Jurnal Presipitasi
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 22, No 1, 2025, 196-208
Article available at homepage presipitasi

Regional Case Study

Exploring the Factor and Cluster of Green Building Practices for Urban Liveability: Case Study Jakarta, Indonesia

Sapta Suhardono[1], Iva Yenis Septiariva[2], Imelda Masni Juniaty Sianipar[3], I Wayan Koko Suryawan[4*]

[1]Department of Environmental Sciences, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta, 57126 Indonesia

[2]Department of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, 57126 Indonesia

[3]PhD Student in Asia-Pacific Regional Studies, College of Humanities and Social Sciences, National Dong Hwa University Hualien 974, Taiwan

[4]Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Jakarta, 12220, Indonesia

* Corresponding Author, email: i.suryawan@universitaspertamina.ac.id

Abstract

This study investigates the multifaceted landscape of green building practices, focusing on their factor structure and cluster characteristics concerning environmental responsibility and urban livability. A comprehensive analysis identifies distinct factors and clusters, each representing different dimensions of sustainable urban development. This study embarks on an exploration of the complex domain of green building practices, employing Exploratory Factor Analysis (EFA) and k-means clustering to dissect the factor structure and clustering characteristics pertinent to environmental responsibility and urban liability. The factors encompass environmental sustainability and urban convenience, highlighting the delicate balance between ecological consciousness and urban functionality. Delving into demographic variables like income, higher education, age, and marital status, our findings reveal statistically significant correlations, emphasizing the pivotal role these individual characteristics play in shaping preferences towards green building practices. Specifically, our analysis crystallizes into two primary clusters. Cluster 1 emphasizes the essence of "Environmental Sustainability," marked by a strong inclination towards energy efficiency, sustainable materials, and green spaces, reflecting a commitment to ecological stewardship. In contrast, Cluster 2, denoting "Urban Convenience and Access," underscores the importance of proximity to public transport, shopping centres, and workplaces, encapsulating a desire for accessibility and convenience in urban design.

Keywords: Green building practice; factor analysis; cluster analysis; environmental responsibility; urban livability

1. Introduction

Green building, also known as sustainable building or eco-friendly building, is an approach to architecture and construction that prioritizes environmental responsibility, resource efficiency, and the well-being of occupants (Masia et al.,2020; Grzegorzewska and Kirschke 2021; Vijayan et al., 2023; Suryawan et al., 2024b). It involves a comprehensive and holistic strategy to minimize the negative impact of buildings on the environment while enhancing their positive contributions to society. The fundamental aim of green buildings is to create structures that operate efficiently, consume fewer resources, and promote a healthier and more comfortable living or working environment (Nadeem et al., 2021). Several key principles guiding its implementation are at the core of green building. Energy efficiency is a central focus, achieved by adopting energy-saving technologies, improved insulation, high-efficiency windows, and energy-efficient appliances and lighting systems (Wan et al., 2022). Water conservation is equally important, and green buildings employ water-saving fixtures, rainwater harvesting systems, and drought-resistant landscaping to reduce water usage (Torres-Bagur et al., 2019). The choice of sustainable materials is another critical aspect of green building, advocating for using eco-friendly and recycled materials with low environmental impact (Junaid et al., 2022). By incorporating such materials, green buildings minimize their ecological footprint and contribute to the preservation of natural resources. Additionally, indoor environmental quality is emphasized, ensuring proper ventilation, low-VOC materials, and adequate daylight to create healthier and more pleasant indoor spaces. Furthermore, green building considers the selection of sites and land use, considering factors such as proximity to public transportation, preservation of green spaces, and the impact on local ecosystems (Huo et al., 2019). Waste reduction and recycling practices are also integrated into green buildings to minimize construction waste and promote responsible waste management during the building's life cycle (Amaral et al., 2020). By embracing green building practices, we can effectively mitigate the effects of climate change by reducing greenhouse gas emissions and conserving valuable natural resources (Oluwunmi et al., 2019). Moreover, green buildings help lower utility costs for occupants, leading to long-term economic savings. Furthermore, improving indoor air quality and comfort promotes better health and well-being among the building's occupants. As more communities adopt green building strategies, they contribute to a more sustainable future and create resilient and environmentally conscious societies. Thus, the transition to green building practices is an urgent necessity and a profound opportunity to create a more harmonious coexistence between human civilization and the natural world (Zhou 2021).

