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Exploring beyond-compliance behaviors of Australian building practitioners: A cluster analysis

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ABSTRACT

To meet Australia's 2030 goal of a zero-energy and carbon-ready residential building industry, new homes must attain high-performance ratings that are beyond-compliance. However, recent Nationwide House Energy Rating Scheme (NatHERS) data shows that most new residential projects in Victoria (Australia) were designed to meet only the minimum compliance level, without going beyond-compliance. Apart from the commonly examined reasons related to clients and policymakers, an underexplored aspect is the diverse behaviors of building practitioners during the compliance process. To effectively motivate different building practitioners to achieve beyond-compliance outcomes, a fundamental yet unanswered question is: how to segment building practitioners based on behavior constructs. To fill this gap, the study conducts a cluster analysis to explore segments of building practitioners with different beyond-compliance behaviors. Data were collected from a questionnaire survey of 73 residential building practitioners in Victoria, including architects/draftspersons, builders, and thermal performance assessors. Victoria was selected because many new Victorian houses still fail to achieve beyond-compliance, highlighting the importance of exploration. Three clusters of building practitioners were identified: lingerer, characterized by low subjective norms, perceived behavioral control; close-follower, marked by high normative alignment but low attitudes; and leader, distinguished by strong attitudes, subjective norms. The most significant difference between clusters was the subjective norms driven by clients' requests. As the first clustering study to segment building practitioners based on beyond-compliance behaviors, the findings facilitate building practitioners to identify key areas for self-improvement, and also help policymakers develop tailored strategies to promote different segments of building practitioners to go beyond-compliance.

1. Introduction

Due to greenhouse gas emissions, climate change has become a global challenge in recent decades [1]. As a response, Australia has committed to reducing its CO_2 output by 43 % of its 2005 levels by 2030, and then to net zero emissions by 2050 [2]. Aligning with this net zero commitment, Australia's "Trajectory for Low Energy Buildings" set out the national plan for the residential building industry to achieve zero-energy and carbon-ready sector by 2030 [3]. In Australia, the minimum energy standards for new buildings are considered essential policy instruments for lowering energy consumption and carbon emissions from the built environment. The minimum performance standard before the 2022 update to the National Construction Code (NCC) was to achieve a Nationwide House Energy Rating Scheme (NatHERS[1]) 6 stars for new housing. However, this minimum standard has increased from 6 to 7 stars under changes to the NCC 2022, which will become mandatory for the State of Victoria in Australia from May 2024. Many researchers have underlined that 6 or even 7 stars are not sufficient for Australia to achieve net zero emissions. An optimal economic and environmental energy standard should be beyond 7.5 stars [4]. Nevertheless, the latest NatHERS data from the HStar[2] dashboards reveal that 79.88 % of new Victorian housing between May and October 2023 (i.e., the transition

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[1] In Australia, the NatHERS is developed to assess the thermal energy load performance of housing. The output is a star score ranging from 0 (worst) to 10 (best). The minimum standards approximated 4 NatHERS stars in 2003, then 5 stars in 2006 and subsequently 6 stars in 2010. Then, in 2022, the NCC prescribes the minimum star rating from 6 to 7 stars for new homes, with an additional Whole-of-Home rating covering energy performance of appliances.

[2] The HStar web portal was created by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) with the support and cooperation of Sustainability Victoria. The HStar dashboards collect certificates and information generated through NatHERS-accredited software.

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period toward the 7-star standard) was designed only to achieve the minimum NatHERS 6-star standard, approximately 7.15 % went 7 stars and beyond, and only around 1.18 % went beyond the optimal 7.5 stars [5]. This lower rate of beyond-compliance design is perhaps expected, given that many of these homes were already in the design or planning stages and thus not required to anticipate the 7-star threshold. Nevertheless, with the 7-star minimum becoming mandatory and the long-term industrial transition toward net zero emissions objectives, limiting new housing to minimum standards may fall short in addressing these goals. Given the gradual pace of regulatory changes, a critical challenge is to foster industry practices that encourage beyond-compliance outcomes. Going beyond minimal compliance will drive substantial progress toward net zero emissions targets, making it an urgent challenge to tackle [6].

On a worldwide scale, similar challenge is observed - Several studies have demonstrated that the energy performance of new houses in many countries, including the US, the United Kingdom (UK), South Korea and Australia, is sub-optimal when considered from an environmental and economic perspective [4]. South Korea introduced its Building Energy Code in 2001, but by 2016, most residential buildings were designed to solely meet minimum standards. Among the 30,489 permits issued that year, just 0.05 % achieved the government-promoted zero-energy level [7]. In the UK, Gupta and Kotopouleas [8] reported that many new homes are also designed to fulfill merely the minimum energy performance standards, with few achieving beyond-compliance outcomes. The UK Committee on Climate Change (2019) has called for new homes to go beyond-compliance for a low-carbon, sustainable future [9]. In Illinois (US), homes must score 62 or lower on the Home Energy Rating System, with lower scores indicating higher energy efficiency. In 2022, the state's average score was 58, just above the required minimum [10].

