Yang, Jay & Yang, Zhengyu
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Critical Factors Affecting the Implementation of Sustainable Housing in Australia

Abstract: Improved public awareness of the environment and available technologies will continue to highlight the importance of sustainable housing in the coming years. Despite this potential, the majority of new housing development in Australia is still "project homes" with few tangible sustainability measures. Stakeholders tend to have different perceptions and priorities on sustainability. To promote the uptake of sustainable housing products, a study of the critical issues affecting the implementation of sustainable housing is necessary. This research investigates multiple factors that may influence key stakeholders' decision-making towards sustainable housing adoption. Drawing insights from combined questionnaire and interview studies, 12 critical factors and their interrelationships are identified based on professional views in the Australian housing industry. The mutual influences, or driving force and dependency, of these factors are further investigated via Interpretive Structural Modelling (ISM) to distinguish those requiring prominent and immediate attention. A hierarchical model is developed to help key stakeholders prioritise actions when implementing sustainable housing.

Key words: sustainability; housing; framework; factors; mutual influence; Australia

Introduction

The Australian housing industry needs to respond to environmental sustainability. For a 67% chance of keeping global warming within 2 degrees above pre-industrial temperatures, research has indicated that it would be necessary for Australia to de-carbonise its economy by 2020 (Melbourne Energy Institute, 2010). Since the construction and housing sector alone accounts for over 11% of all carbon emissions in 2011 (Commonwealth of Australia 2013), industry practitioners are under pressure to deliver sustainable housing products acceptable by the general market.

Despite the potential benefits and technological viability, voluntary up-take of sustainable housing is still in its infancy in Australia mostly driven by motives of experimentation, showcasing and marketing. For example, the Green Building Council of Australia developed a voluntary approach, *Green Star - Multi Unit Residential*, to benchmark sustainable housing development in terms of eight areas of sustainability including energy, indoor environment quality and emissions. Among hundreds of housing development projects, only a modest 17 were endorsed as 4-star or above (GBCA, 2011). Similarly, only 33 projects across Australia have been certified as being developed in a sustainable way under the *EnviroDevelopment* scheme established by the Urban Development Institute of Australia (UDIA, 2011).

International research covered the issue of sustainable housing implementation, such as sustainable housing outcomes from occupants' experiences in Australia (Miller et al 2012); environmental performances of Turkish residential buildings (Centiner& Ceylan 2013); eco-labeling of housing products in Hong Kong and the willingness to pay for them (Yau 2012); and the ABIA framework developed to encourage environmentally responsible behaviours and adoption of sustainable housing in the UK (Hayles et al 2013). While they identified various barriers to implementation, most relate to policy, performance or occupants' behavioural experiences. Problems of key housing stakeholders, particularly those designing, developing and marketing sustainable housing products, have not been studied systematically. Moreover, since the sustainability agenda exceeds traditional economic boundaries to include social, environmental and institutional dimensions, limited exploration of the mutual influences of these multi-bottom-line issues can lead to excessive and sometimes convoluted policymaking which may obstruct sustainable visions (Miller & Buys 2013). Therefore the research reported here sets out to establish a research framework that facilitates a systematic understanding of the priorities and constraints of key stakeholders in the housing industry, and in turn identify and promote their mutually agreeable benefits and targets, to promote sustainable housing products. As part of the overall research, the following discussions centre on the exploration of "factors affecting the implementation" (FAIs) of sustainable housing in Australia. The paper begins with a description of sustainable housing evolution and multiple-bottom-line FAIs identified from existing literature. The significance of and inter-relationships between FAIs are identified through survey studies among key stakeholders in the Australian housing industry. Semi-structured interviews then extend the survey findings to identify the critical FAIs. Interpretive Structural Modelling (ISM) is finally applied to examine the quantitative mutual influences (driving force and dependence) and in turn establish a hierarchical model to guide stakeholder actions towards sustainable housing implementation.

Sustainable housing development in Australia

The evolution of sustainable housing concept and potential benefits

Contemporary research generally builds on the triple-bottom-line (TBL) principle to rationalise the broad connotation of sustainability. In order to facilitate implementation, recent thinking on sustainability tends to add an institutional or governance dimension to the existing financial, environmental and social ones(Spangenberg, 2002). Moreover, sustainability is increasingly highlighted as a positive concept that allows people to improve quality of life and advance ecosystem health, rather than simply alleviating the negative impacts from industrial growth (Birkeland, 2008).

The definition of sustainability remains broad when it comes to the housing industry. For example, sustainability was labelled with different terms such as “low-carbon”,” zero-energy”, “high-performance” and most commonly “green” (Lovell, 2004; Schmidt, 2008; Wedding, 2008). Housing sustainability should not, however, cover only the “green” aspect of energy-efficiency, but include resource usage, natural and socio-cultural systems, growth and economic demands and the lifestyle of current generations (Cole, 2005; Chiu, 2004).