Implementing green building practices in apartments is highly beneficial for green buildings significantly reduce their environmental impact. By incorporating energy-efficient technologies, water conservation measures, sustainable materials, and waste reduction efforts, apartments can lower their carbon footprint, minimize resource consumption, and decrease waste generation. This proactive approach towards sustainability contributes to global efforts to combat climate change and preserve natural resources for future generations. Green building practices offer substantial energy and cost savings for property developers and residents (Debrah et al., 2022). Energy-efficient design elements, such as improved insulation, energy-saving appliances, and smart lighting systems, reduce tenant utility bills. Lower operating costs can make green apartments more economically attractive, ultimately increasing the property's value and potential for long-term returns on investment. Furthermore, green buildings prioritize the health and well-being of their occupants (Zhang and Tu 2021). Indoor air quality is a key focus, as proper ventilation, low-VOC materials, and abundant natural light create a healthier and more comfortable living environment. Improved indoor air quality reduces the risk of respiratory issues and allergies, enhancing residents' overall well-being and productivity (Kraakman et al., 2021). Government incentives also play a pivotal role in encouraging green building adoption. Many governments and municipalities offer various incentives, such as tax breaks, grants, or subsidies, to developers and property owners who embrace sustainable building practices. These incentives help offset the initial costs of implementing green features and encourage wider adoption of eco-friendly building methods. In addition to these benefits (Tehupeiory et al., 2023), the attitudes of apartment residents towards sustainability are crucial for successfully implementing green building initiatives. Residents who are environmentally conscious and willing to embrace sustainable practices can actively contribute to the overall sustainability goals of the building (Bradley and S. 2011). Residents become active participants in creating a more sustainable living environment by adopting energy-saving habits, conserving water, practicing waste recycling, and supporting communal efforts to maintain and optimize green features.

Moreover, a cluster approach within the apartment community can amplify the impact of green building practices. When residents work together towards sustainability goals, they create a collective force that leads to shared benefits. Residents can pool resources and knowledge to invest in renewable energy systems, establish community gardens, implement shared recycling programs, and organize green initiatives within the apartment complex. This cluster approach fosters community and shared responsibility, making sustainable living more accessible and practical. Previous studies on green building implementation in apartments have shown significant progress in understanding the benefits and importance of adopting sustainable practices (Mesthrige and Kwong 2018; Cohen et al., 2019). However, one notable area for improvement in the literature is the limited use of factor and cluster analysis to comprehensively examine the factors influencing green building adoption and identify distinct groups of apartments based on their sustainability practices. Factor analysis can help identify underlying factors contributing to green building implementation, such as energy efficiency, water conservation, materials selection, and indoor air quality. On the other hand, cluster analysis can classify apartments into different groups based on their level of sustainability, providing valuable insights into the variations in green building practices across different housing communities.

This study aims to address this gap by employing factor and cluster analysis to understand better the drivers and barriers to green building implementation in apartments. The study aims to uncover the main factors influencing green building adoption in apartments through factor analysis. This will help policymakers and developers understand the critical aspects to prioritize when promoting sustainability in residential buildings. Using cluster analysis, the study seeks to group apartments based on their level of green building implementation. This will provide a nuanced perspective on the diversity of green practices and shed light on the potential challenges different clusters face. The findings of this study will offer valuable insights for policymakers, developers, and property managers to develop tailored initiatives and incentive programs that encourage green building adoption in apartments.

2. Methods

2.1. Study Design and Sample

In our study focused on green buildings in apartment complexes in Jakarta, the methodology seamlessly integrates the selection of representative samples, structured questionnaire design, and advanced statistical analyses to provide comprehensive insights into the adoption of green building practices. The sampling approach is meticulously designed to represent the diverse characteristics of Jakarta's apartment complexes. Employing purposive sampling, the study deliberately selects apartment complexes that best represent the various aspects of green building practices in the city. This method ensures the inclusion of complexes with specific green features like energy efficiency and sustainable design. Additionally, to capture a broader spectrum of data, the study also adopts stratified random sampling. Here, the population of apartment complexes is categorized into different strata based on characteristics such as location, size, and age, ensuring a diverse representation from all apartment sections. Each stratum is sampled randomly, targeting a sample size that maintains a margin of error below 5%.

The study utilizes a well-structured questionnaire, starting with a concise introduction that outlines the research objectives and emphasizes the significance of sustainable and eco-friendly living environments. It includes a section for gathering demographic information to contextualize the responses against the background of the respondents. The core of the questionnaire revolves around assessing the perceived importance of various indicators relevant to green buildings, such as energy efficiency, water supply, and waste management. A Likert scale ranging from 1 to 5 is employed for this assessment. The questionnaire also delves deeper into understanding the reasons behind the assigned importance of each indicator, exploring potential benefits and challenges. Concluding with a note of gratitude, the questionnaire reassures respondents of the value of their feedback. A pilot test is recommended to refine the questionnaire before its wider distribution.

2.2. Data Analysis

Factor analysis is a statistical technique used to identify correlation patterns between variables in data (Basto and Pereira 2012; Suryawan et al., 2023). In the context of research on green buildings in apartments, factor analysis can help identify the main factors influencing the adoption and application of sustainable practices in these buildings. Reducing the number of variables into interrelated factors, researchers can identify important aspects in efforts to increase sustainability in this residential area. Cluster analysis in this study using the k-means algorithm is a method used to group data into several groups based on specific characteristics in common. This analysis can help identify apartment groups with similar sustainability levels based on predetermined variables in apartment green building research. For example, apartments with low energy and water use levels and adopting environmentally friendly building materials can be grouped with highly sustainable practices. The results of this cluster analysis will assist in formulating more specific policy recommendations and actions to increase the level of sustainability in each apartment group.