Among all the reasons for not exceeding minimal compliance, such as the frequently-researched inadequate transitional support from building authorities and low client demand for homes beyond code minimums, recent studies indicate that one of the arguments is the different behaviors of building practitioners in the compliance process, especially their willingness and ability to achieve beyond-compliance outcomes [11,12]. Since the NatHERS is calculated based on the simulation of the house design, the building practitioners who engage in the design phase of a project (e.g., architects, designers/draftspersons, builders, project managers and thermal performance assessors) are especially relevant. Building practitioners often serve as crucial intermediaries between policy expectations and client preferences. Their role involves executing the policies as well as advising and encouraging clients on the benefits of achieving beyond-compliance [13], which should in turn drive better beyond-compliance outcomes. Nevertheless, most academic works relating to building energy policies as well as sustainable buildings only focus on the top and bottom (i.e., policymakers and building consumers), while neglecting the middle actors' (i.e., building practitioners') willingness and capacity to achieve beyond-compliance with the energy policies [14]. This neglect wrongfully assumes that a zero-energy and low-carbon vision outlined in a policy is straightforwardly and instantly adopted by building practitioners without careful consideration [15]. As is further affirmed by Parag and Janda [16], building practitioners are critical middle actors who can upstream influence top actors like the policymakers, downstream influence bottom actors like the building consumers and also sideways influence the other building practitioners in delivering net zero building industry [17]. Their varying behaviors can lead to different beyond-compliance outcomes in the design stage. The key to achieve an overall beyond-compliance status in Australia is to understand these different behaviors so that building practitioners themselves can identify key areas for self-improvement, and policymakers can develop and execute tailored strategies to effectively motivate different building practitioners to go beyond-compliance. Notwithstanding this significance, no research effort has addressed the fundamental question: how to segment building practitioners based on behavior constructs. Therefore, to fill this research gap, this paper aims to explore the segments of building practitioners based on their beyond-compliance behavior constructs when they face the transition toward 7 stars in the NatHERS. To accomplish this, the researchers employed a questionnaire survey designed based on the beyond-compliance behavior assessment model established in their previous work [18]. This survey collected data on various behavioral constructs of building practitioners. The analysis used k-means cluster analysis to explore segments within the surveyed practitioners based on their constructs. By presenting the first clustering analysis in the context of beyond-compliance with energy performance standards, this study offers valuable insights for building practitioners to identify areas for self-improvements. In addition, the study allows policymakersto identify tailored interventions to stimulate more building practitioners to advance toward achieving beyond-compliance outcomes. With more of them exceeding the minimum standard, the industry's transition to net zero emissions will be accelerated.

In Australia, the minimum energy rating standards vary in different states and territories, making it impractical to analyze the entire country using a single dataset. The study focuses on the State of Victoria (Australia), not only because most houses there are approved using the NatHERS approach, but also due to the significant number of new Victorian houses that still fail to achieve beyond-compliance outcomes, making it crucial to analyze practitioner behavior. The findings from this study can thus present insights that Victorian policymakers can use as a foundation for further developing their policy instruments to encourage beyond-compliance outcome. This paper starts with a description of building practitioners' beyond-compliance behavior regarding the Australia's NatHERS, followed by the methodology and the principal findings. Finally, the discussion and conclusions are presented.

2. Beyond-compliance behaviors of residential building practitioners

Other than the reasons from building authorities and clients, recent literature indicated that one of the prevailing reasons of the failure to achieve beyond-compliance outcomes with the NatHERS was the different behaviors of the building practitioners in the compliance process [11,12]. Their behaviors, decisions, and capacity to act are influenced not only by policy mandates but also by the level of awareness and demand from clients for homes that exceed minimum compliance. Building practitioners are expected to advise and encourage clients on the potential benefits of beyond-compliance outcomes, such as improved energy efficiency, environmental sustainability, and long-term cost savings. However, the extent to which they fulfill this role can vary significantly based on their own willingness, ability, and the specific dynamics of their interaction with clients. This highlights the importance of considering building practitioners' behaviors in the compliance process, as their role can either drive or hinder the achievement of beyond-compliance outcomes. Beyond-compliance behavior encompasses a wide range of behavioral predictions (i.e., willingness and ability to achieve beyond-compliance outcomes) to understand how people respond to rules and come to adapt their behavior to the rules in the compliance process [21,22]. Studies from the residential building industry highlighted a series of building practitioners' behavioral variables which have resulted in their reluctance in achieving beyond-compliance outcomes: (1) poor knowledge of the energy-efficient design and construction techniques as well as the policy content [23], (2) building practitioner's unfavorable attitudes toward achieving beyond-compliance with the energy efficiency standards [12], (3) societal pressure from peer practitioners and clients [24], and (4) moral concerns [25]. However, these variables were scattered in a patchwork of various studies that were seldomly brought together to investigate: how each behavioral variable influences and shapes practitioner's distinct beyond-compliance behavior [11,12]. Against this backdrop, Lu, et al. [18] designed a cross-theoretical beyond-compliance behavior assessment model with building energy regulations, which integrated different compliance theories in the legal and social science disciplines such as the theory of planned behavior [26], norm activation model [27] and the mixed motives compliance model [28]. The model uncovers a comprehensive range of behavioral variables that co-influence building practitioner's beyond-compliance behavior with the building energy regulations. For instance, it incorporates subjective norms, which reflect the influence of social expectations, including client requests, on building practitioners' decision-making. This construct aligns with the intermediary role of building practitioners, as their behavior is often shaped by balancing policy compliance with client preferences and demands. As per the author's model, the beyond-compliance outcome is mainly influenced by the building practitioner's behavioral intention to achieve beyond-compliance, the attitudes, and the personal norms. Then, the behavioral intention is further governed by four predictive variables. Table 1 summarizes these variables.

As seen in Table 1, the first predictive variable is attitudes, which is typically defined as an individual's overall evaluation—positive or negative—toward a specific behavior [26]. To adapt to the current context of building practitioners' beyond-compliance when using the NatHERS, the attitudes refer to an evaluative predisposition toward beyond-compliance as a function of its determinant personal consequences [29]. According to Brown and Loosemore [30], Australian building practitioners' attitudes may stem from perceived benefits through e.g., getting more clients, or differentiating their projects through competitive advantage [30]. Similar arguments were found in China [31]. Alternatively, studies in Australia and the US found that the attitudes can also come from building practitioners' assumption of increased compliance costs with high energy performance designs [25,32].

Subjective norms, which refers to the perceived pressure or motivation from those significant referents, i.e., how the regulated building practitioner feels they will be perceived by others [33]. Tam, et al. [34] and Enker and Morrison [12] stated that Australian building practitioners' beyond-compliance behavior can be influenced by their expectations of industry peers or clients. Zapata-Lancaster and Tweed [15] concluded with similar arguments in the regulatory setting of UK's building industry. Thus, this variable was operationalized to reflect the perceived social pressures from important referent groups such as clients, peers, and other industry stakeholders.

