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Integrating aesthetics and resilience in modular housing design: Generation Z's cognitive and environmental preferences

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Abstract:
Indonesia is a country susceptible to natural disasters. The development of modular housing that integrates disaster risk and aesthetic appeal is a challenge that must be met to provide homes for Generation Z. This study aims to understand Generation Z's preferences regarding the integration of aesthetics and environmental resilience in modular housing design. The research method involves a modular 3D house model experiment designed to reflect Gen Z's preferences. The exploration of design elements in the 3D model, such as movable walls, panel connections, symmetry-asymmetry, texture, contrast colour, and window scale. The exploration of these design elements considers integrating aesthetic value into disaster-resistant home design and the use of renewable, environmentally friendly materials. Data were analysed using Multinomial Logistic Regression (MLR). The results show that removable wall elements and structural connections increase flexibility but require technical robustness in the connections. Symmetrical shapes, wide window scales, use of natural material textures influence the resilience of natural ecosystems. The integration of aesthetic elements such as texture, colour, and window scale enhances the visual appeal of a modular home.

Keywords:
aesthetic integration, natural ecosystem resilience, modular house, disaster resistant design, Generation Z preferences

1. Introduction

Indonesia, located on three large tectonic plates, is prone to disasters, especially earthquakes [1,2]. Earthquakes often damage housing infrastructure, causing casualties and displacement due to damage to homes. Therefore, developing earthquake-resistant housing infrastructure is crucial for sustainable natural resource management. Modular houses have great potential as an adaptive solution to disasters and as environmentally friendly housing that supports ecosystem conservation [3]. The model supports ecosystem preservation by minimising the environmental impact of housing construction, reducing waste, and encouraging more thoughtful and sustainable use of resources [4].

RISHA is one of the modular house models in Indonesia that is disaster-resistant and environmentally friendly, supporting the conservation of ecosystems. However, the main problem is that Indonesian people are not very interested in choosing this house model, which needs to change. In some cases, implementation of RISHA faces challenges in terms of cost, especially in remote areas that require more infrastructure and technology. These limitations challenge the development of transporting and installing modular components, which affects the sustainability of local ecosystems if development is not carefully planned. Furthermore, RISHA is designed to utilise local materials; however, not all locations have access to eco-friendly or sustainable materials that meet the aesthetic preferences of today's Generation Z (Gen Z).

The demand for residential properties continues to increase, especially among the younger generation (Gen Z) [5]. Aesthetics for Gen Z are strongly influenced by visual social media (instagrammable, minimalist, aesthetic, functional but stylish) [6–10]. A house is not just a place to live but also an expression of identity and lifestyle [6]. Multifunctional and flexible spaces with an element of personalisation are considered important. Gen Z, who is highly aware of environmental issues and design innovation, needs functional, aesthetically pleasing, and sustainable housing. Working memory is a system that allows a person to temporarily store and manipulate information for cognitive tasks such as comprehension, reasoning, and learning. Mental load in this research refers to the cognitive resources required to process information in working memory.

For this reason, the development of RISHA modular houses emphasises the importance of integrating aesthetic elements and optimising natural resources. Aesthetic elements, such as texture, colour, scale, and design flexibility, increase psychological comfort and foster a connection with the surrounding environment. Integrating the sustainable use of natural resources, such as using eco-friendly materials and efficient production processes, enhances the appeal and sustainability of these modular houses. This approach supports better resource management, reduces environmental impact, and strengthens local ecosystems.

Aesthetics in residences are essential to creating mood, social comfort, and mental well-being, and they reflect a commitment to nature conservation. In this era, the challenge is that homes must also influence efforts to reduce the carbon footprint and impact on ecosystems, especially if they rely on imported or environmentally unfriendly materials. This research explores integrating aesthetic value and natural resource management in the development of modular houses using 3D modelling. The goal is to provide new insights into creating housing that suits the preferences of the younger generation while supporting ecosystem conservation and encouraging more sustainable management of natural resources.

2. Literature review

The concept of a disaster response system for ecosystem and natural resource management is increasingly being considered amid climate change and the frequency of natural disasters [11]. This system aims to improve the resilience of communities and ecosystems by integrating disaster risk reduction strategies into natural resource management practices [12]. This complex approach requires a thorough understanding of the relationship between natural disasters, ecosystem health, and socio-economic factors.

Disaster risk management frameworks must be tailored to local contexts. The capacity of local governments to respond to disasters is vital [2]. Improving the skills and knowledge of disaster management personnel is essential for developing innovative programs that can anticipate and mitigate the impact of disasters. Vulnerabilities in specific regions allow targeted interventions to meet local needs [1]. This local-based approach is critical for effective disaster preparedness and response, as it identifies high-risk areas and implements appropriate measures to reduce vulnerability.

