	87.6	54.3	63.3	100%	30%	100%	100%
Constraints on wall framing crew utilisation and availability											
20	163.0	166.3	182.2	41.2	9.2	60.1	32.1	100%	100%	70%	100%
15	163.0	166.4	192.7	54.1	12.0	67.3	42.1	100%	100%	70%	100%
10	164.0	169.8	184.0	77.1	17.1	83.8	60.0	100%	100%	70%	100%
5	173.0	377.1	576.5	83.6	18.6	82.5	65.0	100%	100%	70%	100%
20	163.0	169.2	194.9	41.3	9.2	76.1	32.1	100%	100%	50%	100%
15	163.7	177.0	203.5	53.9	12.0	89.0	41.9	100%	100%	50%	100%
10	163.6	288.8	404.6	64.2	14.3	93.4	49.9	100%	100%	50%	100%
5	172.8	511.0	863.7	66.0	14.7	93.5	51.3	100%	100%	50%	100%
20	163.0	186.0	237.3	41.5	9.2	93.7	32.3	100%	100%	30%	100%
15	189.9	544.0	855.3	38.3	8.5	98.0	29.8	100%	100%	30%	100%
10	217.8	796.5	1347.7	38.3	8.5	98.0	29.8	100%	100%	30%	100%
5	227.1	1049.0	1847.7	38.3	8.5	98.0	29.8	100%	100%	30%	100%

Time taken in days				Crew utilisation (%)				Crew availability (%)			
House start intervals	Minimum house completion	Average house completion	Maximum house completion	Concrete	Plumbing	Wall framing	Plastering	Concrete	Plumbing	Wall framing	Plastering
Constraints on plastering crew utilisation and availability											
20	163.0	163.5	173.8	41.6	9.2	27.7	63.5	100%	100%	100%	70%
15	163.0	163.7	173.0	54.1	12.0	36.1	72.0	100%	100%	100%	70%
10	163.0	171.6	210.1	75.2	16.7	50.1	88.5	100%	100%	100%	70%
5	171.0	408.1	652.2	78.1	17.4	52.1	89.7	100%	100%	100%	70%
20	163.0	167.0	188.5	41.5	9.2	27.7	84.3	100%	100%	100%	50%
15	163.0	205.2	255.5	53.9	12.0	35.9	92.9	100%	100%	100%	50%
10	163.0	441.1	730.1	52.0	11.6	34.7	94.0	100%	100%	100%	50%
5	171.6	679.5	1157.7	54.3	12.1	36.2	94.3	100%	100%	100%	50%
20	163.0	428.3	665.8	33.9	7.5	22.6	97.7	100%	100%	100%	30%
15	164.4	639.9	1052.7	35.5	7.9	23.6	98.7	100%	100%	100%	30%
10	163.2	687.3	1365.0	38.1	8.5	25.4	98.5	100%	100%	100%	30%
5	173.3	1063.8	1958.4	36.6	8.1	24.4	97.3	100%	100%	100%	30%
Constraints on all trade crew utilisation and availability											
20	163.9	170.7	189.6	72.6	39.3	60.5	61.6	70%	70%	70%	70%
15	164.1	176.8	201.7	84.4	42.0	65.7	70.8	70%	70%	70%	70%
10	172.9	331.6	483.7	91.6	44.0	70.6	75.9	70%	70%	70%	70%
5	177.9	589.9	976.1	92.0	44.4	70.3	76.5	70%	70%	70%	70%
20	168.1	202.4	229.8	90.6	57.1	80.7	82.3	50%	50%	50%	50%
15	178.9	356.5	516.3	95.8	57.8	84.2	80.9	50%	50%	50%	50%
10	174.5	593.7	936.1	95.4	59.8	86.0	84.5	50%	50%	50%	50%
5	199.8	795.6	1379.1	94.7	61.4	84.6	84.2	50%	50%	50%	50%
20	252.2	700.4	1043.3	95.1	78.7	90.0	93.4	30%	30%	30%	30%
15	234.0	952.7	1509.6	95.0	76.8	85.0	91.6	30%	30%	30%	30%
10	249.6	1249.8	2104.3	93.9	78.3	84.6	92.4	30%	30%	30%	30%
5	250.5	1434.9	2387.5	96.0	78.1	85.6	93.0	30%	30%	30%	30%

Figure 13: Average completion time per house for 100 days at varying commencement times with limited Plumbing Crew availability

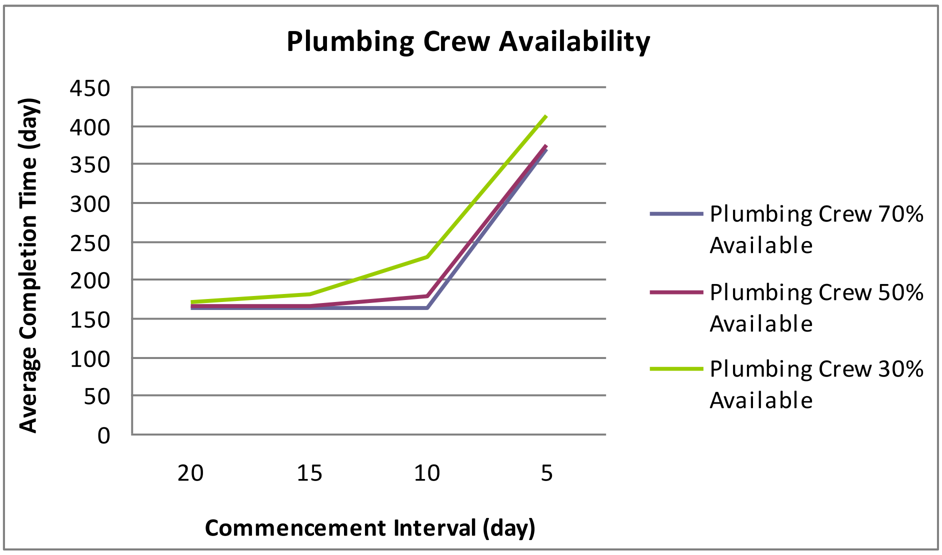


Figure 14: Average completion time per house for 100 days at varying commencement times with limited Wall Framing Crew availability