In the course of technology evolution occurring since the late 1900’s, a large number of sustainable technologies has been gradually introduced to the Australian housing industry. Technologies considered “low-hanging fruit” (easily achievable), such as structural insulation, glazing, passive heating and cooling design and water conservation, have been driven into maturity. “Cutting-edge” energy saving measures such as the use of wind turbines, solar panels and biomass have also proved ecologically appealing despite their additional initial outlay (Eshraghia et al 2014; Santin 2013)Housing estates built with these sustainable measures not only have the potential to receive ‘green’ grants and streamlined land-use permits in the development stage, but also lead to direct cost savings for occupants over the building’s lifetime. In addition, homebuyers have reportedly enjoyed increased property values in countries such as the United States of America and the United Kingdom, where sustainable features are an important determinant of market value (Lorenz et al., 2007). Furthermore, sustainable housing may result in social advantages such as better consumer confidence, increased functionality and durability, less maintenance, a better reputation and most importantly, improved public health (Pilkington et al., 2011; Yates, 2001; Yau 2012). This research adopts a broad Australian context and generally accepted norm of sustainable housing, i.e, those housing products that adopt sustainability principles to improve performance and meet expected outcomes. These principles covers a wide span from technical issues of energy efficiency, water saving and material innovation to social economiocal measures such as indoor environment and accessibility improvement and responsiveness to changing needs, affordability , social cohesion and cultural heritage. This message was conveyed to and agreed upon by the respondents during the survey study of this research.

The complexity of sustainable housing development

Incorporating sustainability to housing development bears extreme complexity for two reasons. There are multiple bottom lines of sustainability and they have been constantly evolving (Yang 2012). The supply chain of housing development involves dozens of stakeholders who often have competing interests. Unlike direct economic activities, the economic value of sustainability rests largely on sound environmental and social practices, which often involve intangible, non-immediate benefits yet more risks to stakeholders (Panawek, 2007; Wilkinson & Reed, 2007; Miller & Buys 2013). This situation is compounded by the diversity and multiplicity of stakeholders in the housing construction industry, with each of them differing in the way they value and perceive sustainability (Thabrew et al., 2009; Turcotte, 2007; Winston, 2010).

These complexities obstruct joint efforts by stakeholders to move towards sustainable housing development. The foremost question in collaborative theories remains unsolved: in what ways can multiple parties with own interests and professional priorities reach a “consensus” on the multi-dimensional knowledge itself? (Healey, 2003; Innes, 2004; Margerum, 2008). Specifically, the current implementation of sustainable housing was affected by a myriad of factors valued by single-issue interest groups, heading in various directions towards different end-points (Shin et al., 2008; Miller et al 2012; Famuyiboa & Strachanba 2013). Various instruments often overlap in strengths and weaknesses in the absence of an overarching goal, hindering the exchange of information, understating and, ultimately, progress (Lowe & Oreszczyn, 2008). Warnock (2007) argues that basic principles for policy and prioritization and co-ordination need to be established. This approach warrants the conceptualisation of theoretical frameworks to consider all players in housing supply chain and how they interact and behave under the sustainability paradigm on a holistic basis (Famuyiboa & Strachanba 2013). For start, it is necessary to capture and calibrate as many convoluted factors of sustainable housing delivery as possible for all key stakeholders involved.

Identifying factors affecting the implementation of sustainable housing

In accordance with the evolving definitions and benefits of sustainability, multiple pull and push factors can be identified as influential to stakeholders’ decision-making for sustainable housing implementation. For example, Miller and Buys (2013) believe sustainable housing as a product can be difficult to define and is strongly influenced by specific urban context that extend users vision of sustainability. Housing market and regulators play critical roles in limiting that vision therefore the implementation of sustainability. Lowe & Oreszczyn (2008) point to insufficient interdisciplinary actions between technology, economy and sociology specialists. They argue that the low level of interactions and collaboration between these experts cause the lack of reliable lifecycle data from exemplar building projects. Aggravating this situation is the stereotyped additional cost of sustainable features, which are oftentimes underrated or ignored in policy (Vandevyvere & Neuckermans, 2005). As a consequence, the sustainability of housing has not been prioritised by stakeholders and this has impacted negatively on the nature of the housing industry (Wilkinson &

Reed, 2007). Van Bueren (2007) thus supported collaborative integration via clear leadership and partnership among stakeholders. This could potentially facilitate long-term planning, early agenda-setting and the integrated design of sustainable housing.