The decline in capital from natural resources due to natural disasters poses a significant challenge to sustainable development. Natural disasters can exacerbate inequality and hinder economic progress [13] This perspective advocates for an integrated disaster risk management program that promotes public awareness and the resilience of human ecosystems [14] Maintaining a healthy ecosystems as buffers against disasters is also vital In addition, as climate change exacerbates the challenges associated with disaster management challenges, climate change adaptation planning must be integrated into disaster risk management frameworks to address risks to natural resources and human health [16] This integration is essential to ensure that communities are prepared for the increasing frequency and intensity of climate-related disasters [17].

Developing disaster response systems for ecosystem and natural resource management requires a complex and integrated approach that combines local knowledge and community involvement [12]. Building resilience at the ecological and community levels can minimise the impact of natural disasters and encourage sustainable development. Synthesising evidence from various studies emphasises the importance of a holistic and inclusive approach to disaster risk management, which prioritises the needs of vulnerable populations and harnesses the potential of ecosystems to improve resilience.

Integrating aesthetic values and natural resources into disaster-resistant modular homes is a complex challenge that is particularly relevant to the preferences of Generation Z [18], [19]. This generation, who are increasingly concerned about sustainability, environmental impact, and the aesthetic quality of living spaces, is driving the need for homes that are not only sturdy in the face of disasters but also in harmony with nature and reflect the aesthetic values they hold.

The architecture and construction field is currently shifting towards the sustainable use of materials, such as renewable natural resources. Wood, for example, is one of the options due to its advantageous physical characteristics in sustainable construction [20]. The rationalisation of using natural resources in architectural design indicates the need for a balanced approach, where aesthetic appeal goes hand in hand with environmental performance [21] In the context of modular homes, the aesthetic integration of natural materials enhances visual appeal and promotes sustainability.

Understanding user preferences across demographic and psychographic segments is crucial for identifying user expectations and developing appropriate strategies for designing environmentally friendly, disaster-adaptive modular housing products. User preferences are useful for product planners and developers to identify the benefits and value of developing new products and formulate and evaluate product development strategies [22–24]. In the product knowledge process, each individual possesses a certain amount of knowledge, meaning, and preferences for a product in their memory that can influence the interpretation and integration process [25].

User preference is the choice or tendency of an individual or group of users towards a product, technology, or service, compared to other choices, reflecting the level of desire or preference for certain attributes of the product or service. User preferences are influenced by cognitive and emotional factors [26–29]. Sources of consumer preferences include information, previous experience, personal values, social environment, and other external factors. Preference is a condition in which objects are assessed by respondents based on dominance relationships. Stimuli are ranked based on preferences related to a particular attribute. Assessment of user preferences is often done through direct ranking methods, paired comparisons, and preference scales.

This study uses working memory (WM) as one of the essential cognitive systems in tasks such as problem-solving, learning, and decision-making. Working memory (WM) can influence both cognitive and emotional aspects. An individual's cognitive processes and decision-making are often influenced by prior knowledge and experiences stored in working memory. The information an individual receives is often complex, while their capacity to process information is limited, as explained in Cognitive Load Theory [31–37]. This forces individuals to rely on heuristics or framing. An individual's memory is not only related to prior information and experiences but also to past social connections that can influence emotional aspects.

User preferences for a product often vary across generations [22–24]. Generation Z is a segment born alongside the development of digital technology. This generation, comprised of students, college students, and young workers, is the most powerful group in the digital industry. This group accesses the internet more frequently than previous generations. Preferences for new products or technologies may differ from those of previous generations, as this generation is more open to new products or technologies, customisation, and diverse tastes.

Previous research has shown that Generation Z consumers are increasingly inclined toward sustainable products and practices. Environmentally conscious Gen Z consumers prefer classic and versatile designs in sustainable fashion, which suggests that similar principles can be applied in home design [10]. This generation values spaces that encourage connection and collaboration, which can be integrated into RISHA's home design through communal areas and shared resources. By creating an environment that supports social engagement, these modular homes can cater to Generation Z's lifestyle preferences, who often seek experiences that reinforce a sense of community and community. Generation Z's consumption behaviour and preferences in the context of sustainability by utilising technology, RISHA homes not only meet the functional needs of residents but also attract their desire for a modern and efficient living environment [30]

Aesthetic preferences can influence Gen Z's choices when meeting their housing needs [38]. By creating an aesthetic and functional space that prioritises well-being and sustainability, RISHA's home can appeal to the younger generations. Nature-inspired design strategies, the use of natural materials, and sustainability efforts not only enhance visual appeal but also encourage environmental responsibility, in line with the aspirations of Generation Z. Therefore, the integration of aesthetic values, sustainability, and durability in modular homes is essential to create attractive and responsible housing solutions for the future.