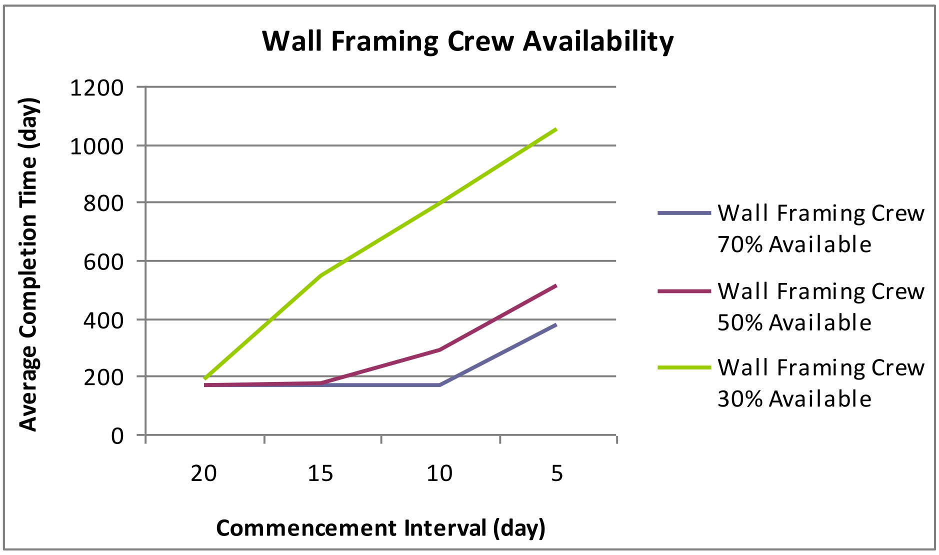


Figure 15: Average completion time per house for 100 days at varying commencement times with limited Plastering Crew availability

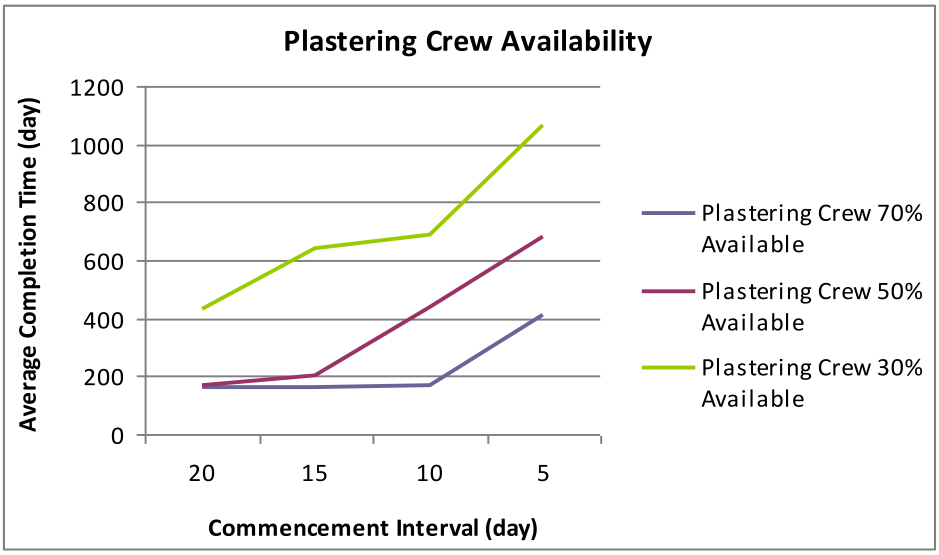
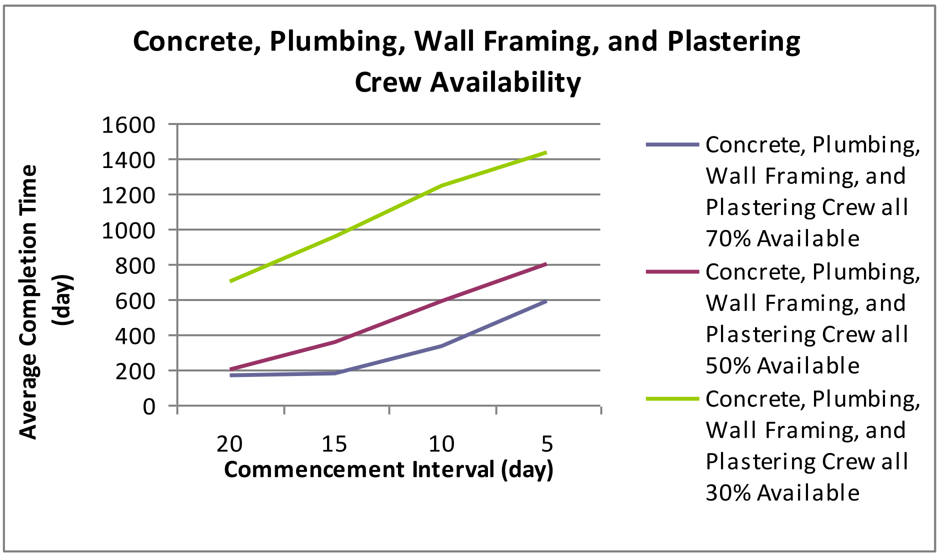


Figure 16: Average completion time per house for 100 days at varying commencement times with limited availability of all four crews



4.5 Summary

This chapter has demonstrated how production theory and simulation modelling can assist in explaining the behaviour of construction systems used by volume builders. The combination of complex interdependent schedules, variations in work times and constrained resources lead to waiting times in the construction systems that quickly cause instability.