To guide subsequent data collection and analysis, this research first developed an analytical protocol (Table 1) by summarizing the most commonly recognized factors in existing literature. In reference to Spangenberg’s sustainability prism (2002), these factors are clustered into four categories: technical and design factors, economic factors, socio-cultural factors and institutional factors. This FAI list was validated by five industry experts and academics to ensure that the contents spell out what is meant to express from an Australian housing industry point of view.

Table 1 - The analytical protocol

Code	**FAIs**	**Key Reference**											
		(Vandevyvere & Neuckermans, 2005)	(McGraw-Hill Construction & U.S Green Building Councill, 2006)	(Williams & Dair, 2007)	(van Bueren, 2007)	(Adeyeye, Osmani, & Brown, 2007)	(Lorenz, Truck, & Lutzkendorf, 2007)	(Wilkinson & Reed, 2007)	(Lutzkendorf & Lorenz, 2007)	(Lowe & Oreszczyn, 2008)	(Shin, ET AL, 2008)	(Ryghaug & Sørensen, 2009)	(Osmani & O'Reilly, 2009)
	Technical and design factors												
T1	Inadequate or untested sustainable technologies or materials					X						X	X
T2.	Lack of professional education and training programs for industry		X	X				X		X		X	X
T3.	Lack of methodologies and tools to consistently define and measure sustainability				X		X	X	X	X		X	
T4.	Lack of integrated design for life-cycle management					X				X			
T5	Insufficient cost-benefit data from interdisciplinary research	X			X	X	X		X	X			X
	Economic factors												
E1.	Unclear benefits from future legislation, policy and market change		X	X	X	X	X	X			X		
E2.	High investment cost	X	X	X		X							X
E3.	Inadequate or inefficient fiscal or other investment advantages	X	X			X		X	X		X		
	Socio-cultural factors												
S1.	Reluctance to leave the comfort zone and change traditional practices	X			X			X		X			
S2.	Insufficient reputation, brand recognition and competitive advantage		X			X					X		X
S3.	Lack of social conscience in climate change and natural resource preservation	X	X	X		X			X		X		X
S4.	Insufficient demand-side education from media and other channels	X	X	X			X	X					X
S5.	Contested functionality for end users		X		X		X	X	X				
	Institutional factors												
I1.	Lack of collaborative integration		X	X	X	X		X		X		X	
I2.	Lack of inter-stakeholder communication networks	X			X				X	X			
I3.	Inadequate policing of green-washing and unsustainable practices										X		X
I4.	Slow and unwieldy administrative processes in certifying and policy-making		X					X				X	
I5.	Lack of a comprehensive code /policy package to guide action on sustainability	X	X	X		X		X		X	X		X
I6.	Duplication and confusion arising from parallel policies/legislation	X			X					X		X	

Research Methodology

This research aims to develop a hierarchical framework that evaluates factors affecting the implementation of sustainable housing (FAIs) in Australia. It adopted a threefold methodology, consisting of both quantitative and qualitative methods.

The first quantitative research was conducted via an on online questionnaire to collect and compare views on the significance of and correlations between the 19 FAIs identified in the analytical protocol. Such surveys allow various stakeholders to be involved in discovering “real” needs and demands (Saunders et al., 2009). Due to the distribution of government body officials, financial lenders, developers, builders, architects/designers, other consultants and real estate agents around Australia, and the time and resource limitation, probability sampling seems impractical. The survey population was therefore confined to 53 organisations acknowledged as being at the forefront of sustainability implementation across Australia, and 27 other reputed organisations without a strong focus on sustainability. The former are best placed to provide positive experiences involving sustainable housing and a considerable understanding of the advantages and disadvantages during sustainable development. The latter may reflect more on the industry perceptions of housing development in general. The questionnaire was comprised of four sections: (1) Respondent Details, (2) General Opinions on Sustainable Housing Implementation, (3) Rating of FAI importance and (4) Further comments. The core questions under “Rating of FAI importance” were designed using a 5-point Likert scale from “1” (Not at all important) to “5” (Extremely important). To ensure their validity, before sending the questionnaires to the full sample group, six pilot surveys were conducted with two builders, two university professionals and two consultants. This confirmed that each question adequately addressed and measured its intended focus

The findings of the questionnaire were developed further via semi-structured interviews. This was to further explore the current status of the 19 FAIs so as to confirm the significance of each and interrelationships between them. This requires interviewees to have robust knowledge and extensive experience in housing development and sustainability issues. Accordingly, a “purposeful snowball sampling” method was adopted to obtain information from 14 interviewees from the original sample and another 6 interviewees from outside this group. The former involved interviewees clarifying facts from their original questionnaire responses, while the latter were newly identified experts and representatives who helped to ascertain the degree of generalisation in the results (Adams, et al., 2010). Three pilot interviews were conducted with one industry consultant and two academics in the field of housing in order to test the suitability and comprehensibility of questions.