Based on the technical and artistic characteristics of a disaster response household, its aesthetic elements can be further explored. The technical elements of a disaster response include movable structures and connections between elements, while artistic elements include texture, symmetry, and scale. In the context of technical elements, modular houses have unique characteristics regarding the connection of the main structure, the relationship between the related panels, and the communication (connection) between elements.

First, a movable wall. Modular homes differ from conventional homes in that they use a knock-down system. These characteristics are not limited to structural elements but also extend to related aesthetic elements, such as art, function (semantics), and technology. On the art side, modular elements allow for changes in the house's colour, texture, and shape. In terms of functionality, the family room can be easily converted into a study or workplace through this modular system. This is important for future home developments that are slimmer but still feel spacious. Internet-connected furniture can be controlled through a single device, allowing residents to quickly turn on lights, open gates, or operate other devices.

Second, panel connection. Modular houses are distinctive in terms of the connection between elements, both the main structure and the associated panels. This joint not only plays a technical role but also has an artistic dimension. In contrast to classical architecture, the beauty of modern architecture often lies in the assembly process, autonomous modules, and interactions between modules [39,40].

Third, texture. According to Semper (1803-1879), the beauty of buildings can arise from the presentation of materials through craft techniques. In the digital age, technological developments facilitate the production and assembly of home elements more efficiently and artistically. The beauty of the texture can vary between user segments; Millennials and Gen Z, for example, tend to prefer minimalist details that reflect personality and experience, while older generations may prefer ornamental details that fit their culture. The development of software such as CAD and CAM allow for detailed building designs using craft techniques such as cutting, printing, and reprinting. Information technology also opens up opportunities for home design that is smarter and more adaptive to the environment.

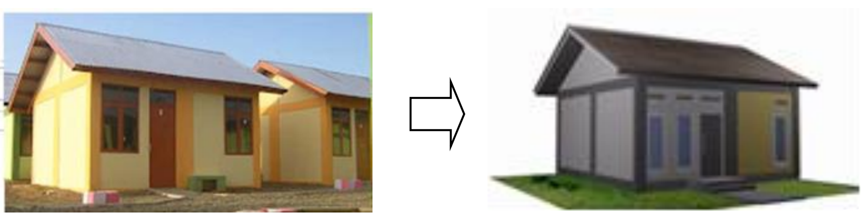
Fourth, symmetry-asymmetry. On the one hand, the building's symmetrical shape is used to resist earthquakes. Many traditional architectures use symmetrical shapes to create natural harmony in the face of potential earthquake disasters. Symmetry is not only applied to the structure of the building but also to the arrangement of the aesthetic elements of the building [41–43]. In contrast, symmetrical shapes create a formal atmosphere, while asymmetrical shapes create a dynamic atmosphere [44].

Fifth is the contrast colour. Colour impacts aesthetic preferences, such as warm-cold, cheerful-sad, and masculine-feminine atmospheres. Studies show that bright, entire colours provide a cheerful atmosphere, especially for children, while colourful spaces can interfere with focus. On the other hand, soft colours can give rise to theta waves that provide a calming effect, as found in hospital patient studies.

Sixth is the window scale. Opening scales often provide a particular atmosphere, such as narrow-wide, magnificent, open-closed, or interconnectedness of outdoor and indoor [45] and energy savings through the use of natural light and natural ventilation [19,46]. Research shows that the plane opening scale and ceiling height affect the relaxation rate of hospital patients [45].

3. Materials and methods

This research was conducted through observations of 3-dimensional objects from RISHA houses in Banyumas Regency, Indonesia, and questionnaires administered to Gen Z. The experimental objects are aesthetic elements of modular houses that serve as a response to earthquake disasters. The object of study is an animated image of a 3 m x 6 m modular house, redrawn in 3D. This visualisation is used instead of an actual image to simplify the modification and control of other variables. Furthermore, the experimental objects are evaluated based on the preferences of the research subjects.



Actual model Animated model

Fig. 1. Modelling Risha

The research subjects were students from several universities in Central Java, Indonesia. The sample used purposive sampling to control variables outside the model, namely with the criteria (1) students outside of study and not currently working in the fields of architecture, design, art and the environment, (2) willing to be research respondents. The experimental objects were evaluated using an online survey via Google Form on 150 respondents. The number of 150 meets the minimum requirement in the survey-based evaluation model, namely 100 respondents.