The simplified examples in this chapter demonstrate this behaviour and increasing model complexity, while being more accurate, would only accentuate the effects evident in the system. The production theory and simulation models have considerable potential for use by volume builders to understand construction system behaviour and to help develop management strategies to improve productivity and resource management.

5 CONCLUSION

This project has explored the volume detached housing construction industry in Australia. The context for this research has been the continuing undersupply of new housing. This has been well documented through the demographic modelling of the National Housing Supply Council and has been included on the COAG policy agenda. The lengthening construction times of new detached housing contributes to this undersupply and has formed the focus of this research.

The initial literature review established that there is a dearth of literature and research on the topic in Australia. Further, there is little international literature on house building that provides insights into the continuing on-site craft-based construction processes that continue to be used in Australia. Therefore, gaps and unresolved research issues abound and provide the context for this initial contribution to better understanding the industry. This was guided by the following overarching research question:

> How is the work of new suburban house building organised and what practices and constraints may contribute to delays in building completion times?

The research approach adopted can be broadly described as institutional analysis and four secondary research questions guided the research for the Positioning Paper and for this Final Report:

- What are the trends in the time taken to build new housing, measured through commencements and completions?
- How do builders typically organise work on new housing projects from commencement to completion through a system of contracts?
- What are the main issues identified by industry participants managing new house building that may relate to and assist in explaining lengthening construction times?
- In what ways might house building arrangements and practices be changed so as to reduce building completion times?

The Positioning Paper *Australian suburban house building: industry organisation, practices and constraints* (Dalton et al. 2011b) presented an analysis of the way house building is organised and shows that construction times have been increasing over recent years and that this trend cannot be sufficiently explained by labour shortages or increased regulation. The Positioning Paper argued that three contemporary features of the volume building industry in part explain increased construction times. They are:

- The trend to larger houses has led to changes in dwelling design, including the growth in the number of house models offered by companies, complexity of house design, especially facades and the increasing proportion of two-storey houses.
- Supervisors coordinate the subcontractors who build these more complex houses and some supervisors struggle with this coordination work, which has consequences for the timely sequencing of subcontractor tasks.
- Building surveyors and in-house company quality assurance people find deficits in the quality of work undertaken by tradespeople, which requires rework, further inspections and rescheduling of subsequent tasks.

5.1 Summary of findings

This report extends the analysis presented in the Positioning Paper in three substantive chapters. A starting point for these chapters is to view house building as a production process consisting of sequenced activities. Supervisors organise multiple, sequenced discrete building activities across a portfolio of houses at different stages of construction. The composition of this portfolio is all the time changing as some houses are completed while other houses are commencing. Supervisors draw on the same pool of subcontractors, contractors and supply and install contractors when they organise work to be undertaken on the houses they are responsible for, usually between 10 and 15 in number. When viewed this way it assists understanding to transcend a house-by-house analysis and see house building as a production process.

Chapter 2 focuses on innovation in the residential housing construction process. There has been considerable *product innovation* evident in product and materials choice and building design. The *process* of house building has been revolutionised by the extensive use of on-site mechanical equipment, mobile telephony and, most recently, the increasing use of ICT systems that support the scheduling and calling up of materials and labour. There is also innovation in *marketing and sales* evident in the presentation of ideas and images centring on themes of location, building and people. However, innovation is also limited. This is evident in the reluctance of the large materials manufacturers to extend their role beyond the supply of bricks and concrete to installing these products. It is also evident in the way housing construction has resolutely remained an on-site production process. Despite much discussion and some experimentation, suburban house building has not moved off-site into factories.

Chapter 3 examines scheduling systems in two firms and reveals substantial differences in the nature and use of their systems. Company A has a generic ‘checklist’ type system whereas Company B uses a scheduling system that is customisable to specific jobs with a different set of standard duration times allocated for single and double-storey houses, thus using schedules that more closely resemble reality. However, this requires more effort to update records, interrogate these records, and investment in both the software and training in the use of it. Therefore, while Company B is more sophisticated in terms of scheduling, questions remain regarding the relative costs and benefits of both systems to the companies and purchasers, and to overall efficiency. The two companies are significantly different in their approach to scheduling, with company B using a more sophisticated approach that provides more dynamic feedback to system users. However, we find in both cases scheduling practices are limited in terms of revising building schedules in response to changes in project delivery. As such, questions remain regarding the costs and benefits of each system to the companies, purchasers, and overall efficiency.

Chapter 4 examines scheduling by using the HCSM to investigate the effects of time delays in parts of the process due to material or labour delays. Resource constrained analysis is explored for concreting, plumbing, framing and plastering crews. This is done for the firm operating at four different levels of intensity that comes with increasing the number of houses started each month. The average completion times vary with the duration of each crew’s work task and where in the construction system the activity occurs. Overall, average house completion times become longer as house construction is delayed by when there are delays in the four work tasks and when the number of starts each month increases. This analysis demonstrates how production theory and simulation modelling can explain the behaviour of construction systems used by volume builders. It also demonstrates just how vulnerable volume building companies, using extensive and complex contract systems, are to delays due to resource constraints.