The synthesized findings from the questionnaire and interview study led to the identification of 12 critical FAIs and their contextual relationships. However, these contextual relationships tend to be unorganised and complex, and in turn cannot be directly used to facilitate stakeholder decision-making. This research thus utilized Interpretive Structural Modelling (ISM) to transform the unordered interrelationships into structural and quantifiable mutual influences (driving force and dependence). This will lead to the development of a hierarchical model to help stakeholders prioritise their sustainability agendas into policy-making and action plans. According to Janes (1988) and Ahuja *et al* (2010), ISM methodology helps to impose order and direction on the relationships between elements in a complex system. It is an appropriate methodology to transform these unclear, poorly articulated, and abstract influences into a visible, well defined overall structure portrayed by a graphical model.

Results and Discussion

The responses from both the quantitative questionnaire and qualitative interviews provided valuable insights into the current status of the 19 FAIs in the implementation of sustainable housing, and strategies to deal with the existing challenges. The results are discussed below.

Background information

50 valid responses were received out of 163 initial attempts, which translates to a response rate of 30.7%. This conforms to an acceptable respondent rate of approximately 30% for a survey focusing on gaining responses from construction industry practitioners (Akintoye, 2000; Love & Smith, 2003). Both the questionnaire respondents and interviewees were suitably distributed over the 7 key stakeholders groups of government bodies, developers, architects/designers, builders, other consultants, financial institutions and real estate agencies. 60.4% of the questionnaire respondents have had at least 10 years industry experience at a senior level and hold a position of either Manager or Director. All 20 interviewees are involved with sustainable housing development currently or previously and 85%hold a director/manager position in their organizations (Table 2). A breakdown of the geographical spread of the respondents and interviewees is summarised in Table 3. The surveys cover major states of Australia including Victoria, New South Wales, Queensland and Tasmania. While Queensland based practitioners are the majority, 17 survey respondents (85%) have had interstate work experiences. All were asked to provide perspectives from broad work experiences and ignore organisational and/or region differences. Furthermore, all Australian states have very similar government structures, policy frameworks and professional organisation in housing

development, thus the data obtained is believed to be sufficiently representative for the Australian context.

Table 2 Statistical Data of Interviewees

Interviewee types		Percentage (%)
By profession	Government Agency Officials	15%
	Developers	15%
	Builders	15%
	Architects/Designers	10%
	Consultants	25%
	Financial Institutions	10%
	Real Estate Agents	10%
By executive level	Director/Manager	85%
	Other	15%

Table 3 Geographical Spread of Survey Respondents and Interviewees

	Geographical Spread			
	NSW	VIC	QLD	TAS
Questionnaire respondents	16%	20%	56%	8%
Interviewees	10%	20%	60%	10%

FAIs Significance

The average mean score and standard deviation (SD) were calculated for each FAI to establish their level of significance and spread dispersion (Table 3). The mean values of the 19 FAIs ranged from 3.35 to 4.12, which indicated a discrepancy in significance among various FAIs. Modest values of standard deviation (0.73 to 1.21) suggested an insignificant diversity in respondent rating.

Table 3 Ranking of the 19 FAIs

FAIs		Mean	Std. Dev.	Rank
Economic factors		**4.08**		
E2.	High investment cost	4.12	0.86	1
E1.	Unclear benefits from future legislation, policy and market change (e.g. increasing energy price and carbon tax)	4.08	0.93	2
E3.	Inadequate or inefficient fiscal or other investment incentives (e.g. green land-use price and access possibility, green mortgages and funding, or other government subsidies)	4.06	0.82	3=
Institutional Factors		**3.84**		
I5.	Lack of a comprehensive code or policy package to guide action regarding sustainability	4.06	0.83	3=
I3.	Inadequate policing of green-washing and unsustainable practices	4.02	0.85	5=
I4.	Slow and unwieldy administrative processes in certifying and policy making	3.84	1.01	8=
I1.	Lack of collaborative integration (e.g. clear leadership and roles among stakeholders)	3.82	0.73	10=
I6.	Duplication and confusion arising from parallel policies/legislation	3.78	0.96	12
I2.	Lack of inter-stakeholder communication networks (e.g. a central knowledge hub)	3.55	0.87	16
Technical and design Factors		**3.74**		
T4.	Lack of integrated design and life-cycle management	4.02	0.95	5=
T5.	Insufficient interdisciplinary research to demonstrate the cost-benefit data	3.90	0.98	7
T2.	Lack of professional education and training programs	3.82	1.17	10=
T3.	Lack of methodologies and tools to consistently define and measure sustainability	3.61	0.95	13
T1.	Inadequate or untested sustainable technologies or materials	3.35	1.11	19
Socio-cultural Factors		**3.58**		
S1.	Reluctance to leave the comfort zone and change traditional practices	3.84	0.99	8=
S4.	Insufficient media promotion of scientific advantages from sustainable housing	3.59	1.19	14
S3.	Lack of social conscience in climate change and natural resource preservation	3.57	1.21	15
S5.	Contested functionality for end users (e.g. health, comfort, maintenance ease)	3.53	1.14	17
S2.	Insufficient reputation, brand recognition and competitive advantage	3.37	0.95	18