Preference assessment was conducted through paired comparisons of 3D model stimuli (Table 2). Respondents were asked to choose based on their likes and dislikes of the alternative development of the Risha 3D model based on aesthetic and ecosystem resilience aspects. The 3D building facade model stimuli consisted of paired models: (1) movable-unmovable wall, (2) static wall - knock down panels, (3) symmetry-asymmetry, (4) textured with details crafting, (5) low-high contrast colour, (6) narrow-wide scale window. The stimulus consisted of 3D images.

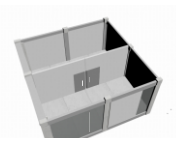
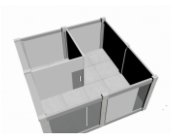
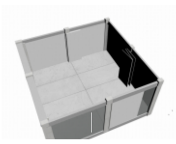
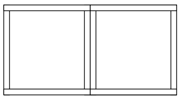
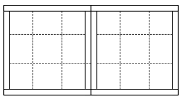
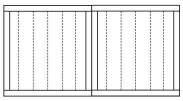
The instrument was developed from previous research [48–52] that was adapted for modular house architectural objects that respond to earthquake disasters. Confirmatory factor analysis (CFA) was used to evaluate the measurement model, while preference analysis used Multinomial Logistic Regression (MLR). The results of the measurement model evaluation showed a loading factor above 0.5, an average variance extracted (AVE) value > 0.5, a composite reliability value > 0.7, and a Cronbach's Alpha value > 0.7 [44]. These results indicate a valid and reliable instrument.

These images are shown to Gen Z for 5 seconds, after which they will be asked to complete an existing questionnaire. The 5-second duration is based on a previous study [42], although other studies use a slightly longer duration, namely, seconds [47]. In this test, Gen Z participants will be asked to sit in front of a computer or tablet screen and observe a series of images, with each image displayed for 5 seconds. After each image, there will be a 2-second pause where the screen goes blank, giving participants time to process the information they just viewed. Afterwards, participants will complete a questionnaire about their perception of the image, the level of difficulty, the focus of attention they experienced, and their aesthetic preferences for visual elements. This process is repeated with various images to measure variation in perceived mental load based on each image's complexity and aesthetic appeal. The questionnaire data were then analysed to evaluate the impact of cognitive load on the participants' working memory toward ecosystem resilience and visual aesthetic preferences.

Table 1. Measurement model

Variables	Resilience	Aesthetics	Outer loadings	Cronbach's alpha	AVE
Movable Wall	structural risk [54]	Flexibility [54]	0.539		
Panel Connection	structural risk [54]	Flexibility [54]	0.569		
Symmetry	earthquake	Pattern [55,41,44]	0.576		
Texture	sustainable materials [56]	sense of place [57,40,58,59]	0.575	0.740	0.522
Contrast Colour	sustainable materials [56]	sense of place [57,27]			
Windows Scale	energy, natural light, natural ventilation [60,45]	views, connectivity [60]	0.566		

Table 2. Variables and visualisations provided in the study

Variables	Description	Visualisation 1	Visualisation 2	Visualisation 3
Movable Wall	Assess the types of walls that can or cannot be movable			
Structural Joint Connection	Assess the Joint Connection			
Symmetry-Asymmetry [61]	Assess the Symmetry-Asymmetry form			
Texture-Detail Crafting	Assess the details of wall panel			
Contrast Colour	Assess the colour choice			
Windows Scale [46]	Assess the Windows Scale			

Data were analysed using Multinomial Logistic Regression (MLR). The independent variable was visual aesthetic preferences, while the dependent variable was ecosystem resilience. Model fit testing used Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), McFadden's pseudo-R^2 (R^2 MCF), Cox & Snell R-squared (R^2 CS), and Nagelkerke's R-squared (R^2 N).

4. Results and discussion

The data collected showed a variety of respondent's characteristics based on their age, gender, recent education, and occupation. Respondents cover a wide age range, from 14 to 34 years old. The majority of respondents are in the young age group, with many of them being students. The data showed that both men and women participated in the survey, with representatives from both gender groups. This distribution provides a balanced perspective in analysing housing needs and preferences. Most respondents have a secondary education background (junior high school and high school or equivalent). Some respondents also have a university education.

This shows that the survey's population covers various levels of education. This variation reflects diverse socioeconomic backgrounds that can influence their housing preferences, particularly for RISHA modular homes. Adaptive and aesthetic residential design and development must consider these factors to effectively meet the needs of diverse community groups.