5.2 Policy implications

As discussed earlier in this report the undersupply of housing is a well-recognised policy problem. This research has showed the increase in the average build times for houses over the past few decades contributes to undersupply. Houses under construction for longer times are houses that if completed in a shorter time would be available to households to live in. The most radical idea about how this might be addressed is the recurring one that there should be a shift towards off-site manufacturing. There is now a long history of discussion and experimentation with little movement to date towards off-site construction of houses. The argument is that factories provide a setting for increased planning and control over all aspects of production. However, as this research has argued in Chapter 2, key features of the existing industry militate against this shift. In particular, the current system allows the industry to ride out the regular economic cycles of shifting demand for new housing.

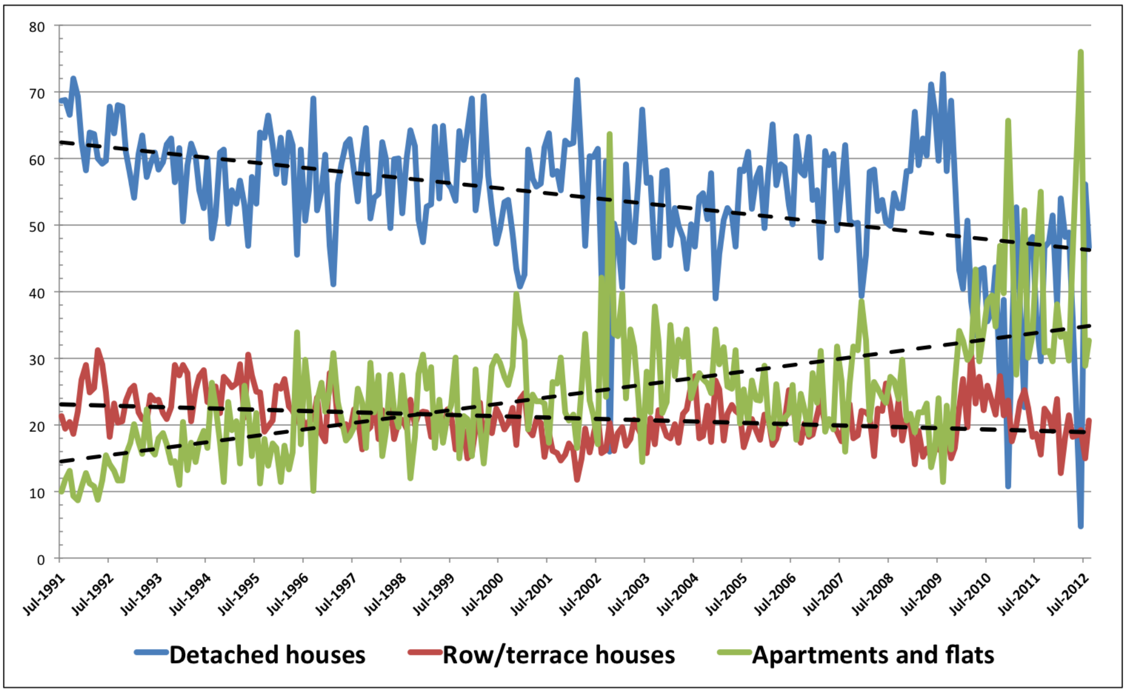
How then might policy be developed in the future that could shape the way larger builders analyse their production processes and change them with a view to reducing production times? Two suggestions are made. The first is to extend the research into the housing industry. The second is to consider how subsidy programs could be developed in ways that promote particular innovation.

There is scope for extending research into housing industry with a particular focus on the production processes of house builders. The research and findings reported here must be regarded as preliminary in the context that there is little earlier research. However, the application of production theory and simulation models has considerable potential for use by volume builders to understand construction system behaviour and to help develop management strategies to improve productivity and resource management. For example, real time data on schedules and work sequencing on construction sites would be invaluable in reviewing and extending the findings of this research. Consideration could be given to a program of research undertaken with companies that researched their construction processes and published their results in ways that stimulated debate about best practice housing production.

There is scope for reviewing the direct subsidies and tax expenditure programs that are used to stimulate demand for new housing. A question could be asked about whether some of these programs should be designed to not only stimulate gross demand for new housing but also influence the form of this housing. In recent years there have been three interventions that have sought to lift the supply of new housing, much of it in response to the Global Financial Crisis. They were the new first homeowner grant programs in the late 2000s; Nation Building support for public and social housing supply; and the establishment of the National Rental Affordability Scheme (NRAS). The design of these assistance programs and future programs could include features that encourage further innovation particularly in relation to product, process and organisational innovation that could lead to reduced completion times.

Finally, it is important to note that suburban detached houses are just one form of residential housing produced by a broadly defined housing industry. Further, the data shows there has also been a decline in the proportion that detached suburban housing forms as proportion of total output of new residential dwellings compared to flats and apartments. While the proportion of houses in new residential production has been declining, the proportion of flats and apartments has been increasing. There has also been a decline, although less pronounced, in the proportion that new row and terrace housing forms of all new residential housing. This changing mix of dwelling types over more than two decades is illustrated in the following Figure 17.