Table 1 presents a concise yet comprehensive overview of key green building indicators that contribute to the ecological integrity and liveability of apartment complexes. These indicators encompass a broad range of considerations, from green space and air quality to waste management and accessibility to amenities, each contributing uniquely to the green profile of urban residential structures. The descriptions of these indicators elucidate the multifaceted benefits they offer not only in terms of environmental impact but also in enhancing the well-being and safety of the residents. For example, the integration of green spaces is highlighted not just for its aesthetic value but also for its role in biodiversity conservation and mitigation of urban heat island effects. Similarly, the emphasis on water supply underscores the adoption of sustainable practices such as rainwater harvesting and greywater recycling, which are essential for water conservation and stress alleviation on local water resources.

Table 1. Indicator and description of green building indicators

No	Indicator	Description	Likert scale Question
1	Green Space (He et al., 2018; Wang et al., 2019)	The incorporation of green spaces within and around buildings has multiple benefits. Green areas improve air quality, enhance biodiversity, provide recreational spaces, and contribute to a sense of well-being for residents. Green spaces also help mitigate urban heat island effects, ensuring a more comfortable and healthier living environment.	I consider incorporating green spaces within and around buildings to promote a healthier and more pleasant living environment (for example, parks, gardens, and green roofs).
2	Air Quality (Wei et al., 2015; Steinemann et al., 2017)	Air quality directly affects the health and comfort of building occupants. Green buildings prioritize good indoor air quality through proper ventilation systems and air purification methods. Clean indoor air reduces the risk of respiratory problems and promotes a healthier lifestyle.	I believe ensuring good indoor air quality through proper ventilation systems and low-VOC materials in a building's design and operation is essential for occupant well-being.
3	Energy Efficiency (Liu et al., 2014; Fan and Xia 2018)	Energy-efficient practices are core to green building. By incorporating energy-efficient appliances, insulation, lighting, and renewable energy sources, green buildings minimize energy consumption and reduce carbon emissions,	I believe that energy-efficient practices, such as using renewable energy sources and efficient appliances, are essential in minimizing energy consumption

No	Indicator	Description	Likert scale Question
		contributing to global efforts to combat climate change.	and reducing environmental impact
4	WWTP (Wastewater Treatment Plant) (Morrison et al., 2016; Suryawan et al., 2024b)	Incorporating efficient wastewater treatment systems in green buildings ensures responsible water management. It reduces the impact on local water bodies, prevents pollution, and supports sustainable water use practices, aligning with environmental conservation goals.	I think incorporating efficient wastewater treatment systems to responsibly manage water usage and prevent pollution in a building's operation is important.
5	Water Supply (Ayuningtyas et al., 2022)	Sustainable water supply practices, such as rainwater harvesting and greywater reuse, reduce demand on conventional water sources. This promotes water conservation, decreases stress on local water resources, and helps create more resilient communities.	I consider sustainable water supply practices, such as rainwater harvesting and greywater reuse, important for conserving water resources and promoting responsible water use.
6	Flood (Houghton and Castillo-Salgado 2017)	Green building strategies often include flood prevention measures, such as proper drainage systems and site planning, which mitigate flood risks. These strategies protect the building's infrastructure, reduce property damage, and enhance safety.	I believe that integrating flood prevention measures, such as proper drainage systems and site planning, is important to minimize flood risks and ensure building safety.
7	Waste Management (Wu et al., 2016; Lu et al., 2019)	Green buildings prioritize waste reduction and recycling. Effective waste management strategies within the building, including recycling programs and waste separation systems, minimize waste sent to landfills and promote responsible resource use.	I think that implementing effective waste management strategies, including recycling programs and waste separation systems, is important to reduce environmental impact and promote responsible resource use.
8	Public Transport (Suryawan et al., 2024b)	Proximity to public transportation options encourages the use of sustainable commuting methods. Green buildings located near public transport hubs promote reduced car usage, lower carbon emissions, and decreased traffic congestion.	I consider the proximity of public transportation options important in promoting sustainable commuting methods and reducing carbon emissions.
9	Shopping Centre	A nearby shopping centre promotes sustainable living by reducing the need for extensive travel for everyday needs (Du et al., 2020). Residents can access goods and services more easily, decreasing transportation-related emissions.	I believe that the presence of a nearby shopping centre is essential to support sustainable living by reducing the need for extensive travel and decreasing transportation-related
10	Near Office	Living close to workplaces reduces commute times and encourages walking, cycling, or using public transport (Yang et	I think that living near workplaces is important in reducing commute times, promoting active

No	Indicator	Description	Likert scale Question
		al., 2022). This decreases carbon emissions, supports a healthier lifestyle, and aligns with mixed-use development.	transportation, and decreasing carbon emissions.

To quantitatively gauge the perceived importance of these green building indicators, a 5-point Likert scale has been employed. This scale ranges from 1 (strongly disagree) to 5 (strongly agree), allowing respondents to express their level of agreement with statements related to each indicator's significance (Suryawan et al., 2023; Sutrisno et al., 2023a, b). This systematic approach to inquiry is designed to capture nuanced opinions and attitudes towards green building practices, providing valuable insights into how these indicators are valued by those who experience them daily. The Likert scale questions associated with each indicator are formulated to reflect the descriptions provided, ensuring that respondents have a clear understanding of the context before expressing their views. This methodological choice facilitates the collection of data that is both robust and reflective of the stakeholders' true perceptions, thereby informing more targeted and effective policymaking and implementation strategies in the realm of green architecture and sustainable urban planning.