The descriptive analysis showed the distribution of data for modular house design elements, such as movable walls and structural joints, with a sample size of 150 and no data loss. The average value ranged from 1.90 to 2.05, with the median consistently at 2. The standard deviation showed the most tremendous variation in structural joints (1.06) and the smallest in texture detail (0.754). Data distribution tends to be skewed, and some elements show a broader or more concentrated distribution (kurtosis). The Shapiro-Wilk test revealed that all elements are not normally distributed ($p < 0.001$).

The results of the *Multinomial Logistic Regression (MLR)* analysis show several measures that describe the model's fit to the data. A Deviance value of 225 indicates that the estimated model has an excellent match to the data. In contrast, a lower Deviance value indicates a better model's ability to predict the actual data. The Akaike Information Criterion (AIC) of 277 is used to evaluate the model's balance between fit and complexity, with lower values indicating a more optimal model. The Bayesian Information Criterion (BIC), with a value of 355, also provides a more significant penalty for complex models, so lower values indicate a preference for those models.

A pseudo-R^2 McFadden (R^2 MCF) size of 0.299 indicates that the model explains about 29.9% of the variation in the data. In contrast, a Cox & Snell R-squared (R^2 CS) of 0.192 indicates that the model explains about 19.2% of the variation. Nagelkerke's R-squared (R^2 N), which is an adjustment of R^2 Cox & Snell, has a value of 0.377, indicating that about 37.7% of the variation in the data can be explained by the model, with a maximum value of 1, indicating an improvement when compared to a model without a predictor.

The models tested in this study showed a moderate fit to the pseudo-R^2 values. This value indicates the model's ability to explain the variability in the data. These results indicate that the model performed well in the relationship between the analysed variables.

Fig. 2. Overview of the research data collection process

Table 3. Model fit measures

Model	Deviance	AIC	BIC	R^2_{McF}	R^2_{CS}	R^2_{N}
1	225	277	355	0.299	0.192	0.377

Table 4. Summary of Omnibus Likelihood Ratio Tests

Predictor	χ^2	df	p
Movable Wall	13.79	4	0.008
Structural Joint Connection	25.55	4	< .001
Symmetry-Asymmetry Form	9.62	4	0.047
Texture-Detail Crafting	19.63	4	< .001
Contrast Colour	23.94	4	< .001
Windows Scale	14.6	4	0.006

The Omnibus Likelihood Ratio test results support the findings of the Multinomial Logistic Regression (MLR) analysis by showing the significance of individual predictors. The wall elements of the movable (χ^2 = 13.79, p = 0.008) and structural joints (χ^2 = 25.55, p < 0.001) exert a significant influence on the durability of RISHA modular houses. The symmetry of shape (χ^2 = 9.62, p = 0.047) and texture and detail (χ^2 = 19.63, p < 0.001) show significance in favour of visual aspects and comfort. Colour contrast (χ^2 = 23.94, p < 0.001) and window scale (χ^2 = 14.60, p = 0.006) play a role in the visual appeal and comfort of the residence. These findings confirm that technical elements dominate in improving durability, while aesthetic elements remain essential for comfort and functionality, demanding a balanced design approach.

The results of the coefficient model for the resilience of modular house ecosystems show a significant influence of design elements, reflecting their close relationship with the theoretical framework of disaster response systems and ecosystem management. Column (1) in Table 5 shows respondents' preferences for ecosystem resilience, while column (2) shows respondents' preferences for the predictor variable, namely visual aesthetic preferences. The pairwise comparison model consists of: (1) movable-unmovable walls, (2) static wall - knock down panels, (3) symmetry-asymmetry, (4) plain wall - textures with detailed crafting, (5) low-high contrast colour, (6) narrow-wide window scale.