Perceived behavioral control concerns an individual's perception of their ability to perform a behavior, determined by their confidence in their knowledge and skills, the perceived ease or difficulty of the task, and external constraints. In this context, according to Cooper [29], it was operationalized to a building practitioner's understanding of their capacity to achieve beyond-compliance outcomes. A report commissioned by the Government of South Australia revealed that situational constraints (such as shortage of specific building materials) hinder building practitioners from achieving higher energy star ratings [35]. In the UK, knowledge and skills possessed by building practitioners to design a high energy star rating house are considered a relevant factor [36].

Personal norms are self-expectations to conduct or refrain from engaging in beyond-compliance [28]. They arise either from internalized moral agreement with the policy objective or from the content of the policy itself [37]. Research in Australia and UK found that beyond-compliance behavior is dependent on building practitioners' moral agreement with substantive goals in the building energy policy, or on the agreement level with the policy content [28,38].

Behavioral intention is a critical determinant of behavior, referring to the motivational factors that influence a person's decision to perform a specific action [26]. In this model's context, the intention to achieve beyond-compliance is measured by the willingness and efforts devoted to executing beyond-compliance outcomes. It reflects a building practitioner's deliberate choice and commitment to exceed the minimal

Table 1
Beyond-compliance behavior assessment model.

Variable	Indicator	Operational definitions or examples in the context of achieving beyond-compliance when using NatHERS
Attitudes toward going beyond minimal compliance	Perceived economic benefits	Perceived benefits through e.g., getting more clients, or differentiating the delivered projects via competitive advantage.
	Perceived economic costs	Perceived increased compliance costs due to high energy performance designs.
Subjective norms	Requests from clients	Pressure from clients' requests.
	Expectations from building industry colleagues and peers	Pressure due to comparing with other building practitioners, or seeking societal intangibles, including reputations or respect or approval from other industry stakeholders.
Perceived behavioral control	Self-efficacy in terms of confidence to go 7 stars and higher	Understanding of compliance options in the NCC, as well as knowledge and skills possessed by building practitioners to design deliver a beyond 7-star house.
	Self-efficacy in terms of perceived easiness to go 7 stars and higher	Perceived level of easiness or difficulty in going 7 stars and higher that can result from past experience.
	Perceived controllability in going 7 stars and higher	Whether going 7 stars and higher is within control, i.e. constraints or facilitators that influence building practitioners' compliance decisions, e.g. shortage or provision of certain sustainable building materials.
Personal norms	Moral agreement with environmental protection	Degree of moral alignment with the goals of environmental protection as a building practitioner.
	Moral agreement with carbon emissions reduction	Degree of moral alignment with the goals of greenhouse gas emissions reduction as a building practitioner.
	Agreement regarding whether going beyond 7 stars is correct	Degree of agreement toward the overall assessment guidance offered by the NatHERS.
	Agreement regarding whether going beyond 7 stars can lead to emissions reduction	Degree of agreement regarding the statement: Going 7 stars and higher benefits carbon reduction for society.
	Agreement regarding whether going beyond 7 stars can lead to energy consumption reduction	Degree of agreement regarding the statement: Going 7 stars and higher benefits energy consumption reduction.
Behavioral intention	Willingness and efforts devoted to executing compliance	The extent to which practitioners are willing to try, and the extent of efforts practitioners are planning to deploy for compliance.
Actual beyond-compliance	Actual beyond-compliance outcome delivered	Frequency of projects being over 7 stars within 10 years.

Source: Lu, et al. [18].

regulatory standards.

Actual beyond-compliance refers to the observed frequency or outcomes of beyond-compliance actions in practice. In this context, following Gram-Hanssen and Georg [39], the operationalization based on the previous frequency of delivering beyond-compliance projects implies the actual beyond-compliance outcomes.

Notwithstanding the identification of these interrelated predictive variables shaping the behavioral intention and actual beyond-compliance outcome, previous studies did not differentiate building practitioners' discrete beyond-compliance behavior in the context of achieving beyond-compliance when using NatHERS [12]. In the other regulatory compliance studies [28,40], investigating and clustering of the regulatees' beyond-compliance behavior were shown to have implications for the regulators to design various interventions for each distinct group. In this way, the policy objective was achieved more efficiently. Therefore, to meet the residential building industry's net zero emissions vision, it is important to explore the segments of the building practitioners based on their beyond-compliance behavior predictive variables regarding the NatHERS.

3. Methods

Based on the above-mentioned beyond-compliance behavior assessment model [18], a questionnaire survey was used for data collection. As previous behavior studies suggested, questionnaire survey can facilitate the retrieval of large dataset that first contains information about building practitioners' different kind of variables that co-shape their beyond-compliance behaviors, and secondly, includes data with a broad variety of occupational characteristics [28]. In a similar vein, Li, et al. [41] used questionnaire survey to obtain data for examining building practitioners' construction waste reduction behavior.

3.1. Data collection

To enhance the clarity of the questionnaire, a pilot survey was conducted with two academics, as recommended by Bailey [42]. One academic was an experienced architect and teaching academic in Victoria, while the other was a post-doctoral research fellow in construction management. After minor rewording, the questionnaire survey was conducted between February and June 2023, targeting building practitioners with over 2 years of relevant work experience in Victoria to ensure they possessed sufficient industry exposure for informed feedback. This survey has obtained ethical approval from the Human Ethics Advisory Group at Deakin University (Ref No. SEBE-2022-54). A total of 600 questionnaires were distributed via Qualtrics (an online survey platform), with participants approached via email through industrial professional bodies such as Design Matters National and Master Builder Victoria. To enhance that individuals in the targeted population had an identical chance of being selected, a cluster sampling technique was used. According to the State of Victoria [43], a range of qualified and registered professionals in Victoria—including architects, designers, draftspersons, and thermal performance assessors —play a critical role in designing, preparing, and reviewing building plans and documents to ensure compliance for building permits [44]. Depending on the project's procurement model, builders may also contribute during the design phase. Accordingly, 80 % of the questionnaires were distributed to architects, designers, draftspersons and thermal performance assessors. The remainder were allocated to builders and project managers. The survey obtained 73 complete responses, resulting in a 12.17 % response rate. According to Fosnacht, et al. [45], data estimates can remain reliable with a 10 % response rate if the sample size is at least 500. The sample of 73 also exceeds that of a previous clustering study, which employed 55 participants [46]. Furthermore, Formann [47] recommended that the minimum sample size for k-means cluster analysis should be greater than 2^m cases, where m is the number of cluster variables. As this study uses 4 variables for k-means analysis (see Section 3.2), a minimum sample size of 16 is sufficient. Therefore, the sample size of 73 in this study supports robust analysis.