Across the 4 micro categories, stakeholders believed economic factors affect their benefits the most (mean value=4.08). “High investment cost” (E2) (mean value = 4.12) is the most significant issue identified by all. Interviewees perceived a 2.5-10% extra cost on a sustainable housing project, depending on the level of sustainability targeted. One consultant stated “If housing is to be sustainable economically it’s got to be affordable.” Closely following E2 are “Unclear benefits from future legislation, policy and market change” (E1) and “Inadequate or inefficient fiscal or other investment incentives” (E3), with an importance level of 4.08 and 4.06 respectively. This result reveals that the current housing industry in Australia values economic returns over all other forms of softer benefits. The significance of E3 was further supported by those who take direct risks such as developers, builders and homebuyers.

The broad category of Institutional factors being ranked second overall (mean value=3.84) confirms the need for better policy-making and intensive collaborative structures around sustainability. "Lack of a comprehensive code or policy package to guide action regarding sustainability" (I5) (mean value = 4.06) was ranked third with a small standard deviation of 0.83, which signifies a collective need for a consistent mechanism to systemize available instruments for sustainability, rather than a one-sided energy efficiency mandate. Next in this category is I3 "Inadequate policing of green-washing and unsustainable practices" (mean value = 4.02), however two interviewees indicated that this issue would be automatically solved as soon as reliable cost-benefit data is established. "Slow and unwieldy administrative processes in certifying and policy making" (I4, mean value = 3.84, ranked 8th) and "Duplication and confusion arising from parallel policies/legislation" (I6, mean value = 3.78, ranked 12th) also raised considerable concerns from developers, builders and consultants. I4 belongs in the policy-making field and should be aligned with I6. Two developers commented that the two factors together represent the effectiveness of policy making and require more resources and money to be allocated from governments. I1 "lack of collaborative integration" was ranked 10th with the smallest SD of 0.73 among all 19 FAIs. This finding reinforced a collective call for more intensive collaboration as the fundamental factor to maximize mutual benefit for stakeholders.

Questionnaire results revealed that the housing industry believes sustainable technologies and design are feasible and economically viable and do not obstruct sustainable housing development in large. This is evidenced by the fact that "Inadequate or untested sustainable technologies or materials" (T1) scored only 3.35 and was subsequently ranked last among all FAIs. However, one interviewee advised that "Given the current technology, designers struggle to get eight stars once more renewable thoughts come into play". In fact, two other FAIs highlighted in this category were considered crucial to sustainable performance: "Lack of integrated design and life-cycle management" (T4) (mean value = 4.02, ranked 5th) and "Insufficient research to demonstrate the cost-benefit data" (T5) (mean value = 3.90, ranked 7th). These two factors emphasise benefits to housing's life cycle and could eventually solve the 'who pays and when' puzzle. This in turn could drive sustainable housing development into a market-oriented cycle as many have expecting for some time.

While much research highlights socio-cultural issues as one of the main barriers to sustainable housing development, this research shows the opposite (mean value = 3.58, ranked 4th among 4). "Lack of social conscience in climate change and natural resource preservation" (S3), "Contested functionality for consumers” (S5) and “Insufficient reputation, brand recognition and competitive advantage” (S2) were all ranked in the bottom five with a mean value of 3.57, 3.53 and 3.37 respectively. This indicates the attitudinal readiness and heightened awareness of environmental issues amongst government officials, industry practitioners and consumers. The interview results also indicate that these three factors are becoming obsolete due to a changing regulatory environment and heightened public awareness in the past decade.