Table 5. MLR Model coefficients analysis results

Ecosystem Resilience	Predictor	Estimate	SE	Z	p
	Intercept	0.647	1.044	0.620	0.535
	Movable Walls:				
	2 – 1	0.517	0.638	0.810	0.418
	3 – 1	0.243	0.629	0.385	0.700
	Structural Joint Connection:				
	2 – 1	-1.478	0.682	-2.166	0.030
	3 – 1	-2.782	0.650	-4.279	< .001
	Symmetry-Asymmetry Form:				
	2 – 1	1.633	0.682	2.395	0.017
2 – 1	3 – 1	1.318	0.596	2.212	0.027
	Texture-Detail Crafting:				
	2 – 1	0.226	0.626	0.36	0.718
	3 – 1	-0.709	0.712	-0.996	0.319
	Contrast Colour:				
	2 – 1	-2.269	0.651	-3.487	< .001
	3 – 1	-2.077	0.785	-2.647	0.008
	Windows Scale:				
	2 – 1	1.926	0.736	2.617	0.009
	3 – 1	1.840	0.767	2.399	0.016
	Intercept	2.319	1.169	1.983	0.047
	Movable Walls:				
	2 – 1	-1.958	0.803	-2.437	0.015
	3 – 1	-1.336	0.751	-1.779	0.075
	Structural Joint Connection:				
	2 – 1	0.225	0.735	0.306	0.759
	3 – 1	-0.719	0.7	-1.027	0.304
	Symmetry-Asymmetry Form:				
	2 – 1	-0.124	0.913	-0.136	0.892
3 – 1	3 – 1	0.216	0.583	0.37	0.712
	Texture-Detail Crafting:				
	2 – 1	-1.647	0.747	-2.203	0.028
	3 – 1	0.437	0.69	0.634	0.526
	Contrast Colour:				
	2 – 1	-1.686	0.726	-2.323	0.020
	3 – 1	0.206	0.794	0.259	0.795
	Windows Scale:				
	2 – 1	-0.423	0.854	-0.495	0.621
	3 – 1	-1.158	0.994	-1.165	0.244

A movable wall element with a significant negative influence on category 3-1 (coefficient -1.958, p = 0.015) suggests that although this element provides structural flexibility, it can increase the risk to ecosystem resilience under certain conditions. The theory states that flexibility must be balanced with structural strength to overcome disaster challenges – an imbalance of flexibility and stability risks triggering vulnerability, especially in extreme disaster situations.

The panel connection showed a significant negative influence in category 2-1 (coefficient: -1.478, p = 0.030) and stronger in category 3-1 (coefficient: -2.782, p < 0.001). This suggests that suboptimal joints can weaken the resilience of modular homes. Disaster risk management emphasises the importance of structural solid elements for physical resilience. Weak joints increase the impact of disasters, demonstrating the importance of careful design and proper material selection.

The symmetry showed a significant positive influence in category 2-1, with a coefficient of 1.633 (p = 0.017) for category 2-1 and 1.318 (p = 0.027) for category 3-1. Symmetrical design helps with structural stability and disaster resistance. It also creates a visual/physical harmony that supports resilience.

