WELL building for developing countries: critical design criteria for residential buildings in Malaysia

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Abstract

Purpose – This study aims to investigate the interrelationship between critical design criteria (CDC) that affect health, well-being and productivity (i.e. WELL) for residential buildings in developing countries, using Malaysia as a case study. To achieve the aim, the objectives are to identify CDC that affect WELL collectively; determine CDC that affect health, well-being, and productivity simultaneously; and analyze the interrelationship between the CDC.

Design/methodology/approach – Data from the semi-structured interviews and a systematic review of the existing literature were gathered for survey development. Next, survey data was collected from 114 professionals living in multistory buildings. Finally, normalized mean analysis, analytic hierarchy process (AHP), agreement analysis and Spearman correlation analysis were used to analyze the collected data.

Findings – Out of the 51 potential design criteria, 16 are critically affecting WELL collectively. Furthermore, six are critically affecting WELL collectively as well as health, well-being and productivity simultaneously: property price, water flow and supply, water treatment, pest management, management services and waste management. Finally, "water treatment" is highly correlated to "water management" and "water flow and supply." In addition, "waste management" and "management services," as well as "fire safety" and "emergency evacuation plans," are highly correlated.

Originality/value – This study's originality includes investigating the CDC of residential buildings for the first time, to the best of the authors' knowledge, in a developing country. As a result, this study uncovers

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holistic design criteria for policymakers to establish holistic building assessment tools for residential buildings.

Keywords Architecture, Residential buildings, Building performance, Architectural design, Design criteria, WELL building

Paper type Research paper

Introduction

Industrialization, infrastructure development, cultural diversity and other socio-economic factors are resulting in the rapid growth of residential buildings in urban areas (Ma *et al.*, 2022). However, these residential buildings are negatively affecting the health, well-being and productivity of residents (Mirrahimi *et al.*, 2016). These buildings can also strain the resources, infrastructure management and social cohesion in urban areas. Nevertheless, the increasing land price in urban areas elevates the opportunities to construct high-rise residential buildings to optimize land usage and efficiently accommodate the growing population (Wu, 2022). Due to the high density of residential buildings, there has been a significant decline in resident comfort. Also, residents in urban areas are facing loneliness, depression and isolation (Kearns *et al.*, 2015). Furthermore, the social effects of high-rise residential buildings include low familiarity with neighbors and neighborhood deprivation (Kearns *et al.*, 2015).

The WELL Building Standard includes design criteria that affect health, well-being and productivity (i.e. WELL). The WELL multifamily residential index incorporates the same design criteria as the WELL Building Standard; however, it adapts to the needs and characteristics of multifamily residential environments. Therefore, several research and standards have investigated the design criteria that affect health, well-being and productivity for residential buildings (IWBI, 2022; IWBI, 2020). However, the output is explicitly catered for developed countries (Poirier *et al.*, 2021). Moreover, the design criteria of WELL buildings in developed countries often do not fit the contexts of developing countries due to different needs (Tan *et al.*, 2023). For example, developed countries have higher income levels, a more advanced infrastructure and better local technology and materials to incorporate advanced design criteria into residential buildings. In contrast, developing countries may require cost-effective design criteria due to lower income and limited infrastructure. As a result, the priority of design criteria is ranked differently between developed and developing countries in the WELL Feature ranking (IWBI, 2022). Therefore, there is a need for different design criteria for WELL buildings in developing countries.

Integrating WELL for residential buildings in developing countries is needed to reduce any adverse effects on health, well-being and productivity. However, developing countries have a limited capacity to invest in residential buildings as developed countries due to lower economic growth and higher rates of low-income populations (World Bank Group, 2016). Having appropriate design criteria for residential buildings in developing countries can lead to sustainable growth and better urban resilience (IPCC, 2023). Also, improving indoor and outdoor environment quality in residential buildings enhances WELL living and increases resilience to environmental shocks and stressors (Manisalidis *et al.*, 2020). Hence, investigating the design criteria that affect WELL for residential buildings in developing countries is vital to facilitate cohesive decisions for policymaking. Furthermore, the interrelationship between critical design criteria (CDC) encompasses optimizing performance and a comprehensive approach. Considering how various criteria influence each other also ensures that the design is coherent and effective in meeting goals. In other words, understanding the relationships between design criteria provides further insights into the decision-making process. In summary, investigating design criteria that affect WELL for residential buildings in developing countries can facilitate the decision-making process of the relevant stakeholders and policymakers.