The Identification of Critical FAIs

A list of critical factors affecting the implementation (FAI) was eventually finalised based on the survey and interview findings over a three-step examination. In Step 1, seven insignificant or less essential factors were removed from the original FAI list. Particularly, “Unclear benefits from future legislation, policy and market change” (E1) and “Reluctance to leave the comfort zone and change traditional practices” (S1) were separated from the rest of the list because of the low ranking. To facilitate the analysis in Step 2, the non-parametric test Spearman’s rho was employed to describe the correlations between each pair of FAIs based on the questionnaire results. This resulted in two pairs of FAIs being merged into two single FAIs due to their inherent connections. Firstly, T1 “Inadequate or untested sustainable technologies or materials” and T4 “Lack of integrated design and life-cycle management” were combined as one factor “Technology and Design R&D” due to connection between them (correlation coefficient =0.376). This was supported by interview findings where one consultant highlighted that these two factors together laid the foundation of R&D. Additionally, I4 and I6 were merged to become “Effective regulating mechanism” (correlation coefficient =0.555). Finally in Step 3, two latent factors emerged in the interview study were subsequently added: “market demand” and “market scale”. After the analysis presented thus far, 10 essential FAIs and two emerging factors were identified as the critical factors of sustainable housing (CFAMBs) affecting the implementation of sustainable housing. They are: (1) technology and design R&D, (2) professional re-education & Up-scaling, (3) rating tools, (4) cost-benefit data, (5) cost Issues, (6) incentive system, (7) public education & awareness, (8) green washing, (9) effective regulatory system, (10) market demand, (11) market scale and (12) innovative collaboration. These form the essential elements of the mutual-benefit framework.

Building the ISM model based on FAI Mutual Influences

The individual interrelationships between each pair of critical FAIs were identified through qualitative content analysis and the Spearman’s rho test. This research utilizes Interpretive Structural Modelling (ISM) to present these complex relationships, and further transform them into structural and quantifiable mutual influences to facilitate stakeholder decision-making. It should be noted that the factor “innovative collaboration” was not included in the modelling as it is pre-identified as the fundamental driving factor of all other critical factors according to the survey findings. However, it will be incorporated in the final structural model. The ISM process follows four steps and will be discussed in the following sections (Ahuja, 2007; Singh & Kant, 2008).

Step 1: formulating a structural self-interaction matrix (SSIM) of elements to display the pair-wise relationship between FAIs

In Step 1 four symbols are used to denote the existence of a relation between any two FAIs (i and j) the direction of their interrelationship. The connotation of these symbols and corresponding examples are given in Table 4.

Table 4 Symbols of mutual influence in ISM and examples

Symbol	Rationale	Example	Displayed value in reachability matrix
V	FAI i will aggravate FAI j	Stronger rating tools to measure sustainability will increase the economy scale of sustainable housing. Therefore, the mutual influence between FAI 3 and FAI 11 is “V”.	(i, j) entry=1 (j, i) entry=0
A	FAI i will be aggravated by FAI j	Cost issues will be alleviated by the increased economy scale and the corresponding possibility of wholesale manufacturing. Thus, the mutual influence between FAI 5 and FAI 11 is “A”.	(i, j) entry=0 (j, i) entry=1
X	FAI i and j will aggravate each other	When cost issues are alleviated through wholesale manufacturing of sustainable technologies and products, developers and builders tend not to claim and charge for green features they did not incorporate; this will in turn lessen the cost burden on customers. Therefore, the mutual influence between FAI 5 and FAI 8 is “X”.	(i, j) entry=1 (j, i) entry=1
O	FAI i and j are unrelated	No direct relationship appears to exist between BSC 2 (Professional Education & Up-scaling) and BSC 9 (Effectiveness of Regulating System), so the relationship is “O”.	(i, j) entry=0 (j, i) entry=0

The initial structural self-interaction matrix was developed accordingly as shown in Table 5.

Table 5 Initial Structural Self-interaction Matrix of critical FAIs

NO.	Critical FAIs	11	10	9	8	7	6	5	4	3	2
1	Technology and design R&D	A	O	O	O	O	A	V	V	O	A
2	Professional re-education & up-scaling	O	O	O	O	V	O	O	A	A	O
3	Rating tools	V	O	A	O	V	O	O	A	O	O
4	Cost-benefit Data	O	O	O	O	V	A	O	O	O	O
5	Cost issues	A	V	O	X	O	A	O	O	O	O
6	Incentive system	O	O	A	O	O	O	O	O	O	O
7	Public education & awareness	O	V	O	V	O	O	O	O	O	O
8	Green washing	O	O	O	O	O	O	O	O	O	O
9	Effective regulatory system	O	O	O	O	O	O	O	O	O	O
10	Market demand	V	O	O	O	O	O	O	O	O	O
11	Market scale	O	O	O	O	O	O	O	O	O	O

Step 2: developing a reachability matrix from the SSIM, and checking the matrix for transitivity