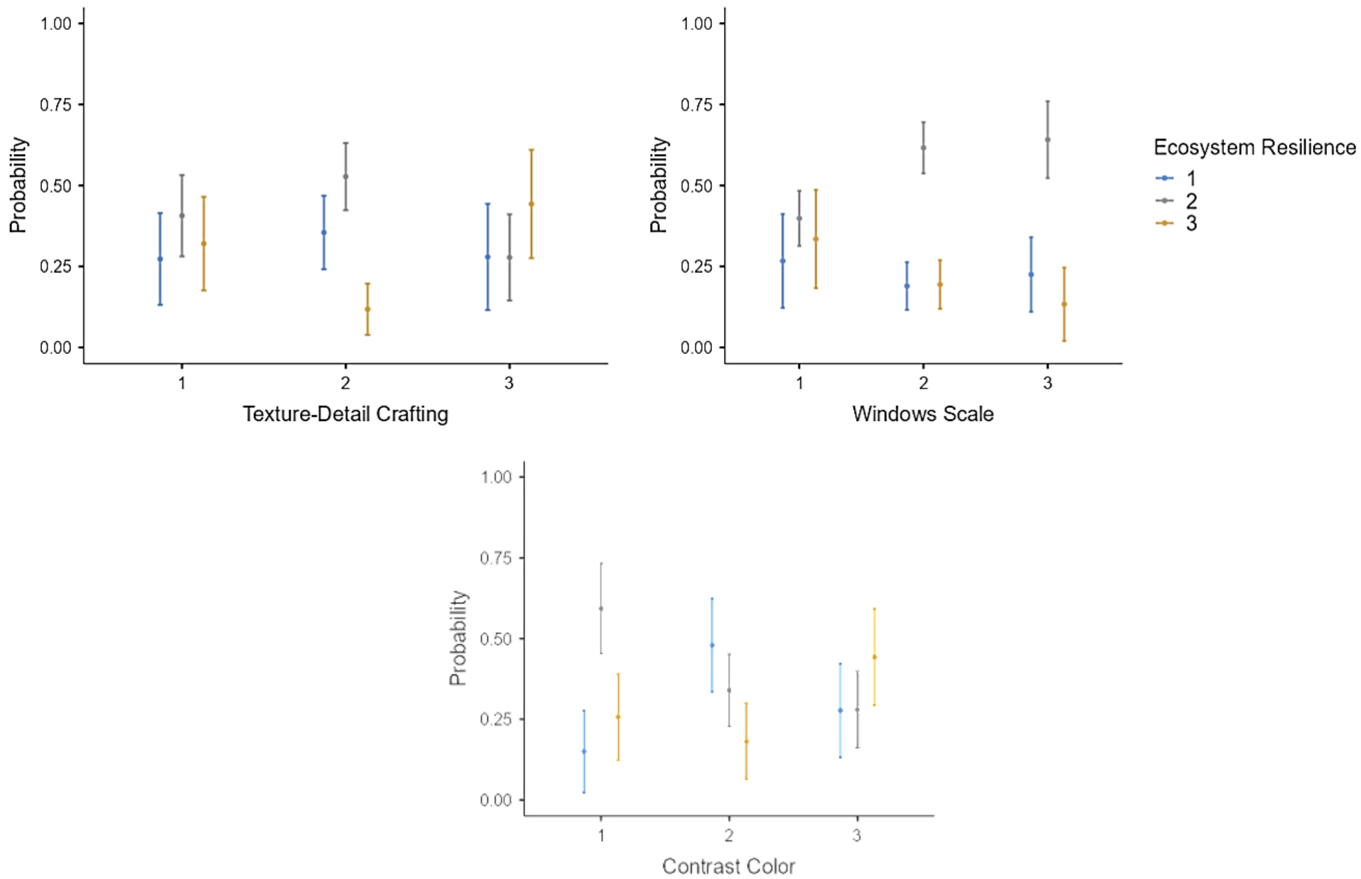


Fig. 3. Estimated marginal means model fit

The window scale showed a significant positive influence in category 2-1, with a coefficient of 1.926 (p = 0.009) for category 2-1 and 1.840 (p = 0.016) for category 3-1. Window scale has a significant positive impact, increasing durability through natural lighting/air circulation and creating space comfort. A holistic approach is needed to integrate the technical and aesthetic design of modular houses that are adaptable to climate change and disasters and attractive to the community. This integration enhances the durability, comfort, and aesthetics of the residence.

Texture and detail negatively impacted category 3-1 (coefficient -1.647, p = 0.028), indicating that aesthetic complexity can weaken durability. Decorative elements should be combined with technical elements. Colour also shows a negative influence on durability. The colour showed a significant negative influence in category 2-1, with a coefficient of -2.269 (p = < 0.001) for category 2-1, and -2.077 (p = 0.008) for category 3-1.

The study underscores the importance of integrating technical and aesthetic elements to optimise durability. Estimated marginal means show that design elements such as texture detail and colour contrast affect the probability of ecosystem resilience with varying impacts, where colour contrast tends to decrease resilience. In contrast, window scale increases the probability of durability due to its contribution to lighting and circulation. The interaction of these technical and aesthetic elements reflects the complex influence on the durability of modular homes. The texture, detail, and scale of windows in modular home designs affect the resilience of ecosystems in different ways, where colour contrast tends to decrease stability. In contrast, window scale contributes to natural lighting and better air circulation.

Modular design elements also relate to participants' mental load, preferences, and performance, depending on how these elements are designed and integrated. Complex structural joints and flexible walls can increase cognitive load. At the same time, simple aesthetic elements create a more enjoyable experience, especially for Generation Z, who love aesthetic and functional design. This analysis provides insights into creating a more optimal modular environment that meets the user's needs by balancing technical, aesthetic, and mental load considerations.