Several research works indicate that Australian residential building practitioners can exhibit various beyond-compliance behaviors depending on their occupation-related characteristics, such as work experience, occupation, involved project types (volume homes versus custom homes) and involved project areas (urban areas versus regional areas) [48,49]. Therefore, to examine the potential relationship between clustering and building practitioner's occupational backgrounds, the first section of the questionnaire collected building practitioners' occupational characteristics, as summarized in Table 2.

The second section of the questionnaire aimed to measure the beyond-compliance behavior of each respondent following the model by Lu, et al. [18]. The variables were measured by the corresponding indicators on a 5-point Likert Scale, with 1 representing the lowest value and 5 the highest. According to the beyond-compliance behavior assessment model (Table 1), each indicator was operationalized with relation to achieving beyond-compliance when using NatHERS, i.e. delivering a project at 7 stars and higher. All the indicators were also coded (e.g. ATT1, ATT2) for the convenience of the analysis. For instance, the variable of perceived behavioral control included three indicators. PBC 1 and PBC 2 described the building practitioners' self-efficacy by asking the respondent about their confidence and perceived easiness to go 7 stars or higher. PBC 3 described the building practitioners' perceived controllability. It asked the respondents to rate if going 7 stars and higher is within their control.

3.2. Data analysis

In the last three decades of regulatory studies and policymaking, much has been discussed around people's beyond-compliance behaviors. Segmentation is usually the first step in the development of different interventions for different groups of people in the market. To perform the segmentation, two stages were involved, as illustrated in Fig. 1.

According to Fig. 1, stage 1 was related to initial data processing. In stage 1, factor analysis was used to firstly assess the reliability and validity of the variables to ensure the psychometric properties, and secondly, to ensure the adequacy of sample size [50]. This technique is commonly used as an initial analysis in several compliance behavior studies [28].

Stage 2 was the main analysis for segmentation. To identify segmentations of building practitioners based on the four predictive variables (i.e., attitudes, subjective norms, perceived behavioral control and personal norms), cluster analysis was performed using SPSS 28.0. Cluster analysis is an exploratory method widely applied across various disciplines for its ability to distinguish objects into different segments [46]. Among different clustering approaches, the k-means clustering

Table 2
Occupational characteristics of the 73 building practitioners.

Responding building practitioners	Frequency
Years of work experience	
2–10 years	9
11–20 years	14
More than 20 years	50
Occupation	
Architect and building designer (draftsperson)	60
Thermal performance assessors	5
Builder and construction supervisor	8
Involved project type	
Mostly custom homes	58
Equally between custom homes and volume homes	12
Mostly volume homes	3
Involved project area	
Mostly in cities and major urban population areas	37
Equally between urban and rural areas	22
Mostly in rural and regional areas	14

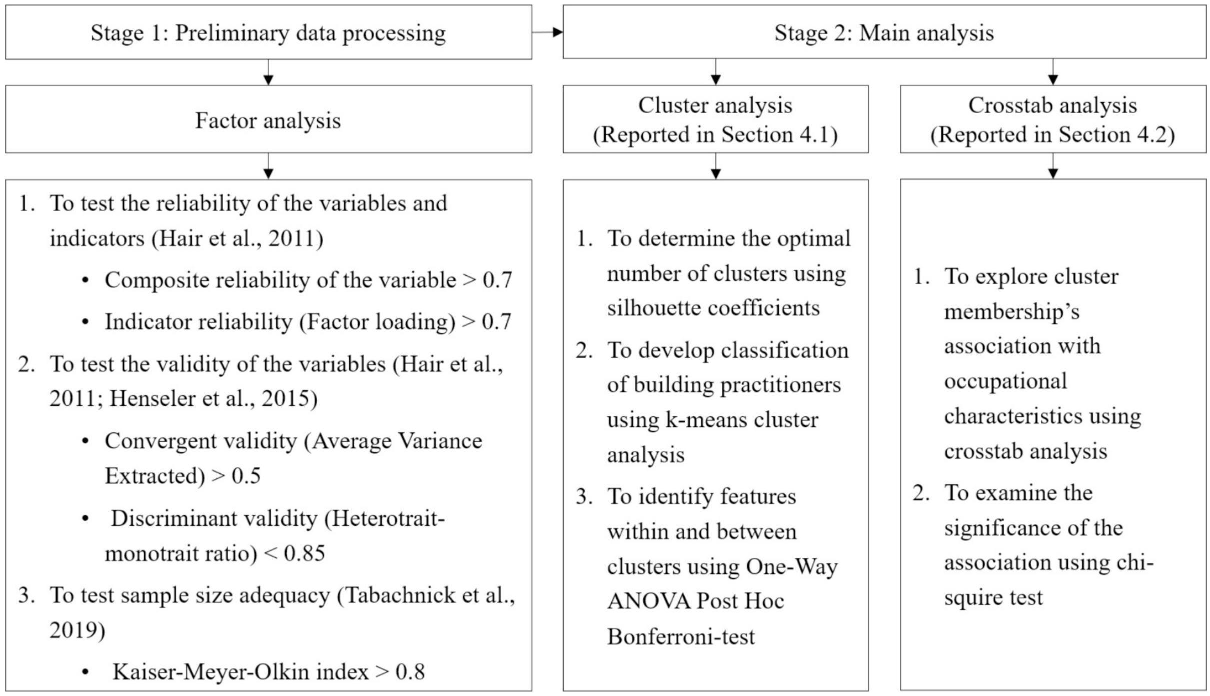

Fig. 1. Stages in data analysis.