The Initial Structural Self-interaction Matrix is then transformed into a binary matrix, called the reachability matrix, by substituting V, A, X, O by 1 and 0 as appropriate. The rules for the substitution of 1's and 0's are also shown in the last column of Table 4. However, before the reachability matrix is finalised, transitive links that may exist between remotely connected variables need to be investigated. For example, in Table 5 there is no direct relationship between FAI 1 "Technology and Design R&D" and FAI 7 "Public Education & Awareness". However, FAI 1 aggravates FAI 4 "Cost-benefit Data" and FAI 4 aggravates FAI 7. Hence according to Step 4 of the ISM process, it can be inferred that FAI 1 has an aggravating impact on FAI 7. Thus, in the final reachability matrix the cell entry (Row 1, Column 7) is 1 as shown in Table 6. It should be noted that adjustments on transitive links were only conducted for one iteration to ensure that indirect links are strong enough between FAIs. Several other transitive links were changed in the same way and shown in Table 6, together with the driving power and the dependence of each FAI. The driving power for each FAI is the total number of FAIs (including itself) on which it might impact. Dependence of a FAI is the total number of FAIs (including itself) which may be impacting upon it. This preliminarily depicts the mutual influence of FAI s in a quantitative manner.

Table 6 Final reachability matrix

NO.	Critical FAIs	1	2	3	4	5	6	7	8	9	10	11	Driving Power
1	Technology and design R&D	1	1*	1*	1	1	0	1*	1*	0	1*	1	8
2	Professional re-education & up-scaling	1	1	0	1*	1*	0	1	0	0	1*	0	6
3	Rating tools	1*	1	1	0	1*	0	1	1*	0	1*	1	8
4	Cost-benefit Data	1*	1	1	1	0	0	1	1*	0	1*	1*	8
5	Cost issues	0	0	0	0	1	0	0	1*	0	1	1	5
6	Incentive system	1	1*	1*	1	1	1	1*	1*	0	1*		9
7	Public education & awareness	0	0	0	0	1	0	1*	1	0	1*	1*	5
8	Green washing	0	0	0	0	1	0	0	1	0	0	0	2
9	Effective regulatory System	1*	1*	1	1*	0	1	1*	0	1	0	1*	8
10	Market demand	1*	0	0	0	1*	0	0	0	0	1	1	4
11	Market scale	1	0	0	0	1	0	1	1*	0	1*	1	5
Dependence		8	6	5	5	9	2	7	8	2	9	7	

Step 3: partition the reachability matrix into different levels

The partition levels were identified based on the final reachability matrix as a hierarchical reference for the final model. The 11 FAIs were prioritised and grouped into 8 levels after 11 iterations of analysis as shown in Table 7. Elements in the top-levels of the hierarchy will not reach any elements above their own level. In other words, the high-level FAIs would generally have little impact on FAIs above their level, while the lower-level FAIs tend to provide a foundation for tackling those below their level.

Table 7 Overview of partition levels

Levels	No.	FAIs	Reachability set R	Antecedent set A	Intersection set I
8	8	Green washing	5,8	1,3,4,5,6,7,8,11	5,8
	10	Market demand	1,5,10,11	1,2,3,4,5,6,7,10 ,11	1,5,10,11
7	5	Cost issues	5 ,11	1,2,3, 5,6,7, 11	5,11
	11	Market scale	1,5,7, 11	1,3,4,5,7,9,11	1,5,7, 11
6	7	Public education & awareness	7	12,3,4,6,7,9	7
5	1	Technology and design R&D	1,2,3,4	1,2,3,4,6,9	1,2,3,4
	2	Professional re-education & up scaling	1,2,4	1,2,3,4,6,9	1,2,4
4	3	Rating tools	3	3,4,6,9	3
3	4	Cost-benefit data	4	4,6,9	4
2	6	Incentive system	6	6,9	6
1	9	Effective regulatory system	9	9	9

Step 4: MIC-MAC analysis and directed graph to conceptualize the ISM model

Based on the quantifiable driving power and dependence identified in Table 6, analysis of cross Impact Matrices-Multiplication Applied to Classification (MIC-MAC) analysis was conducted to divide the critical FAIs into different groups. By assigning the level of dependence and driving power as the x-coordinate and y-coordinate of each CFAMB respectively, all the CFAMBs are classified under four quadrants (Mandal & Deshmukh, 1994). Figure 1 shows that the 11 FAIs fall in the first three quadrants as driving variables, linkage variables and dependent variables. No particular CFAMBs were identified in the quadrant "autonomous variables", which normally defines factors disconnected from the system. This proves the solidarity of the FAI selection in terms of their significance and interrelationships.

{insert Figure 1}

On such a platform, a structural model is established by means of vertices or nodes and lines of edges to visualize the partitioned levels in Table 7 into the four categories. This model is depicted in Figure 2 where the 12 critical FAIs are grouped under the four levels according to their mutual influence as indicated with arrows. If the achievement of FAI j will help tackle FAI i, then an arrow points from i to j.