The final phase of the methodology involves rigorous statistical analyses. Factor analysis is used to discern correlation patterns between variables related to green practices (Sianipar and Lee 2024; Suhardono et al., 2024; Suryawan and Lee 2024; Suryawan et al., 2024a; Sutrisno et al., 2024; Sianipar et al., 2024), thereby identifying the main factors influencing the adoption of sustainable practices in these buildings. Cluster analysis, utilizing the k-means algorithm, further categorizes apartment complexes into groups based on their sustainability levels. This analysis aids in identifying groups of apartments with similar sustainability practices, facilitating the formulation of more targeted policy recommendations and actions to enhance sustainability levels in each group. Through this comprehensive methodological approach, the study aims to provide a nuanced understanding of green building practices in Jakarta's apartment complexes, contributing significantly to the body of knowledge in sustainable urban development

3. Result and Discussion

3.1. Factor and cluster analysis

Table 2 presents the outcomes of the factor analysis, summarizing the cumulative sum of squared loadings, which together explain 62.843% of the total variance in the dataset. This percentage reflects the extent to which the factors identified through the analysis account for the overall variability observed. The cumulative variance explained increases as each factor, ranked by the magnitude of their eigenvalues, is considered in the analysis. This cumulative percentage is a key indicator of the factor analysis's capacity to reveal the underlying structure and patterns in the data. Furthermore, the analysis's validity is supported by a Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy of 0.76, indicating that the sample is suitable for factor analysis. Additionally, the Bartlett's test of sphericity shows a significance level of less than 0.001 ($p < 0.001$), confirming that the variables are sufficiently correlated for factor analysis (Sianipar and Lee 2024; Suhardono et al., 2024; Suryawan and Lee 2024; Suryawan et al., 2024a; Sutrisno et al., 2024; Sianipar et al., 2024). These statistical tests provide the necessary validation for the factor analysis conducted, underscoring its reliability in uncovering significant patterns within the dataset(Sianipar and Lee 2024; Suhardono et al., 2024; Suryawan and Lee 2024; Suryawan et al., 2024a; Sutrisno et al., 2024; Sianipar et al., 2024).

Table 2. Extraction sums of squared loadings cumulatively KMO=0.76 and Bartlett test p>0.001)

Factor Loading	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.550	45.499	45.499	4.550	45.499	45.499
2	1.734	17.344	62.843	1.734	17.344	62.843

Table 3 presents the factor loading, which illustrates the loadings of variables onto the extracted components resulting from the factor analysis. The analysis reveals that the first component encompasses sustainability aspects of building design and operation, including green space, air quality, energy efficiency, WWTP (Wastewater Treatment Plant), water supply, flood, and waste Management. These variables collectively represent a shared underlying factor associated with environmental considerations in green building practices. Conversely, the second component aggregates variables linked to urban convenience and accessibility, including public transport, shopping center, and near office. These variables together reflect a distinct factor capturing the aspects of proximity to essential amenities and efficient commuting options within the context of sustainable living environments. The component matrix aids in interpreting the relationships between variables and extracted components, providing valuable insights into the underlying structure of the data and contributing to understanding how different indicators group together based on their shared characteristics'.

Table 3 Factor Loading

Variable	Factor loading	
	1 Environmental Sustainability	2 Urban Convenience and Access
Green Space	0.735	
Air Quality	0.780	
Energy Efficiency	0.709	
WWTP (Wastewater Treatment Plant)	0.711	
Water Supply	0.742	
Flood	0.715	
Waste Management	0.803	
Public Transport		0.673
Shopping Centre		0.720
Near Office		0.700

The first component, "Environmental Sustainability," encapsulates a collection of key variables that collectively underscore the multifaceted aspects of fostering ecological responsibility and environmental friendliness within the framework of green building practices. Within this component, a set of indicators including green space, air quality, energy efficiency, WWTP (Wastewater Treatment Plant), water supply, flood, and waste management have been aggregated to signify the comprehensive efforts towards creating living environments that are in harmony with the environment. Green Space signifies the integration of natural elements like parks and gardens within and around buildings, enriching urban landscapes with biodiversity and providing areas for relaxation (Lau et al., 2014). Air quality highlights the vital need for maintaining high indoor air quality through the utilization of proper ventilation systems and materials with low volatile organic compounds (VOCs), fostering occupant health (Palmisani et al., 2021).