This study explores the interrelationship between CDC that affect health, well-being and productivity (i.e. WELL) for residential buildings in developing countries, using Malaysia as a case study. The objectives of this study include to:

- identify CDC that affect WELL collectively;
- determine CDC that affect health, well-being and productivity simultaneously; and
- analyze the interrelationship between the CDC.

The study outputs benefit public agencies, researchers and industry practitioners in improving the existing WELL Building Standard. In addition, this study is one of a kind that quantitively investigates the design criteria that affect WELL for residential buildings in a developing country.

Background

WELL building

Residents are facing complex challenges that require comprehensive strategies in urban residential buildings. As a result, the WELL Building Standard was established by the International WELL Building Institute (IWBI) in 2016 to support occupant's health, well-being and productivity. The standard provides a framework for designing buildings. The framework includes ten concepts: air, water, material, light, nourishment, mind, thermal comfort, sound, community and movement. Furthermore, there are also WELL Feature Rankings for different countries, including developing countries in Asia. The WELL Feature Rankings involve ranking the existing design criteria in the WELL Building Standard according to the country's context. In other words, different design criteria affect the WELL of building occupants. Therefore, to develop new WELL Building standards, it is necessary to investigate the design criteria that affect those standards, especially for different building types (Potrč Obrecht *et al.*, 2019). However, relevant research related to the WELL Building Standard includes investigating design criteria in residential buildings (Zamani *et al.*, 2023) and office buildings (Tan *et al.*, 2024).

Design criteria that affect health, well-being and productivity in developed countries

Many developed countries have adopted different building design standards, including the WELL Building Standard. Furthermore, extensive research has investigated the design criteria that affect WELL for residential buildings in developed countries. In addition, Poirier *et al.* (2021) have identified the effect of indoor air quality (IAQ) on residents in France. Previous research has also explored the design criteria that affect health, well-being or productivity for office buildings in developed countries. For instance, Durrani and Kim (2021) researched the effect of biophilic design criteria on health and productivity in South Korea. In addition, Bae *et al.* (2017) identified the effect of IAQ, furnishings, lighting, daylighting and movement on health and well-being in the USA. Finally, Palacios *et al.* (2020) addressed several dimensions of WELL design criteria in The Netherlands.

Design criteria that affect health, well-being and productivity in developing countries

Besides developed countries, researchers from developing countries also explored the effect of design criteria on health, well-being and productivity. In their research, Tan and Lee (2022) emphasize the role of residential environment characteristics on the well-being of elderly residents in Malaysia. Awang *et al.* (2022) emphasize that green spaces, waste management, health maintenance, landscaping and building upkeep are critical for improving residents' well-being in urban recreational centers in Malaysia. According to Kamaruzzaman and Azmal (2019), design criteria such as noise levels, glare and artificial lighting within residential buildings are crucial for health and well-being in Malaysia.

In addition, there is prior research on design criteria that affect health, well-being and productivity for different building types in developing countries. For example, Mansor and Sheau-Ting (2020) identified CDC that affect well-being, including comfort, health, adaptation and safety in office buildings in Malaysia. In another research, Jamaludin *et al.* (2016) identified design criteria affecting indoor environment quality in educational buildings in Malaysia. The research conducted by Riley *et al.* (2018) explored the relationship between health, well-being and productivity in office buildings in Malaysia. In contrast, Ho *et al.* (2022) identified acoustic comfort as the top CDC for office buildings in Malaysia.

Research gap and study positioning

In summary, the WELL Building Standard has a set of design criteria that affect health, well-being and productivity of building occupants. However, the WELL Building Standard needs to be further developed. Therefore, researchers have extensively investigated the design criteria that affect health, well-being and productivity. However, research on design criteria for residential buildings in developing countries is limited. Zamani *et al.* (2023) stand out as it addresses all three aspects of WELL for residential buildings. However, the research could not identify any significant trends within the data as it only collected qualitative data. Consequently, this study expands that research by collecting quantitative data to obtain a more comprehensive understanding of the design criteria that affect health, well-being and productivity for residential buildings in a developing country, using Malaysia as a case study.