Figure 17: Change in housing types (monthly) Australia 1991–2012



Source: Australian Bureau of Statistics 2012

This observation about the changing mix in residential house types suggests that it is important to relate the production of houses to change and challenges in other parts of the industry, especially the production of apartments and flats. As Rowley and Phibbs (2012, p.1) observe in their research into the supply of new housing on infill sites, including medium density flats and apartments, 'the policy formation process is hampered by a lack of fundamental understanding about the nature of housing supply'. As this research has demonstrated, the same can be said about the production of detached housing. More broadly there is a case for further applied research into the production of all forms of housing that develops a deeper understanding of the way housing is produced. This could lead to the development a 'housing industry policy' endorsed by industry and government about goals for the industry and realignment of policies.

REFERENCES

Australian Bureau of Statistics (2008a) *Average quarterly completions times for new houses* Feature article, Australian Bureau of Statistics, Canberra. http://www.abs.gov.au.

--- (2008b) *Environmental Issues: Energy Use and Conservation*, 4602.0.55.001 Canberra.

--- (2010a) 8752.0—*Building Activity*, Directory of Statistical Sources by Topic, Australian Bureau of Statistics, Canberra. http://www.abs.gov.au.

--- (2010b) *Building Activity Survey*, Average completion time for newly completed dwellings: new houses, Australian Bureau of Statistics, Canberra.

--- (2012) *8731.0 Building approvals, Australia: Table 20.* Number of dwelling units approved in new residential buildings original - Australia, Australian Bureau of Statistics, Canberra.

--- (2013a) *8752.0—Building Activity, Australia*, Table 33. Number of dwelling unit commmencements by sector, Australia, Australian Bureau of Statistics, Canberra. http://www.abs.gov.au.

--- (2013b) *8752.0—Building Activity, Australia*, Table 37. Number of dwelling unit completions by sector, Australia, Australian Bureau of Statistics, Canberra. http://www.abs.gov.au.

Australian Centre for Innovation and International Competitiveness (1992) *Innovation in the housing industry*, Occasional Series No. 4, Housing and Urban Development Program, Australian Housing Industry Development Council, Canberra.

Berry, M. (1999) 'Unravelling the 'Australian housing solution': the Post War Years', *Housing, Theory and Society*, Vol. 16, No. 3, pp.106–21.

Blakey, F. (1977) *An overview of Australian housing construction*, CSIRO, Division of Building Research, Highett, Melbourne.

Blayse, A. M. and Manley, K. (2004) 'Key influences on construction innovation', *Construction Innovation: Information, Process, Management*, Vol. 4, No. 3, pp.143–54.

Bowman, C. (2001) 'Tacit knowledge: some suggestions for operationalisation', *Journal of Management Studies*, Vol. 38, No. 6, pp.811–29.

Bresnen, M. J., Wray, K., Bryman, A., Beardsworth, A. D., Ford, J. R. and Keil, E. T. (1985) 'The Flexibility of recruitment in the construction industry: formalisation or re-casualistion', *Sociology*, Vol. 19, No. 1, pp.108–24.

Bureau of Industry Economics (1990) *Instability in the Australian house building industry,* Discussion paper 10, Bureau of Industry Economics, Canberra.

Burke, T. and Hulse, K. (2010) 'The Institutional Structure of Housing and the Sub-prime Crisis: An Australian Case Study', *Housing Studies*, Vol. 25, No. 6, pp.821–38.

Coiacetto, E. (2006) 'Real estate development industry structure: Consequences for urban planning and development', *21*, Vol. 4, pp.423–41.

Council of Australian Governments (2009) *COAG Communique: Attachment B, Housing reform agenda and timeline* Council of Australian Governments, Canberra.

Crabtree, L. and Hes, D. (2009) 'Sustainability Uptake in Housing in Metropolitan Australia: An Institutional Problem, Not a Technological One', *Housing Studies*, Vol. 24, No. 2, pp.203–24.

Dalton, T., Horne, R., Chettri, P., Groenhart, L. and Corcoran J. (2011a) *Understanding the patterns, characteristics and trends in the housing sector labour force in Australia*, Positioning Paper No 142, Australian Housing and Urban Research Institute, Melbourne.

Dalton, T., Wakefield, R. and Horne, R. (2011b) *Australian suburban house building: industry organisation, practices and constraints*, AHURI Positioning Paper No. 143, Australian Housing and Urban Research Institute, Melbourne.

Davison, G. (1981) *The Rise and Fall of Marvellous Melbourne*, Melbourne University Press, Melbourne.

Dowling, R. (2005) 'Residential Building in Australia, 1993–2003', *Urban Policy and Research*, Vol. 23, No. 4, pp.447–64.

Eather, W. (1988) 'We Only Build Houses: the Commission 1945-60', in Howe, R. (Ed.) *New Houses for Old: Fifty Years of Public Housing in Australia 1938-1988*, Ministry of Housing and Construction, Melbourne.

Frost, L. (1991) *The New Urban Frontier: Urbanisation and City-building in Australasia and the American West*, New South Wales University Press, Sydney.

Gann, D. (2000) *Building innovation: complex constructs in a changing world*, Thomas Telford, London.

Garden, D. (1992) *Builders to the nation: the A. V. Jennings story*, Melbourne University Press, Melbourne.

Gharaie, E. (2011) *House completion time in Australia: workflow planning approach*, PhD, School of Property, Construction and Project Management, RMIT University, Melbourne.

Gharaie, E., Wakefield, R. and Blismas, N. (2010) 'Explaining the Increase in the Australian Average House Completion Time: Activity-based versus Workflow-based Planning', *Australasian Journal of Construction Economics and Building,* Vol. 10, No. 4, pp.34–49.