algorithm remains the most popular clustering algorithm [52]. The k-means algorithm was also used by many studies based on cluster analysis in the building industry [53]. It was also adopted by studies in relation to compliance and regulation [40]. Hence, the k-means cluster analysis approach was selected for this research. As presented in Fig. 1, to start the k-means cluster analysis, an optimal number of clusters (i.e., the "k") needs to be determined. According to Gaitani, et al. [54], an optimal "k" can be determined using the silhouette function, which represents the cohesive degree of clusters among the samples and the separated degree of each cluster. The optimal cluster number emerges when the silhouette coefficient simultaneously exhibits the maximal mean and the minimal number of negative values. Following the decision of cluster number, it was needed to find out what characterized each of the identified clusters and how they were different from one another. To achieve that, mean values of the four beyond-compliance behavior predictive variables for each cluster were generated and compared. Next, the researchers pairwise compared each cluster's score on the predictive variable, and tested whether or not the clusters' mean scores were significantly different from each other by using the One-Way ANOVA Post Hoc Bonferroni-test. The Bonferroni-test also allowed us to identify what predictive variable made the cluster distinguishable from the others [28]. Subsequently, the cluster membership's association with building practitioners' occupational characteristics was explored. The crosstab analysis function in the SPSS 28.0 was used to identify the association, followed by the test of significance of the association using chi-square tests [28].

4. Results

Following Fig. 1, the preliminary factor analysis was performed in the first instance. Most of the variables and indicators in the questionnaire showed their reliability and validity (see Appendix 1). There were only two exceptions. The factor loading of the indicator PBC3 "Perceived controllability in going 7 stars and higher" in the perceived behavioral control was 0.578, which was below the threshold of 0.7. According to Francis, et al. [55], the variable of perceived behavioral control must include two dimensions: controllability (PBC3) and self-efficacy (PBC 1 and PBC 2). Therefore, the researchers chose to accept PBC 3 despite its low loading index. A similar approach was used by Nielsen and Parker [28]. Another indicator PN5 "Agreement regarding whether going beyond 7 stars can lead to energy consumption reduction" for the variable personal norm had a factor loading of 0.699, which was below the cutoff of 0.7. Hair, et al. [56] argued that in exploratory research, a coefficient greater than 0.6 was also deemed acceptable. Hence, this item was kept. In addition to the assessment of reliability and validity, the Kaiser-Meyer-Olkin index was reported at 0.808, which suggested sample adequacy. Following the confirmation of the reliability, validity, and sample size adequacy, the main analysis was conducted and presented in the next sections.

4.1. *Clusters of building practitioners' beyond-compliance behavior*

As per Fig. 1, to determine the optimal cluster number, silhouette coefficients were compared between various clustering options ranging from 2-cluster to 6-cluster (see Appendix 2). It was found that the coefficients for 2-cluster and 3-cluster solutions were higher and similar: 0.381 and 0.361. Then, the numbers of negative silhouettes for the 2 and 3-cluster options were compared. It showed that the 3-cluster option had a lower value of negative silhouette. In conclusion the 3-cluster segmentation has a relatively high mean cluster silhouette while presenting the lowest negative silhouette. Thus, the 3-cluster grouping was considered as the optimal solution for segmentation. This 3-cluster result also resonated with several clustering studies in the domain of compliance or regulation (e.g., [28,40]).

Next, k-means cluster analysis was performed for developing the clustering of building practitioners on the four behavioral variables (attitudes, subjective norms, perceived behavioral control, and personal norms). Further, to identify what characterized each cluster and to assess what beyond-compliance behavior predictive variable were different from one another, a Post Hoc Bonferroni test was applied using SPSS 28.0. The results were depicted in Table 3. To indicate each cluster's behavioral intention and its actual beyond-compliance outcomes, the values of these two variables were also incorporated in Table 3.

Table 3 shows that the three clusters can be mostly distinguished due to their differences in the variable of subjective norms. It meant that clients' requests on home energy efficiency designs, together with colleagues and the industry's opinion around going higher stars were the

Table 3
Three clusters of building practitioners in terms of their beyond-compliance behaviors.

		Cluster information			Between-cluster difference		
		Cluster 1	Cluster 2	Cluster 3	Clusters 1 and 2	Clusters 1 and 3	Clusters 2 and 3
		Lingerer	Close-follower	Leader			
Variables and indicators of beyond-compliance behavior[a]					Mean difference of variables and their significance[b]		
Variable	Indicator	Value					
Attitudes		**1.73**	**1.88**	**3.67**	**0.15**	**1.94***	**1.79***
	ATT1	1.55	1.87	3.5			
	ATT2	1.91	1.88	3.84			
Subjective norms		**2.68**	**4.06**	**4.58**	**1.38***	**1.90***	**0.52***
	SN1	2.45	3.96	4.45			
	SN2	2.91	4.17	4.71			
Perceived behavioral control		**2.61**	**3.58**	**3.95**	**0.97***	**1.34***	**0.37**
	PBC1	3.18	4.33	4.29			
	PBC2	2.45	3.58	3.76			
	PBC3	2.18	2.83	3.79			
Personal norms		**3.05**	**4.28**	**4.61**	**1.23***	**1.55***	**0.32**
	PN1	3.00	4.54	4.74			
	PN2	2.73	4.29	4.53			
	PN3	3.27	4.33	4.71			
	PN4	2.64	3.88	4.45			
	PN5	3.64	4.38	4.61			
Behavioral intention	INT	2.82	4.50	4.39	–	–	–
Actual beyond-compliance	COM	1.36	1.90	2.61	–	–	–

[a] Cell entries are the mean values of designated items for building practitioners comprising the designated cluster of compliance behavior predictive variables calculated using K-means clustering.
[b] For each comparison the difference of means, the Post Hoc Bonferroni test is: * = $p < .05$.

main circumstances that differentiate the building practitioners. In addition, all three groups rated their personal norms fairly high. This reflected that an agreement with net zero transition was a shared fundamental element for all responding practitioners. This agreement included a moral alignment with NatHERS substantive goals and an internal acknowledgement of the NatHERS guidance toward the achievement of the low-carbon vision. The following parts described each cluster's feature in detail.