{insert Figure 2}

Discussions

Based on the shared vision of 12 critical issues in the structural model in Figure 2, different strategies were developed and prioritised to enforce the implementation of sustainable housing in Australia. The structural model consists of four levels of implementation, highlighting that resolution of critical FAIs on the bottom levels could help promote FAIs on the higher-up dependent levels. This offers a vision and the opportunity for a prioritised agenda for policymaking. Industry practitioners may also be able to using findings of this research to formulate guidelines or check-lists to drive their business initiatives and engage with most appropriate stakeholders according to their professional needs.

Specifically, the first level includes the pre-identified factor “innovative collaboration”, serving as “a prerequisite” for the other 11 factors in the model. It is the fundamental factor that creates and communicates mutual benefits for multiple stakeholders. This factor calls for a clear stakeholder structure that explicates the leadership and individual roles and outlines how each stakeholder can ultimately benefit from engaging in sustainable housing as opposed the conventional housing.

The second level includes those regulatory factor FAIs which fell into the first quadrant in Figure 1. They are: effective regulating mechanism, incentive system, reliable cost-benefit data and a consistent nationwide rating tool. These normally have robust driving power but weak dependence, and therefore define what we call “driving variables”. They are the necessary initial triggers for a positive cycle of sustainable housing development and drive FAIs on higher levels before mainstream market buy-in occurs. Particularly, two factors should be acted on immediately: an incentive system to reward production of sustainable housing (such as a tax reduction scheme) and a government-allied, scientific and longitudinal cost-benefit database. Firstly, access to funds in order to finance sustainable housing still remains the domain of government investment rather than private financial lenders. Failure in this regard is normally the major cause of the ‘valley of death’ between the demonstration and full market uptake of any innovation (Sustainability Victoria, 2011). Secondly, in relation to the cost-benefit database, it is the most significant barrier to “economies of scale” and should go hand in hand with the existing rating tools.

Level 3 includes three factors with relatively strong driving power and dependence: technology and design R&D, professional education and up-scaling and public education and awareness. They are defined as the “linkage variables” of sustainable housing development and play the intermediate roles in delivering the driving forces from level 1 and 2 to level 4. In fact, these R&D and educational factors can create geometric effects in influencing market demand and have always had a stronger influence than regulatory factors (the top-down approach) in boosting market scale. This finding supports the significance of the education and awareness campaign by Lutzkendorf & Lorenz (2005) and Osmani & O'Reilly (2009). However, the progress of educational is much slower than regulations in achieving reform.

Level 4 includes the four FAIs with weak driving power but strong dependence in the last quadrant of Figure 1. It includes four dependent yet decisive factors that ultimately indicate the success or failure of the implementation of sustainable housing: market scale, cost issues, green washing and market demand itself. However this market adaptation process has limited creative force in itself. As one interviewee indicated, it would be unrealistic for end users to ask for ten-star housing in terms of the level of energy efficiency accredited by the Building Code of Australia in the first place, because the supply side has not presented anything for consumers to feel and understand. However, challenges on this level could consecutively be tackled once other factors on the three lower levels are resolved. For example, pressure from green washing will be alleviated as soon as cost issues are tackled, education is in place, and a consumer-friendly rating tool is established.

Conclusions

This research aims to establish a hierarchical model that encompasses critical factors affecting the implementation of sustainable housing in Australia. This was achieved through a quantitative questionnaire study, a qualitative interview study and Interpretive Structural Modelling. The systematic model prioritizes 12 critical Factors Affecting Implenentation, distinguishes four categories of factors based on their interdependency and driving force, and calls for the attention and coherent strategies of resolution from government agencies and housing industry practitioners. Particularly, three critical factors are highlighted as the foundation of this model and requiring urgent action. One imperative is to establish a clear reward system by the governments and developers. A cost-benefit research regime with scientific rigor and a longitudinal approach needs to be developed. However, environmental collaboration should be acted upon as the prerequisite to achieve the first two initiatives.

This investigation of the complex mutual influences among critical factors bridged the gap in previous research, where the examination of individual factors led to the development of isolated strategies for sustainable housing implementation. It is recognised that this study represents a small sample and as such is more an Australian expert evaluation rather than a fully-fledged worldwide industrial viewpoint. Opportunities exist to tailor-make specific strategies for each critical factor. For example, the specific needs of different key stakeholders may be taken into consideration to generate interest among certain stakeholder groups, rather than reaching out for all encompassing solutions. The findings are generally applicable in those developed countries sharing similar political and economic systems with Australia. But political, cultural and religious influences do impact upon housing development practices. Therefore in future research, this work can be expanded and tested in other regions. More emphasis will also need to be placed on the specific benefits, risks and collaboration activities that cater for individual stakeholders in order to pursue systematic implementation of the identified hierarchical model.

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