Methodology

This study adopted a quantitative approach of using questionnaire surveys to achieve the study objectives. According to Hoxley (2008), surveys offer a significant degree of anonymity when addressing a sensitive topic such as the one under consideration. Therefore, this approach was extensively used to collect the viewpoints. Figure 1 overviews the study methodology.

Survey development

The survey development involved a two-stage process to ensure the survey's appropriateness and rationality. The first stage involved semi-structured interviews with ten built environment professionals and ten individuals residing in multistory residential buildings in Malaysia. The purposeful sampling method was used to identify the interviewees. This method is more effective with a smaller sample size that is incredibly knowledgeable about or experienced with a phenomenon of interest (Naderifar *et al.*, 2017). The snowball sampling method was also used to solicit participants among the initial interviewees (Naderifar *et al.*, 2017). The interviews focused on identifying design criteria that affect health, well-being and productivity according to the participants' experience and professional expertise. This method was chosen as it enabled interviewees to express their opinions about the subject matter (Boyce and Neale, 2006). The interviews involved three main questions:

Q1. What criteria affect health in residential buildings?

Q2. What criteria affect well-being in residential buildings?

Q3. What criteria affect productivity in residential buildings?

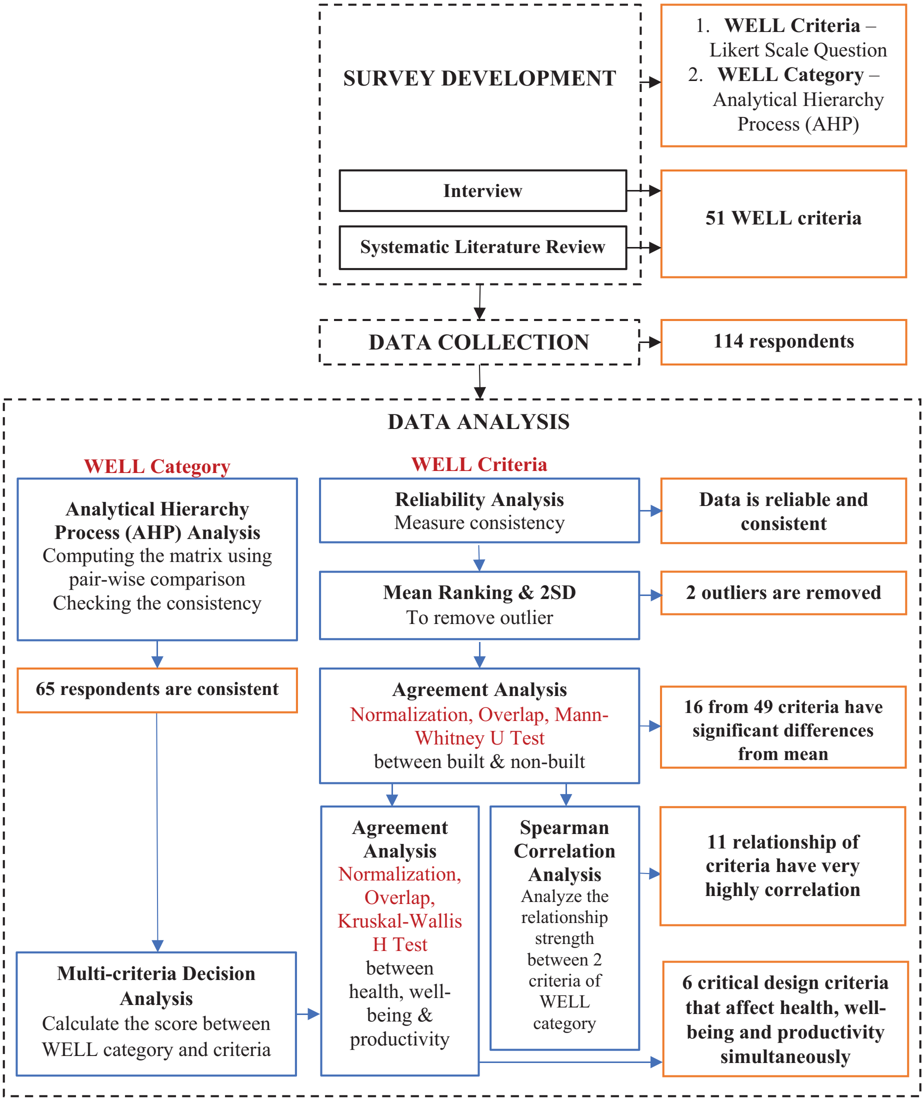


Figure 1.
Research framework

These open-ended questions allow participants to express their opinions through in-depth discussions. Then, the interview process continued with follow-up questions to clarify the respondents' answers. As a result, this process produced 30 potential design criteria for health, 24 for well-being and 21 for productivity after analyzing the collected data using the thematic analysis approach.