Cluster 1 was labelled as “lingerer”. Building practitioners in this cluster were distinguished from the other three clusters by their significantly lowest scores on subjective norms, perceived behavioral control and personal norms, indicated by the asterisk symbols in Table 3. In terms of their subjective norms, lingerers essentially reported that their clients did not ask for a high-energy performing house (SN1 = 2.45), and the peers surrounding them did not expect the building practitioners to deliver a high-performing project (SN2 = 2.91). In relation to the low perceived behavioral control, lingerers generally demonstrated low controllability (PBC3 = 2.18) to deliver a beyond-compliance project due to several constraints. As shown in existing literature, such constraints may include the shortage of certain material [35]. Thirdly, the comparatively lowest score on the personal norms, in particular the low value of PN4 at 2.64, indicated that lingerers generally disagreed that delivering projects at 7 stars and higher can contribute to industry's transition toward net zero emissions. This exemplified their distrust or frustration with the current guidelines of the NatHERS framework. The same implication was found in several studies. For example, Daniel, et al. [57] argued that the NatHERS may not be suitable for assessing low energy dwellings that are intended to use little or no heating and cooling during operation. Furthermore, it was not surprising that this cluster had the lowest intention to go 7 stars and above. The value of behavioral intention was 2.82, which was far below that of the other clusters. Their actual beyond-compliance outcome was also the weakest (1.36) among the three clusters. The lowest scores on both the behavioral intention and the actual beyond-compliance outcome demonstrated their potential delay in achieving a beyond-compliance outcomes of 7 stars and above, and hence the name “lingerer”.

Cluster 2 was labelled as “close-follower”. As per Table 3, it was observed that all four behavior variables in this cluster stood between the other two clusters. Furthermore, it was found that close-followers' attitudes (1.88) were closer to lingerers (1.73), which were very low. However, the rest of the three variables (subjective norms, perceived behavioral control, and personal norms) were high, which was close to the third cluster. This feature indicated that, in general, close-followers had high normative alignment with the NatHERS, and they usually possessed good knowledge and capability to deliver high-performing projects. However, their low attitudes implied that close-followers generally considered a 7-star project as high additional costs. Furthermore, although the behavioral intention to achieve beyond-compliance of close-followers was very high (4.50), their actual beyond-compliance outcome was still low (1.90) as compared to the third cluster (2.60). Thus, this cluster was named “close-follower”.

Cluster 3 was labelled as beyond-compliance “leader”. As per Table 3, leaders were characterized by their highest scores in attitudes (3.67) and subjective norms (4.58). The highest attitudes indicated their favourable opinion on the material benefits regarding the potential competitive advantage of delivering 7-star projects. It also indicated their recognition that delivering 7-star houses can bring them more clients and revenues. Further, building practitioners in this group reported that they usually work with clients who have a high willingness to own energy-efficient homes (SN1 = 4.45). Leaders also valued highly of building industry's overall perception in relation to high-performing buildings, which was an indication of wanting to establish a good reputation and win respect within the building industry (SN2 = 4.71). Leaders were also confident of their capability to deliver over-compliant projects as well (PBC1 = 4.29). In this cluster, building practitioners also had fairly high scores on personal norms (4.61), meaning that they intrinsically agreed with the NatHERS' goal of a net zero building industry and its guidance of delivering such outcomes. The behavioral intention for this cluster was not significantly different compared to the cluster of close-followers. Nevertheless, their actual beyond-compliance outcome was significantly higher (2.61) than the other two clusters (1.36 and 1.90), which made them the “leaders” among the 73 respondents in the 6 to 7-star transition.

4.2. Cluster membership with occupational characteristics

According to Fig. 1, further examination was conducted on the association between the cluster membership with building practitioners' occupation-related characteristics. Using the crosstab analysis function in SPSS 28.0, Fig. 2 was generated to present the distribution of cluster memberships in each occupational sub-group.

Fig. 2 indicated that some building practitioners with specific occupational characteristics had different distribution features. For instance, when examining the length of work experience, the building practitioners with 11 to 20 years of work experience mostly belonged to close-followers. This suggests that this group may stick to the minimum standards without fully embracing beyond-compliance practices. In addition, for building practitioners working on different types of projects, most custom-home practitioners were in the cluster of leaders while most volume-home practitioners were in the cluster of close followers. This indicates that custom-home building practitioners have a greater inclination toward achieving beyond-compliance, while those who work on volume homes emphasized more on the economic benefits of the projects than the other sub-groups. Finally, in terms of different occupations, more builders and construction supervisors (25 %) were found to be in the cluster of lingerers compared to close-followers (12.5 %). This implied that, in promoting beyond-compliance behaviors, this type of professional should be targeted at the first place, as their tendency to remain in the lingerers clusters indicates potential for significant behavioral change within this professional group. Overall, the insights from Fig. 2 highlight the need for tailored strategies that consider the diverse motivations and behaviors of building practitioners across different experience levels, project types, and occupations.

Next as per Fig. 1, the researchers investigated whether the above associations between the cluster membership and building practitioner's occupational characteristics were significant or not. After conducting chi-square tests on the association between cluster membership and building practitioners' occupational characteristics, all the 2-sided asymptotic significance (p-values) index were above 0.05 (see Appendix 3). This meant that there was no significant relationship between clusters and building practitioner's occupational variables. It further implied that the four predictive variables can independently contribute to explaining building practitioners' differences in beyond-compliance behaviors, regardless of their occupational characteristics.

5. Discussion

The study explores Victorian (Australian) building practitioners' beyond-compliance behaviors through differentiating them into three distinct clusters. In this section, the authors first discuss the three clusters' features with prior research across different countries, highlighting common patterns and divergences. Following this, the discussion shifts to the differences between the clusters, primarily driven by variations in subjective norms, and provides insights on strategies to bridge these disparities.