The emphasis on energy efficiency underscores deploying energy-saving techniques such as energy-efficient appliances, effective insulation, and renewable energy sources to curb energy consumption and reduce carbon emissions (Deb and Schlueter 2021). WWTP (Wastewater Treatment Plant) inclusion underscores the commitment to judiciously manage water resources through efficient wastewater treatment systems that curtail pollution and ensure responsible water use practices (Cui et al., 2021). Addressing water supply, the component underscores sustainable water management strategies encompassing practices like rainwater harvesting and reusing greywater, thereby lessening water demand and promoting water conservation. The mention of Flood underlines the proactive implementation of flood mitigation measures involving proper drainage systems and meticulous site planning to thwart flood risks and bolster building and occupant safety. Waste management, as a significant component, accentuates strategies (Suryawan et al., 2022; Suryawan and Lee 2023; Suhardono et al., 2023), including recycling programs and effective waste separation systems, which collectively curb waste generation, foster responsible resource employment, and contribute to overall environmental preservation.

The second component, "Urban Convenience and Access," constitutes a cohesive set of variables that collectively accentuate the pivotal role of proximity to vital urban amenities and efficient transportation alternatives within the paradigm of green building practices. Within this component, a cluster of indicators encompassing public transport and shopping centre, alongside near office if applicable, converge to underscore the crucial aspect of creating living environments that blend the essence of urban convenience with sustainability imperatives. Public transport emerges as a significant variable, spotlighting the paramount importance of seamless access to public transportation options (Hine and Scott 2000). This recognition underscores the pivotal role of sustainable commuting methods in reducing individual dependence on private vehicles, thereby alleviating traffic congestion, and reducing carbon emissions that detrimentally impact the environment. The inclusion of shopping centre within this component accentuates the pertinence of accessible commercial centres. This factor underscores the pivotal role of such establishments in diminishing the necessity for extensive travel to procure everyday essentials, consequently mitigating emissions associated with transportation and fostering an ethos of sustainable living. If present, near office signifies the advantage of residing within proximity to one's workplace. this concept aligns seamlessly with the overarching theme of this component, as it champions the notion of curtailing commuting distances. This not only engenders active transportation modes but also curbs carbon emissions entailed by protracted commutes. Then, the cluster from two factor from green building attitude show in Table 4.

Table 4. Cluster result

Factor	Cluster		
	1	2	3
Environmental Sustainability	0.100	-1.617	0.393
Urban Convenience and Access	-1.534	0.195	0.428
n	113	95	362

In striking juxtaposition to Cluster 1, Cluster 2 is a testament to the profound significance of "Urban Convenience and Access." Anchored by the variables "Public Transport," "Shopping Centre," and possibly "Near Office," this cluster paints a portrait of urban spaces designed to encapsulate accessibility and convenience. "Public Transport" takes centre stage, heralding the pivotal role of seamless access to public transportation options in mitigating traffic congestion and reducing individual reliance on private vehicles, thereby reducing carbon emissions. This symbiosis between accessibility and convenience resonates deeply with "Shopping Centre," a proponent of localized shopping hubs that galvanize the diminution of travel-related emissions by rendering daily essentials readily accessible. Should "Near Office" be part of this cluster, it attests to the merits of dwelling in close quarters to workplaces, extolling the virtues of reduced commuting distances and fostering active transportation modes. Cluster 3 emerges as a fascinating juncture where the narratives of environmental sustainability and urban convenience converge, intertwining and creating a tapestry that harmoniously encapsulates both realms. The presence of variables from both clusters heralds an intriguing amalgamation of principles, signifying that certain indicators resonate with the essence of both "Environmental Sustainability" and "Urban Convenience and Access." This hybrid character underscores the intricacies of green building practices, where the pursuit of ecological equilibrium intertwines seamlessly with the practicalities of urban living.

3.2. Segmentation Analysis

Table 5 presents a comprehensive cross-tabulation showcasing the interplay between the three distinct clusters identified and a set of pivotal demographic variables: gender, income, higher education, age, and marital status. This meticulous analysis has yielded a remarkable revelation, a statistically compelling association, where the chi-squared significance attains a remarkable level of 0.1% (Suryawan and Lee 2023). This outcome holds particularly true for the demographic variables of Income, Higher Education, Age, and Marital Status. The import of this statistical significance reverberates through the very essence of the study. As a defining socio-economic indicator, income remarkably aligns with the emergent clusters, painting an intriguing portrait of how financial strata intermingle with the ethos of environmental sustainability and urban accessibility. The correlation between higher education and the clusters unveils a profound insight into the nexus between knowledge acquisition and the propensity for greener, more accessible living spaces. The influence of age on cluster distribution weaves a narrative that encapsulates generational disparities and their synchronization with diverse green building inclinations. Lastly, marital status—a facet of personal life—resonates with the clusters' thematic underpinnings, adding complexity to the interrelation between personal circumstances and green living preferences.

The χ^2 significance at 0.1% heralds a resounding signal, resonating beyond statistical confines (Table 4). It underscores that the clusters are not randomly distributed across demographic contours but rather intricately woven with the fabric of individual lives. This revelation becomes a lodestar, guiding the formulation of strategies that bespoke different clusters' attributes to distinct demographic segments. The implications are monumental urban planners, architects, and policymakers are bestowed with a compass calibrated by demographic nuances, enabling them to steer green building practices with a nuanced, individualized approach.