The second stage of the survey development involves a review method to identify a comprehensive set of potential design criteria from the existing body of literature. This study adopts the systematic review method as it allows the compilation and summarization of extensive literature pertinent to the subject matter (Grant and Booth, 2009). The execution of the systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as the approach enhances transparency, completeness and accuracy in systematic review reporting (Page *et al.*, 2020). Much prior research has used this approach, including Alankarage *et al.* (2023). Figure 2 summarizes the system review process using the PRISMA approach. The first step involves determining the eligibility criteria related to study aim and determining appropriate keywords, search engines and databases. This study considered all research on variables (e.g. element, criteria, index) that affect health, well-being or productivity in residential buildings as eligible for the review. The Scopus search engine was used as it is an extensive database, that encompasses a more significant number of journals than other search engines and is widely used for systematic review (Airyalat *et al.*, 2019). Specific keywords were selected to ensure the search was aligned with the study objectives. The keywords used were (health OR well-being OR productivity) and ("residential building") and (element OR criteria OR index). Herein, the search was restricted to the "journal" category as journals have a rigid peer-reviewed process. In addition, the search was restricted to environmental science and engineering areas to limit the extent of the existing knowledge of the built environment. The search was also limited to "English" language to overcome translation bias and document type "article" to include research with empirical results not based on reviews. From the search results, only journals that have two or more articles were included as deemed as specialized to the subject matter. The search coverage was not limited to any time frame. Accordingly, the original search on July 19th, 2022, yielded 860 articles, with the first published in 1997. Then, 567 articles were removed after the search was limited to journals, engineering and environmental science subject areas, English, article document type and source titles that have more than two articles. The remaining 293 articles were screened

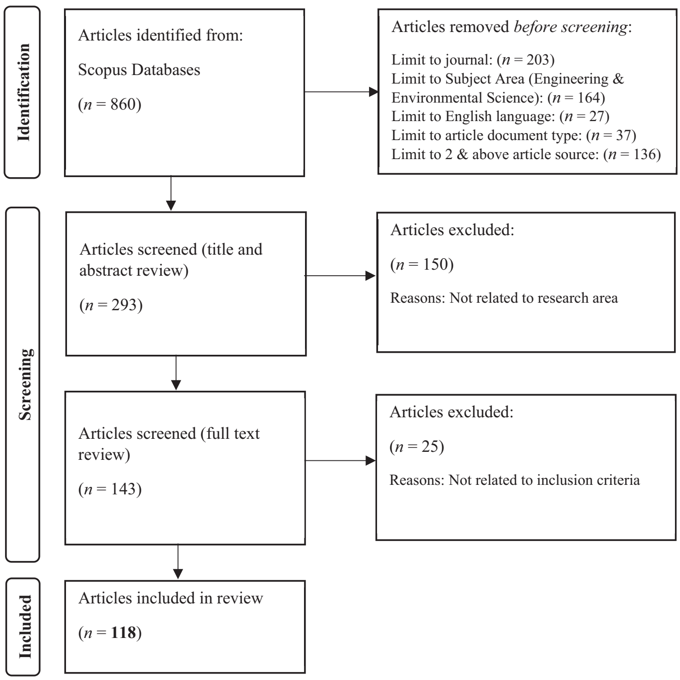


Figure 2.
Flowchart of the systematic review process (PRISMA flow diagram)

based on the title and abstract. Following the title and abstract screening, 150 articles were excluded as the articles were not related to the subject matter of this study. Finally, the full text of the remaining 143 articles was reviewed, and 118 articles were identified as relevant and subjected to further analysis. The analysis involved extracting and consolidating potential design criteria that affect health, well-being and productivity in residential buildings. This systematic review process produced 42 potential design criteria. Nevertheless, this systematic review process and output were reviewed by three reviewers to ensure good reliability.