In the cluster of lingerer, building practitioners exhibit the lowest attitudes, indicating a general disinterest in exceeding the minimum requirements. Their subjective norms and perceived behavioral control are also relatively low, suggesting that they neither feel significant pressure from external stakeholders nor are confident in their ability to deliver high-performance outcomes. This aligns with findings from studies in the UK where certain building practitioners similarly reported low interest or motivation to go beyond the minimum energy requirements due to perceived financial burdens [58].

Building practitioners in the cluster of close-followers express strong subjective and moral motivations to achieve beyond-compliance, as indicated by their high values of subjective norms, perceived behavioral control, and personal norms, but they fall short in action, with low attitudes scores holding them back. This suggests that while they recognise the importance of energy efficiency, especially in the context of environmental responsibility, they are constrained by perceived high costs or practical barriers. This behavior state is reflected in Swedish studies [59]. Although many Swedish building practitioners understand the benefits of low-energy buildings, economic constraints and client demand can act as significant barriers, preventing them from successfully delivering projects that go beyond the basic requirements.

Australian building practitioners in the cluster of leaders demonstrate high attitudes, subjective norms, perceived behavioral control and

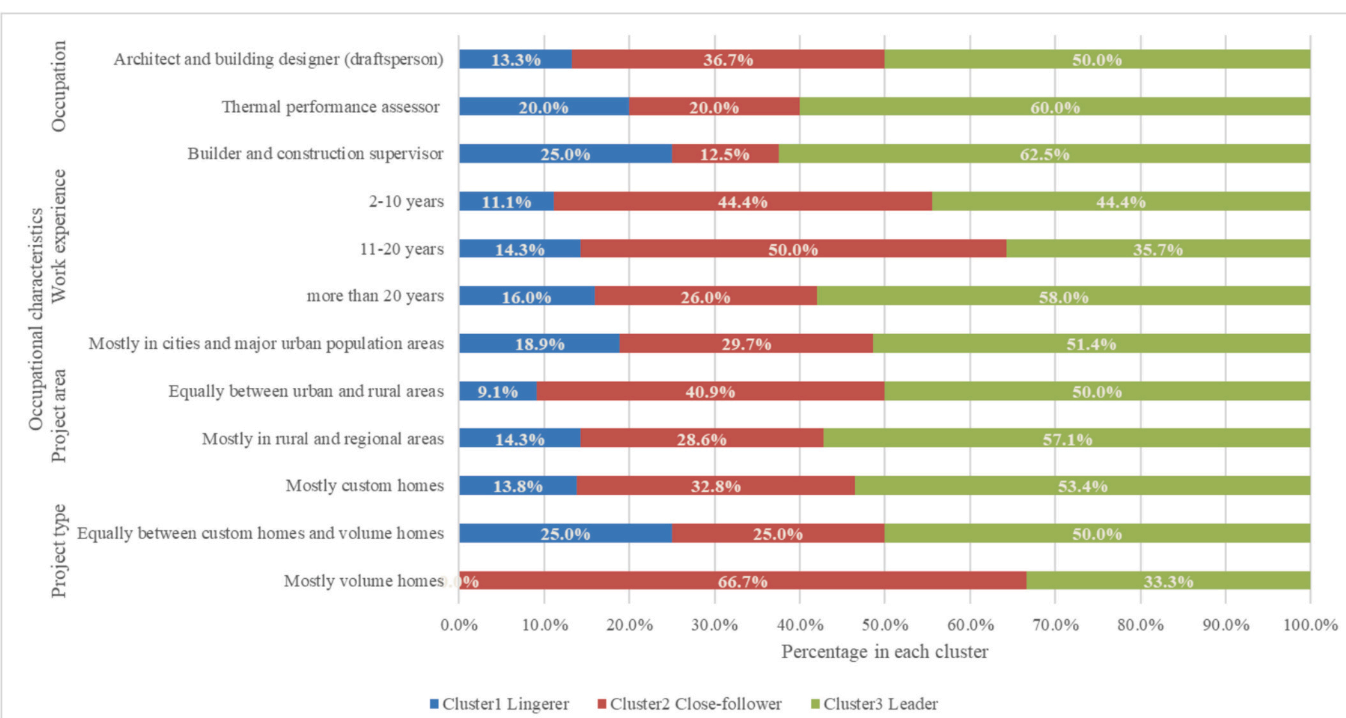

Fig. 2. Cluster membership associated with building practitioners' occupational characteristics.

personal norms scores, indicating both strong motivation and confidence in their ability to deliver energy-efficient buildings. These practitioners recognise the business opportunities associated with high-performing projects and respond positively to both industry norms and client demand for sustainable, energy-efficient homes. This state mirrors findings from Amoruso, et al. [60] comparing the German and Norwegian situations. They found that the most successful building practitioners in achieving high energy efficiency tend to view beyond-compliance as a competitive advantage. They also found that practitioners who had successfully adopted energy-efficient practices often did so because of clear economic incentives and the ability to position themselves as market leaders. Additionally, in England and Wales, there is evidence of a small group of high performers who see the financial and reputational benefits of exceeding regulatory requirements, using energy efficiency as a unique selling point to attract clients [23]. As with the cluster of leaders in the current study, these practitioners often lead the market in delivering beyond-compliance projects.

The above discussion indicates that the findings from this Australian study fit well within the broader international context. The differentiation of building practitioners into the three clusters—lingerer, close-followers, and leaders—reflects common patterns across different countries. Similar to Australia, building practitioners in Sweden, the UK, and Germany face challenges related to economic constraints, practical barriers, and client demand. However, those in State 3, both in Australia and internationally, recognise beyond-compliance as a strategic advantage, using it to gain market leadership and respond to increasing demand for sustainable practices. These findings highlight the importance of addressing barriers in lingerers and close-followers and promoting behavior changes for building practitioners to successfully achieve beyond-compliance outcomes globally.