Goodman, R., Buxton, M., Chhetri, P., Taylor, E. and Wood, G. (2009) *Planning and the characteristics of housing supply in Melbourne*, AHURI Final Report No. 157, Australian Housing and Urban Research Institute, Melbourne.

Hampson, K. and Brandon, P. (2004) *Construction 2020: a vision for Australia's property and construction industry*, Cooperative Research Centre for Construction Innovation for Icon.Net Pty Ltd, Brisbane.

Hopp, W. J. and Spearman, M. L. (2008) *Factory physics*, 3rd ed., McGraw-Hill/Irwin/Irwin, New York, NY.

Housing Industry Association (2010) H*ousing 100, 2009/10, Australia's Largest Home Builders and Residential Developers,* Housing Industry Association, Canberra.

--- (2011) *Sham Arrangements & the use of Labour Hire in the Building and Construction Industry*, Submission to the Austraian Building and Construction Commissioner on Sham Contracting, Housing Industry Association, Canberra.

Housing Supply and Affordability Reform Working Party (2012) *Housing supply and affordability reform*, Council of Australian Governments, Canberra.

Jacobs, K., Berry, M. and Dalton, T. (2013) ''A dead and broken system?': 'insider' views of the future role of Australian public housing', *International Journal of Housing Policy*, No. DOI:10.1080/14616718.2013.785716.

Johnson, L. (1993) 'Text-ured Brick: Speculations on the Cultural Production of Domestic Space', *Australian Geographical Studies*, Vol. 31, No. 2, pp.201–13.

Johnson, L. C. (2006) 'Style Wars: revolution in the suburbs?', *Australian Geographer*, Vol. 37, No. 2, pp.259–77.

Kriese, U. and Scholz, R. W. (2011) 'Lifestyle Ideas of House Builders and Housing Investors', *Housing, Theory and Society*, Vol. 29, No. 3, pp.288–320.

Leonard, L., Perkins, H. and Thorns, D. (2004) 'Presenting and creating home: The influence of popular and building trade print media in the construction of home', *Housing, Theory and Society*, Vol. 21, No. 3, pp.97–110.

Lloyd, C. (1950) *The Australian carpenter*, Macmillan & Co, Melbourne.

London, K. and Siva, J. (2012) 'Accumulating intellectual capital for a novel housing construction system in integrated supply chain environments', in *7th International Conference on Innovation in Architecture, Engineering & Construction,* August 2012. São Paulo, Brazil.

Manley, K. (2003) 'Frameworks for understanding interactive innovation processes', *International Journal of Entrepreneurship and Innovation*, Vol. 4, No. 1, pp.25–36.

--- (2008) 'Implementation of innovation by manufacturers subcontracting to construction projects', *Engineering, Construction and Architectural Management,* Vol. 15, No. 3, pp.230–45.

McGuirk, P. and Dowling, R. (2007) 'Understanding Master-Planned Estates in Australian Cities: A Framework for Research', *Urban Policy and Research*, Vol. 25, No. 1, pp.21–38.

Morschel, R. (2003) *Building Products Innovation Council to lead reform of building regulation*, Press release, Building Products Innovation Counci, Sydney.

Morse, J. and Richards, L. (2002) *ReadMe First For a User's Guide to Qualitative Methods*, Sage Publications, Thousand Oaks, CA.

Mubarak, S. A. (2010) *Construction project scheduling and control,* John Wiley and Sons, Inc, New Jersey, USA.

National Housing Supply Council (2009) *State of Supply Report*, National Housing Supply Council, Department of Families, Housing, Community Services and Indigenous Affairs, Canberra.

--- (2010) *2nd State of Supply Report*, National Housing Supply Council, Department of Families, Housing, Community Services and Indigenous Affairs, Canberra.

--- (2012) *Housing supply and affordability—key indicators, 2012*, National Housing Supply Council, Department of the Treasury, Canberra.

O'Brien, M., Wakefield, R. and Beliveau, Y. (2000) *Industrialising the residential construction site,* U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, DC.

O'Brien, M. J., Wakefield, R. R. and Beliveau, Y. (2002) *Industrializing the Residential Construction Site Phase III Production Systems* Department of Housing and Urban Development, Office of Policy Development and Research, Washington, DC.

OECD (2005) *The Measurement of Scientific and Technological Activities (Oslo Manual): Guidelines for collecting and interpreting innovation data* OECD and Eurostat.

Palmer, C., Ziersch, A., Arthurson, K. and Baum, F. (2004) 'Challenging the Stigma of Public Housing: Preliminary Findings from a Qualitative Study in South Australia', *Urban Policy and Research*, Vol. 22, No. 4.

Robinson, D. and Edwards, D. (2009) 'Sustainable housing design: measurement, motivation, and management in Sutherland Shire, Sydney, Australia', *Environment and Planning B: Planning and Design*, Vol. 36, No. 336–54.

Rowley, S. and Phibbs, P. (2012) *Delivering diverse and affordable housing on infill development sites,* AHURI Final Report No. 193, Australian Housing and Urban Research Institute, Melbourne.

Salvador, F., de Holan, P. M. and Piller, F. (2009) 'Cracking the code of mass customisation'*, MIT Sloan Management Review*, Vol. 50, No. 3, pp.71–78.

Stockland (2012) Living at Arbourlea Series Volume, Report Number, Institution. http://www.stockland.com.au/residential/vic/arbourlea-living-at-arbourlea.aspx, accessed 23rd Feb, 2013

Task Force to Investigate Modern Housing Techniques (1974) *Modern housing techniques: report to Minister for Housing and Construction*, Australian Government Publishing Service, Canberra.