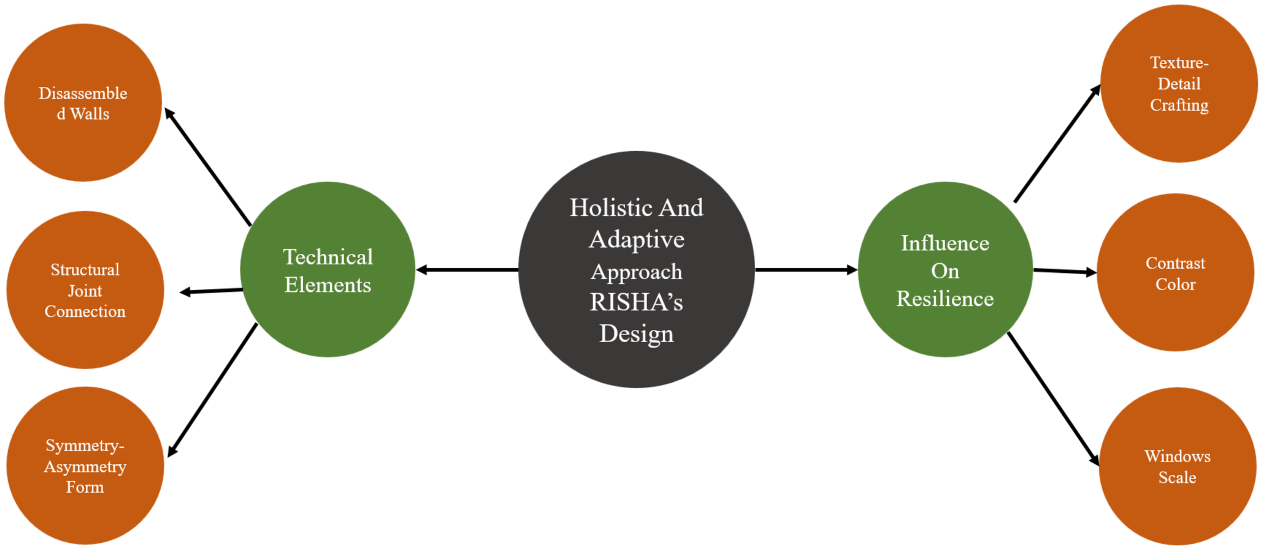


Fig. 4. Conceptual theoretical framework's holistic and adaptive approach RISHA's design

These results also reinforce the theoretical framework's call for a holistic and adaptive approach, as demonstrated by the interaction between technical elements (such as structural joints) and their influence on resilience. These findings confirm that poorly executed joints can undermine structural integrity, highlighting the need for integrating local knowledge, innovative solutions, and careful technical optimisation to improve resilience.

The concept shown in the diagram above illustrates a holistic and adaptive approach to RISHA design, in which technical and aesthetic elements interact to influence the ecosystem's resilience. Technical elements such as detachable walls, structural joints, and symmetrical-asymmetrical shapes significantly influence durability, as shown in the study's findings. These elements directly contribute to the stability and flexibility of the structure, demonstrating the importance of a design approach that focuses on strengthening the durability of modular homes. This holistic approach emphasises the need to blend technical and aesthetic elements to achieve optimal resilience to society's needs and the ever-evolving challenges of the environment. These findings confirm that each technical and aesthetic element plays a complementary role in creating RISHA's design, which can withstand disasters and support the well-being of its residents.

5. Conclusion

The conclusion of this study shows that the design elements of disaster-resistant RISHA modular houses significantly influence ecosystem resilience, with a primary focus on technical elements such as structural joints and detachable walls. These elements have provided the flexibility and structural strength necessary to deal with natural disasters. However, it also requires careful design to avoid deterioration in durability due to weaknesses in joints or structural modifications. Coefficient model analysis shows that structural joints significantly negatively influence durability if not designed well, while aesthetic elements such as symmetry, colour contrast, and texture have a more diverse influence, both positive and negative, depending on the condition.

Window scale contributes significantly to durability and positively impacts natural lighting and air circulation. Although aesthetic elements contribute to visual comfort and occupant experience, this study emphasises the importance of balancing technical and aesthetic aspects in creating optimal modular homes. The strength of this research lies in its ability to provide in-depth insights into the relationship between technical and aesthetic elements, which can guide the development of modular homes that are adaptive, disaster-resistant and environmentally efficient.

The results of this study have practical implications for architects and urban developers involved in constructing modular housing that is environmentally adaptive and aesthetically appealing. First, prefabricated walls and knockdown panels offer construction time efficiency and functional appeal, but require further study of connection technique strength. Second, symmetrical elements can be used for aesthetics and earthquake resistance. Third, large windows can be used for aesthetic purposes, to increase room comfort, and to save energy through the use of natural light and ventilation. Fourth, elements of texture and colour can be used to create atmosphere and psychological comfort within a space.

This research has several limitations. First, the study was conducted with a cross-sectional design. Research may vary with different technological developments. The impact of climate change and new technologies, such as renewable energy systems and intelligent sensors, can further contribute to the resilience and sustainability of RISHA's modular homes. Testing of new technologies and long-term studies are also needed to ensure modular homes can continue to provide optimal durability, comfort, and sustainability. Second, social, cultural, and community acceptance factors for modular house design must be considered more deeply. Future research is suggested to consider social, economic, and cultural variables to understand the acceptance of modular home design in local communities and the impact of climate change on design. Overall, the findings of this study provide new empirical evidence against theoretical assumptions within the framework and highlight the need to expand discussions on aesthetic complexity as well as potential compromises that may occur to technical resilience in disaster-responsive modular homes.

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