Table 5. Sociodemographic between cluster

Demographic		Cluster			χ^2	df	pvalue
		1	2	3			
Gender	Male	50	50	163	1.954	2	0.37644
	Female	63	45	199			
Income	≤ IDR 5,000,000	78	49	137	38.493	6	9E-07
	IDR 5,000,001 – IDR 10,000,000	13	20	82			
	IDR 10,000,001 - IDR 15,000,000	8	17	74			
	> IDR 15,000,000	14	9	69			
Higher education	Magister above	7	6	51	24.98	4	5.08E-05
	Bachelor's degree	58	55	232			
	High school and below	48	34	79			
Age	20-29	85	67	175	35.656	8	2.03E-05

Demographic		Cluster 1	Cluster 2	Cluster 3	χ^2	df	pvalue
	30-39	21	24	147			
	40-49	5	4	30			
	50-59	2	0	7			
	>60	0	0	3			
Marital status	Married	20	28	134	15.102	2	0.000526
	Single	93	67	228			

The discovery of significant associations between clusters and demographic factors like income, education level, age, and marital status calls for policy strategies that are both nuanced and personalized. This study's insights stress the critical role of customized communication and education strategies in policymaking. By understanding the relationship between higher education and specific clusters, for example, policymakers could devise educational programs aimed at fostering sustainable living practices among well-educated demographics. Tailoring messages to accommodate income variations can also help in promoting the adoption of green building practices, taking financial constraints into consideration.

Moreover, these findings underline the importance of inclusive urban planning and design. The correlations observed between demographic factors and clusters highlight the necessity for urban spaces to be designed with the diverse needs and preferences of various demographic groups in mind. By ensuring green building practices are in harmony with the desires of distinct clusters, urban development can be made more inclusive(Phan et al., 2022; Suryawan and Lee 2023; Suryawan et al., 2023).

Additionally, the results point towards the requirement for targeted infrastructure development. Insights into the preferences of different age groups, based on their cluster association, can inform the development of infrastructure that appeals to specific demographics. For example, recognizing that younger individuals might gravitate towards certain clusters could lead to the development located conveniently close to urban amenities (Florida et al., 2023). The significant relationship between certain clusters and aspects like "Urban Convenience and Access" suggests a push for mixed-use developments (Hewa Welege et al., 2023). Such projects, combining residential, commercial, and transport infrastructure, can foster lively urban environments where essential services are readily accessible. These approaches align with cluster preferences for ease of access and convenience, presenting a compelling case for integrated urban planning initiatives that cater to the specific characteristics of each cluster.

4. Conclusions

This study delves into the multifaceted landscape of green building practices, unveiling a rich tapestry of insights interweaving environmental sustainability, urban convenience, and demographic dynamics. The study illuminates the interconnectedness of indicators that shape modern urban living environments by meticulously analysing factors and clusters. The extracted clusters "Environmental Sustainability," "Urban Convenience and Access," and the hybrid cluster testify to the intricate dance between eco-consciousness and pragmatic urban design. The study's findings underscore that green building is not a monolithic concept but a harmonious symphony of diverse factors. The "Environmental Sustainability" cluster emphasizes the importance of ecological stewardship, weaving elements like green spaces, air quality, energy efficiency, and responsible waste management into the fabric of sustainable living. Conversely, the "Urban Convenience and Access" cluster illuminates the significance of accessibility to amenities, transportation options, and workplaces in fostering a liveable urban environment. Moreover, the convergence within the hybrid cluster underscores the dynamic interplay between these realms, where environmental responsibility aligns seamlessly with urban convenience, creating a space where sustainable living thrives in harmony with pragmatic urbanity. The study uncovers the demographic nuances that intricately intermingle with these clusters. The statistically significant associations with variables such as income, higher education, age, and marital status illuminate the diversity of perspectives and priorities within the green building landscape. These findings hold profound policy implications, advocating for tailored approaches that consider the unique characteristics of different demographic segments. In the broader context, this study reframes green building practices as an art of balance a harmonization of sustainability and accessibility, a synergy of ecological stewardship and urban pragmatism. It encourages policymakers, urban planners, and architects to view green building as a holistic endeavour that transcends generic solutions, urging them to customize initiatives that resonate with the diverse needs of the populace.

References

Amaral, R.E.C., Brito, J., Buckman, M., Drake, E., Ilatova, E., Rice, P., Sabbagh, C., Voronkin, S., Abraham, Y.S., 2020. Waste management and operational energy for sustainable buildings: A review. Sustainability.

Ayuningtyas, U., Susanto, D.A., Buwana, E., Emelia, T., 2022. The compliance of water conservation aspects of clean water, wastewater, and rainwater management for residential buildings to support the green building concept. IOP Conference Series: Earth and Environmental Science 1108:12015.

Basto, M., Pereira, J.M., 2012. An SPSS R-Menu for ordinal factor analysis. Journal of Statistical Software 46:1–29.

Bradley, R.L., Anantatmula, S.V., 2011. Greening project management practices for sustainable construction. Journal of Management in Engineering 27:48–57.

Cohen, C., Pearlmutter, D., Schwartz, M., 2019. Promoting green building in Israel: A game theory-based analysis. Building and Environment 163:106227.

Cui, M., Ferreira, F., Fung, T.K., Matos, J.S., 2021. Tale of two cities: How nature-based solutions help create adaptive and resilient urban water management practices in Singapore and Lisbon. Sustainability.