Thorpe, D., Ryan, N. and Charles, M. B. (2009) 'Innovation and small residential builders: an Australian study', *Construction Innovation: Information, Process, Management,* Vol. 9, No. 2, pp.184–200.

Tibbits, G. (1988) 'The Enemy Within Our Gates': Slum Clearance and High-Rise Flats', in Howe, R. (Ed.) *New Houses for Old: Fifty Years of Public Housing in Victoria,* Ministry of Housing and Construction, Melbourne.

Turner and Townsend (2012) *International construction cost survey 2012*, Turner and Townsend, Brisbane. http://www.turnerandtownsend.com/

Urban Development Institute of Australia (2012) *The 2012 UDIA state of the land report: Urban Development Institute of Australia National Land Supply Study*, Urban Development Institute of Australia, Canberra.

URBIS (2009) *National Dwelling Costs Study,* National Housing Supply Council, Canberra. http://nhsc.org.au/

Wajcman, J. (2002) 'Addressing technological change: the challenge to social theory', *Current Sociology*, Vol. 50, No. 3, pp.347–63.

Wakefield, R. R. and O'Brien, M. J. (2004) *Industrializing the Residential Construction SitePhase IV: Production Simulation,* Department of Housing and Urban Development, Office of Policy Development and Research Washington, DC.

Wakefield, R. R., O'Brien, M. J. and Beliveau, Y. (2001*) Industrializing the Residential Construction Site—Phase II Information Mapping* Department of Housing and Urban Development, Office of Policy Development and Research, Washington, DC.

Zipkin, P. (2001) 'The limits of mass customisation', *MIT Sloan Management Review*, Vol. 42, No. 3, pp.81–87.

APPENDICES

Appendix 1: Interview questions

Australian suburban house building:

industry organisation, practices and constraints

Questions for volume builder senior design, planning and marketing managers

1. Can you describe the way your company relates to prospective customers and signed up customers for:
    a. Houses chosen from your catalogue by the customer.
    b. Already completed houses purchased by customer.
2. Can you describe the history of 'mass customisation' in your company that is evident in the large number of models and extensive model variation now offered to prospective customers?
3. How does your company work out what prospective purchasers are looking for in their future house and build these expectations into new designs?
4. How important are display villages in the presentation of houses and the development of company/customer relationships and sales strategies? Can you describe the processes that lead to the design and building of display villages?
5. What is the typical process used in designing and documenting a new house model? Is the model tested against criteria that assess the efficiency and practically of the processes required to build the new house model?
6. Who influences suburban house design, apart from customers? In particular how do the following interests shape the house design process:
    a. developers
    b. local government
    c. state government
    d. federal government
    e. utility companies.
7. What are the implications of 'mass customisation', evident in the large number of house models and extensive model variation, for the production of new housing by your firm?
8. Can you provide an assessment of the increase in the level of complexity in the design and construction of the new suburban house? What are the key features or key dimensions of this increased complexity?
9. What is the extent and nature of innovation in housing construction in recent years? What are the opportunities and the constraints experienced by your company in considering and introducing construction innovation?
10. How does your company assess and respond to competition in the new house market?

November 2011

Appendix 2: Construction cost comparisons

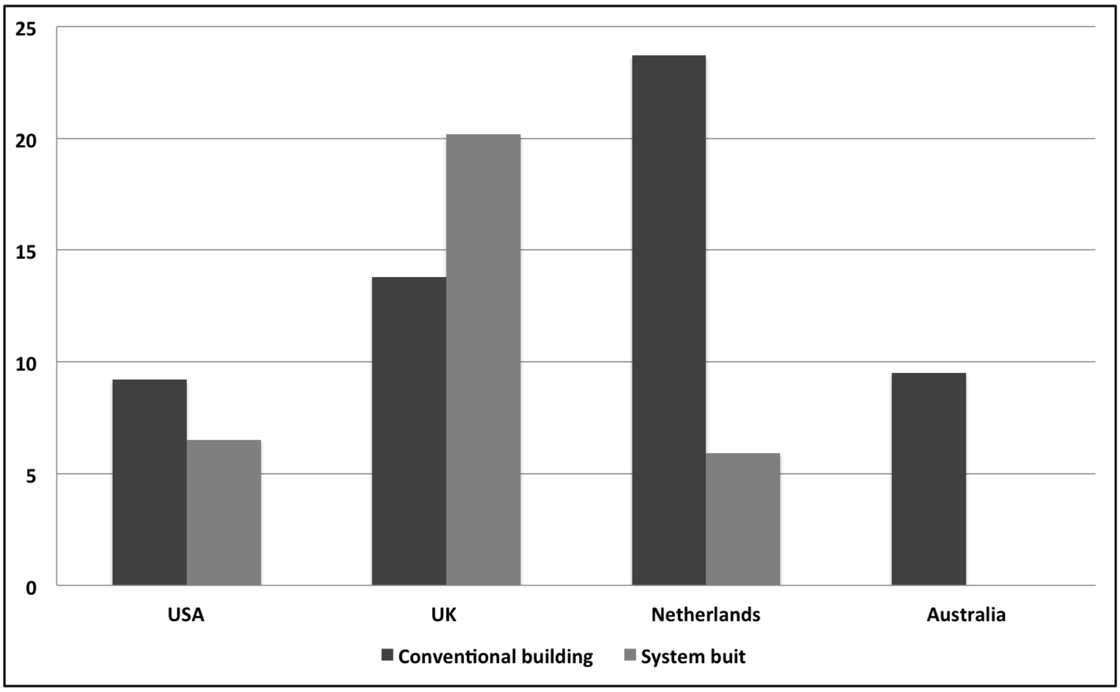
Limited available evidence from the mid-1970s and early 2000s suggests that the cost of production of Australian suburban housing production compares well with the production costs of similar housing in other countries.