Beyond this, the study also found that the difference between the three clusters was primarily shown as a big difference in the subjective norms. This implied that the client's request for home design, or the desire to earn the acknowledgement of others were the main reasons that differentiated these 73 building practitioners in the decision-making of whether to go 7 stars or higher. According to the middle actor perspective introduced in Section 1, building practitioners possess an agency that extends beyond simply meeting client demands. This perspective offers deeper insights into the behavior and agency of building professionals. Recent findings by Simpson, et al. [61] highlight that building practitioners are eager to build their confidence through funded training, enabling them to more effectively recommend beyond-compliance solutions to clients. Such training not only increases their technical knowledge but also bolsters their confidence in advocating for beyond-compliance solutions to clients. In addition to training, building practitioners express an interest in incentives that recognise their role as an informal advisor to clients. For example, models like the gold-standard Construction Skills Certification Scheme in the UK could be adapted to recognise and reward their expertise. Practitioners have indicated that receiving commissions or similar rewards would encourage them to promote beyond-compliance practices to clients. These insights from Simpson, et al. [61] could be valuable for Australian policymakers seeking to empower building practitioners, enabling them to better influence clients toward adopting beyond-compliance house designs.

6. Conclusions

The escalating impacts of climate change and environmental crises are manifesting worldwide. However, failing to achieve beyond-compliance energy standards in new homes exacerbates energy consumption, increases carbon emissions, and undermines these long-term climate goals. Therefore, this study explores Australian building practitioners' behavior in beyond-compliance when using NatHERS, and develops a clustering of them based on their beyond-compliance behavior predictive variables. The results revealed that there exist three clusters of building practitioners: lingerer, close-follower, and leader. The difference between the clusters is primarily shown as a large disparity in subjective norms. Furthermore, lingerers are shown to have significantly lower attitudes, subjective norms and perceived behavioral control. Close-followers exhibit poor attitudes, but their other variables are relatively high. Leaders are distinct by their highest attitudes and subjective norms. The contributions are twofold. First, this study represents the first clustering analysis of beyond-compliance behavior related to residential energy performance standards, marking an advancement in knowledge in this area. Second, for building practitioners themselves, the findings highlight key areas for self-improvement, such as strengthening attitudes toward beyond-compliance outcomes and leveraging client expectations to reinforce subjective norms. This presents opportunities for policymakers to develop more tailored strategies to motivate more building practitioners to achieve beyond-compliance outcomes in Australia.

This study acknowledges several limitations. It relied on questionnaire survey instruments based on self-reported responses from building practitioners. Such limitations include concerns related to self-presentation, socially desirable responses, honesty, memory recall, and discrepancies between reported behaviors and actual practices. While these biases are inherent in self-reporting, efforts were made to mitigate their effects by ensuring absolute confidentiality and anonymity for survey respondents, following Dillman, et al. [62]. In addition, the study was solely conducted in the State of Victoria. A change of the behavior constructs' values may alter the composition of the clustering solution and the generalizability of the results. Future research could be carried out in other Australian jurisdictions as well as in different countries, examining to what degree the clustering solution is affected by regulatory environments. In addition, future research should investigate how each behavioral variable influences beyond-compliance outcomes. By determining the extent of each variable's influence, this research could offer concrete recommendations to policymakers regarding which variables to target and tailor in their initiatives.

CRediT authorship contribution statement

Yi Lu: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Gayani Karunasena:** Writing – review & editing, Visualization, Supervision, Conceptualization. **Chunlu Liu:** Writing – review & editing, Visualization, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Parameters of reliability and validity of the variables and indicators

Indicator reliability, variables' composite reliability and convergent validity

Variable	Indicator	Indicator reliability (factor loading)	Composite reliability	Convergent validity (average variance extracted)
Attitudes	ATT1: Perceived economic benefits	0.941	0.94	0.886
	ATT2: Perceived economic costs	0.941		
Subjective norms	SN1: Requests from clients and thermal performance assessors	0.863	0.854	0.745
	SN2: Expectations from building industry colleagues and peers	0.863		
Perceived behavioral control	PBC1: Self-efficacy in terms of confidence to go 7 stars and higher	0.81	0.788	0.559
	PBC2: Self-efficacy in terms of perceived easiness to go 7 stars and higher	0.829		
	PBC3: Perceived controllability in going 7 stars and higher	0.578		
Personal norms	PN1: Moral agreement with environmental protection	0.865	0.908	0.666
	PN2: Moral agreement with carbon emissions reduction	0.861		
	PN3: Agreement regarding whether going 7 stars and above is correct	0.787		
	PN4: Agreement regarding whether going 7 stars and above can lead to emissions reduction	0.857		
	PN5: Agreement regarding whether going 7 stars and above can lead to energy consumption reduction	0.699		
Behavioral intention	INT: Willingness and efforts devoted to achieving beyond-compliance outcomes	1	–	–
Actual beyond-compliance	COM: Actual beyond-compliance outcome delivered	1	–	–

Variables' discriminant validity (Heterotrait-monotrait ratio)

	Attitudes	Subjective norms	Perceived behavioral control	Personal norms	Behavioral intention	Actual beyond-compliance
Attitudes	–					
Subjective norms	0.628	–				
Perceived behavioral control	0.380	0.728	–			
Personal norms	0.567	0.638	0.397	–		
Behavioral intention	0.329	0.577	0.495	0.589	–	
Actual beyond-compliance	0.515	0.438	0.446	0.440	0.381	–

Appendix 2. Silhouette coefficients of different clustering options

	2-Cluster option	3-Cluster option	4-Cluster option	5-Cluster option	6-Cluster option
Mean cluster silhouette	0.381	0.361	0.322	0.28	0.326
Number of negative silhouettes	1	0	1	2	1

Appendix 3. Chi-Square tests on the association between cluster membership and building practitioner's occupational characteristics

	Value	df	2-Sided asymptotic significance (p-value)
Cluster with years of work experience	3.62	4	0.46
Cluster with occupation	2.526	4	0.64
Cluster with project type	2.802	4	0.591
Cluster with project area	1.605	4	0.808

Data availability

Data will be made available on request.

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