Deb, C., Schlueter, A., 2021. Review of data-driven energy modelling techniques for building retrofit. Renewable and Sustainable Energy Reviews 144:110990.

Debrah, C., Chan, A.P.C., Darko, A., 2022. Green finance gap in green buildings: A scoping review and future research needs. Building and Environment 207:108443.

Du, X., Zhang, Y., Lv, Z., 2020. Investigations and analysis of indoor environment quality of green and conventional shopping mall buildings based on customers' perception. Building and Environment 177:106851.

Fan, Y., Xia, X., 2018. Energy-efficiency building retrofit planning for green building compliance. Building and Environment 136:312–321.

Florida, R., Rodríguez-Pose, A., Storper, M., 2023. Critical commentary: Cities in a post-COVID world. Urban Studies 60:1509–1531.

Grzegorzewska, M., Kirschke, P., 2021. The impact of certification systems for architectural solutions in green office buildings in the perspective of occupant well-being. Buildings.

He, Y., Kvan, T., Liu, M., Li, B., 2018. How green building rating systems affect designing green. Building and Environment 133:19–31.

Hewa Welege, N.M., Pan, W., Kumaraswamy, M.M., 2023. Engaging stakeholders to overcome the common constraints for delivering low carbon buildings in high-rise high-density cities. Journal of Construction Engineering and Management 149:4022157.

Hine, J., Scott, J., 2000. Seamless, accessible travel: Users' views of the public transport journey and interchange. Transport Policy 7:217–226.

Houghton, A., Castillo-Salgado, C., 2017. Health co-benefits of green building design strategies and community resilience to urban flooding: A systematic review of the evidence. International Journal of Environmental Research and Public Health.

Huo, X., Yu, A.T.W., Darko, A., Wu, Z., 2019. Critical factors in site planning and design of green buildings: A case of China. Journal of Cleaner Production 222:685–694.

Junaid, M.F., Rehman, Z. ur, Ijaz, N., Čekon, M., Čurpek, J., Babeker Elhag, A., 2022. Biobased phase change materials from a perspective of recycling, resources conservation and green buildings. Energy and Buildings 270:112280.

Kraakman, N.J.R., González-Martín, J., Pérez, C., Lebrero, R., Muñoz, R., 2021. Recent advances in biological systems for improving indoor air quality. Reviews in Environmental Science and Biotechnology 20:363–387.

Lau, S.S.Y., Gou, Z., Liu, Y., 2014. Healthy campus by open space design: Approaches and guidelines. Frontiers of Architectural Research 3:452–467.

Liu, Y., Guo, X., Hu, F., 2014. Cost-benefit analysis on green building energy efficiency technology application: A case in China. Energy and Buildings 82:37–46.

Lu, W., Chi, B., Bao, Z., Zetkulic, A., 2019. Evaluating the effects of green building on construction waste management: A comparative study of three green building rating systems. Building and Environment 155:247–256.

Masia, T., Kajimo-Shakantu, K., Opawole, A., 2020. A case study on the implementation of green building construction in Gauteng province, South Africa. Management of Environmental Quality: An International Journal 31:602–623.

Morrison, M., Srinivasan, R.S., Ries, R., 2016. Complementary life cycle assessment of wastewater treatment plants: An integrated approach to comprehensive upstream and downstream impact assessments and its extension to building-level wastewater generation. Sustainable Cities and Society 23:37–49.

Nadeem, M.W., Goh, H.G., Hussain, Mudassar, Ponnusamy, V. a/p, Hussain, Muzammil, Khan, M.A., 2021. Internet of Things for green building management.

Oluwunmi, A.O., Oladayo, O.P., Role, B.A., Afolabi, T.O., 2019. Benefits and barriers to the implementation of green building standards in universities: What are students' views? IOP Conference Series: Materials Science and Engineering 640:12031.

Palmisani, J., Di Gilio, A., Viana, M., de Gennaro, G., Ferro, A., 2021. Indoor air quality evaluation in oncology units at two European hospitals: Low-cost sensors for TVOCs, PM2.5 and CO2 real-time monitoring. Building and Environment 205:108237.

Phan, T.T., Nguyen, V. V, Nguyen, H.T., Lee, C.-H., 2022. Integrating citizens' importance-performance aspects into sustainable plastic waste management in Danang, Vietnam. Sustainability.

Sianipar, I.M.J., Lee, C.-H., 2024. Reshaping marine debris management post-COVID-19: Integrating adaptive attributes for enhanced community engagement. Ocean and Coastal Management 253:107149.

Sianipar, I.M.J., Lee, C.-H., Wang, H.-J., Kim, D.-C., 2024. Unraveling factors influencing local willingness to participate in sustainable Komodo conservation and protected area tourism. Forests and Society 8:350–371.

Steinemann, A., Wargocki, P., Rismanchi, B., 2017. Ten questions concerning green buildings and indoor air quality. Building and Environment 112:351–358.