A comparison was first made in the 1970s by (Blakey 1977) from the Commonwealth Scientific and Industry Research Organisation (CSIRO), Division of Building Research, using the labour productivity measure of man-hours/square metres. The context for this comparison was policy discussion stimulated by the Task Force to Investigate Modern Housing Techniques (1974) established by the Federal Government to inquire into whether government should encourage growth in off-site production of housing.

Blakey (1977) measured labour productivity for Australian suburban housing construction through on-site observations and by consulting with industry experts. He concluded that 'something in the range of 8.6–14.5 man-hours/square metres with a national average of 9.5 man-hours/square metres' was a typical measure of labour productivity. He then compared this measure to available measures from other countries for both 'conventional' on-site construction and 'system built' off-site prefabrication.

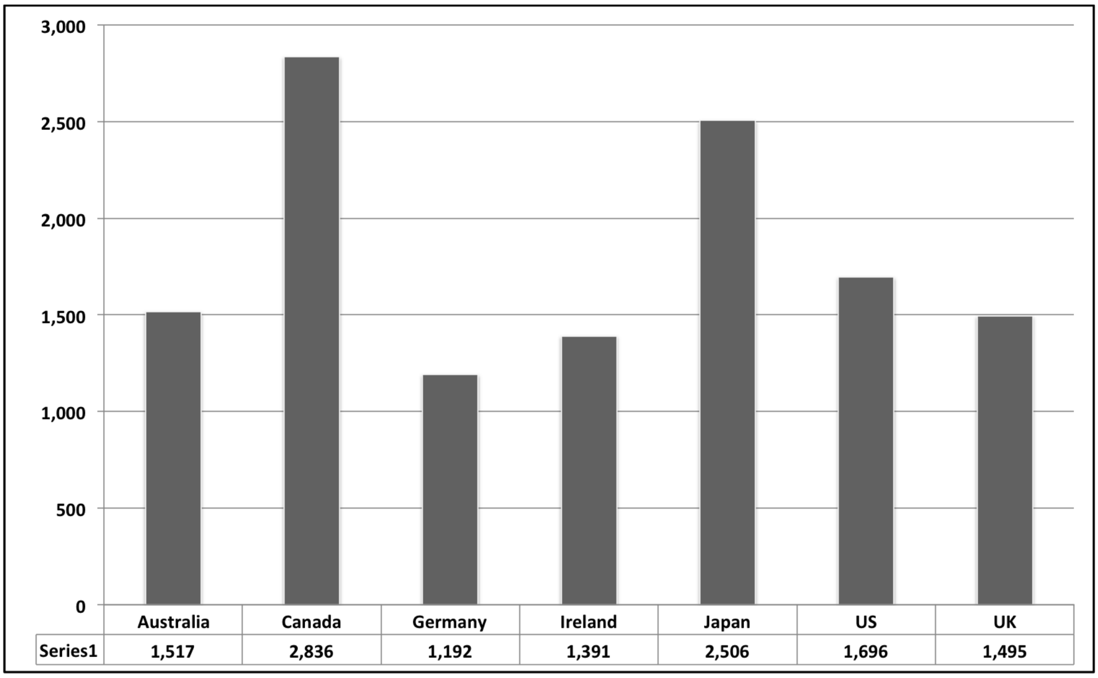
Figure A1 below presents a comparison drawn from the Blakey (1977) data. It shows that labour productivity in the USA and Australia was similar for conventional construction. The UK and the Netherlands had considerably lower levels of labour productivity for conventional construction. However, it also shows that labour productivity for system built housing in the USA and in the Netherlands was higher than for Australian conventional construction. This research continues to be cited by the Housing Industry Association (2011, p.6) when it presents a case for maintaining the sub-contracting system.

Figure A1: Dwelling construction productivity (hours/square metre) early 1970s



More recent construction cost data from Turner and Townsend (2012) supports the earlier Blakey research. This data compares construction, materials and labour costs for different types of buildings across a number of countries. The cost per square metres for detached houses of a medium standard is one of the comparisons made. It shows a rank order of Germany, Ireland, UK and Australia. In other words, Australia does not produce the cheapest medium standard suburban housing but ranks fourth. The US, Japan and Canada are more expensive in that order.

Figure A2: Houses medium standard cost per square metres ($USD)—2011



It is reasonable to conclude using these two comparisons that the cost of construction of detached housing in Australia compares well internationally. However, it can also be argued that if the time taken to build this housing was less, then this reduced time would be reflected in a reduced cost per square metres.

AHURI Research Centres

AHURI Research Centre—Curtin University

AHURI Research Centre—Monash University

AHURI Research Centre—RMIT University

AHURI Research Centre—Swinburne University of Technology

AHURI Research Centre— University of Adelaide

AHURI Research Centre—University of New South Wales

AHURI Research Centre—University of Queensland

AHURI Research Centre— University of Sydney

AHURI Research Centre—University of Tasmania

AHURI Research Centre—University of Western Australia

AHURI Research Centre—University of Western Sydney

Australian Housing and Urban Research Institute

Level 1, 114 Flinders Street, Melbourne Victoria 3000

Phone +61 3 9660 2300 Fax +61 3 9663 5488

Email information@ahuri.edu.au Web www.ahuri.edu.au