Suhardono, S., Fitria, L., Suryawan, I.W.K., Ulhasanah, N., Sari, M.M., Septiariva, I.Y., Prayogo, W., 2024. Multidimensional factors of community behavioral responses and implications to landfill closures: A case study in Yogyakarta, Indonesia. Environmental Advances 16:100533.

Suhardono, S., Septiariva, I.Y., Prayogo, W., Suryawan, I.W.K., Sari, M.M., 2023. Current situation of solid waste management to archive sustainability in Klungkung Regency, Bali. Journal of Sustainable Infrastructure 2.

Suryawan, I.W.K., Gunawan, V.D., Lee, C.-H., 2024a. Assessing the importance-performance analysis of adaptive capacity programs for sustainable mangrove conservation in the Taman Nasional Bali Barat conservation area. Ocean and Coastal Management 257:107345.

Suryawan, I.W.K., Lee, C.-H., 2024. Importance-performance dynamics and willingness to pay in coastal areas for climate-adaptive marine debris management. Regional Studies in Marine Science.

Suryawan, I.W.K., Lee, C.-H., 2023. Citizens' willingness to pay for adaptive municipal solid waste management services in Jakarta, Indonesia. Sustainable Cities and Society 97.

Suryawan, I.W.K., Mulyana, R., Yenis Septiariva, I., Prayogo, W., Suhardono, S., Sari, M.M., Ulhasanah, N., 2024b. Smart urbanism, citizen-centric approaches and integrated environmental services in transit-oriented development in Jakarta, Indonesia. Research Global 8:100181.

Suryawan, I.W.K., Septiariva, I.Y., Fauziah, E.N., Ramadan, B.S., Qonitan, F.D., Zahra, N.L., Sarwono, A., Sari, M.M., Ummatin, K.K., Wei, L.J., 2022. Municipal solid waste to energy: Palletization of paper and garden waste into refuse derived fuel. Journal of Ecological Engineering 23:64–74.

Suryawan, I.W.K., Septiariva, I.Y., Sari, M.M., Ramadan, B.S., Suhardono, S., Sianipar, I.M.J., Tehupeiory, A., Prayogo, W., Lim, J.-W., 2023. Acceptance of Waste to Energy (WtE) technology by local residents of Jakarta City, Indonesia to achieve sustainable clean and environmentally friendly energy. Journal of Sustainable Development of Energy, Water and Environment Systems 11:1004.

Sutrisno, A.D., Chen, Y.-J., Lee, C.-H., 2023a. Building a community's adaptive capacity for post-mining plans based on important performance analysis: Case study from Indonesia. Land.

Sutrisno, A.D., Chen, Y.-J., Suryawan, I.W., Lee, C.-H., 2023b. Establishing integrative framework for sustainable reef conservation in Karimunjawa National Park, Indonesia. Water.

Sutrisno, A.D., Lee, C.-H., Suhardono, S., 2024. Evaluating factors influencing community readiness for post-mining environmental development strategies. Journal of Environmental Management 366:121823.

Tehupeiory, A., Mulyana, R., Sianipar, I.M.J., Septiariva, I.Y., Prayogo, W., 2023. The environmental challenges of urban living: Why willingness to pay for apartments matters. Environmental Challenges 100766.

Torres-Bagur, M., Ribas, A., Vila-Subirós, J., 2019. Incentives and barriers to water-saving measures in hotels in the Mediterranean: A case study of the Muga River Basin (Girona, Spain). Sustainability.

Vijayan, D.S., Devarajan, P., Sivasuriyan, A., Stefańska, A., Koda, E., Jakimiuk, A., Vaverková, M.D., Winkler, J., Duarte, C.C., Corticos, N.D., 2023. A state of review on instigating resources and technological sustainable approaches in green construction. Sustainability.

Wadu Mesthrige, J., Kwong, H.Y., 2018. Criteria and barriers for the application of green building features in Hong Kong. Smart and Sustainable Built Environment 7:251–276.

Wan, S., Ding, G., Runeson, G., Liu, Y., 2022. Sustainable buildings' energy-efficient retrofitting: A study of large office buildings in Beijing. Sustainability.

Wang, W., Lin, Z., Zhang, L., Yu, T., Ciren, P., Zhu, Y., 2019. Building visual green index: A measure of visual green spaces for urban building. Urban Forestry & Urban Greening 40:335–343.

Wei, W., Ramalho, O., Mandin, C., 2015. Indoor air quality requirements in green building certifications. Building and Environment 92:10–19.

Wu, Z., Shen, L., Yu, A.T.W., Zhang, X., 2016. A comparative analysis of waste management requirements between five green building rating systems for new residential buildings. Journal of Cleaner Production 112:895–902.

Yang, H., Zhang, Q., Helbich, M., Lu, Y., He, D., Ettema, D., Chen, L., 2022. Examining non-linear associations between built environments around workplace and adults' walking behaviour in Shanghai, China. Transportation Research Part A: Policy and Practice 155:234–246.

Zhang, D., Tu, Y., 2021. Green building, pro-environmental behavior and well-being: Evidence from Singapore. Cities 108:102980.

Zhou, X., 2021. Ecological civilization in China: Challenges and strategies. Capitalism Nature Socialism 32:84–99.