After conducting interviews and reviewing existing literature, a list of potential design criteria was created. The interviews identified 30 criteria for health, 24 for well-being and 21 for productivity. In addition, the SLR identified 42 design criteria. All potential criteria were reviewed, combined and finalized, resulting in a final list of 51 design criteria (see Table 1). These 51 design criteria were used to draft the survey. The drafted survey consists of three sections: (A) respondent profile, (B) evaluation of the potential design criteria and (C) evaluation of the relative criticality of the main categories of WELL (i.e. health, productivity and well-being). For section B, respondents rated the criticality of the design criteria in affecting health, well-being and productivity in residential buildings using a five-point Likert scale (1 = not critical; 2 = slightly critical; 3 = moderately critical; 4 = critical and 5 = very critical). For section C, respondents rated the relative criticality between health, well-being and productivity using the nine-point analytic hierarchy process (AHP) scale developed by Saaty (1980). The nine-point scale was recommended for AHP-based pairwise comparison surveys to reduce expert judgment fuzziness (Saaty, 1980). Then, three built environment professionals and four nonbuilt environment professionals reviewed the drafted survey to validate the question design, response time and ease of understanding. This validation process ended as additional reviews did not provide value-added insights in improving the drafted survey (i.e. data saturation).

Data collection

The respondents for survey data collection were professionals living in residential buildings with and without built environment backgrounds in Malaysia. The sample used nonprobability sampling for the survey data collection because there was no sampling frame in this study. According to Naderifar *et al.* (2017), nonprobability sampling can be used to create a representative sample when choosing respondents randomly from the total population is impossible. In this case, the willingness of respondents to engage in the study can be used to select them. The data collection starts by approaching respondents from five different regions in Malaysia, consisting of professionals who have been directly involved and not involved in the built environment industry as initial respondents. Then, the initial respondents were asked to share information about other suitable participants as subsequent respondents. Finally, subsequent respondents were approached to fill out the survey. The survey data collection results in 114 valid respondents (respondent profile as per Table 2). Experts concur that 30 is appropriate for statistical data analysis and generating relevant conclusions (Pallant, 2016). In addition, this study aimed to highlight the interrelationship of the design criteria rather than presenting the population. Therefore, it is decided that the sample size is adequate.

Analysis and results

Reliability analysis

The data analysis starts with checking the reliability of the collected data. First, the Cronbach's alpha test was used to evaluate the consistency and reliability of the Likert scale

Code	Criteria	Source: Systematic review	Source: Interview	Source: WELL building standard
C1	Increased ventilation	●	●	●
C2	Air filtration	●		●
C3	Combustion minimization	●		●
C4	Ventilation design	●		●
C5	Air quality	●		●
C6	Operable windows	●		●
C7	Building amenities	●		
C8	Property price	●		●
C9	Pet policy	●		
C10	Beauty and design/aesthetic	●	●	●
C11	Biophilia (nature and living things)	●	●	●
C12	Location	●		
C13	Coverage		●	
C14	Social outdoor spaces	●		
C15	Social interaction	●		
C16	Neighborhood		●	
C17	Outdoor environment	●	●	
C18	Indoor place	●	●	
C19	Building structure	●	●	
C20	Parcel room		●	
C21	Water features landscape	●		
C22	Water management	●		●
C23	Water flow and supply		●	
C24	Water treatment		●	●
C25	Moisture management	●	●	●
C26	Local technology and materials	●		
C27	Nonallergic finishes material	●		
C28	Pest management	●	●	●
C29	Home appliance	●		
C30	Construction technology	●		
C31	Thermal comfort/room temperature	●		●
C32	Accessible design	●	●	●
C33	Security features (e.g. CCTV, access card, boom gate)	●	●	
C34	Building density	●	●	
C35	Parking (design and facilities)	●		
C36	Population	●		
C37	Management services	●		
C38	Waste management	●		●
C39	Maintenance cost	●		
C40	Mechanical and electrical services	●		
C41	Maintenance services	●		
C42	Recycle practice	●		
C43	Legal	●		
C44	Garbage management		●	
C45	Emergency evacuation plans	●		
C46	Fire safety		●	
C47	Sound barriers	●		●
C48	Positive sound		●	
C49	Solar glare control	●		●
C50	Daylight design strategies/natural lighting	●		●
C51	Physical activity spaces		●	●

Table 1.
List of design criteria and their related sources

Characteristics	Categories	Built Frequency	Built %	Nonbuilt Frequency	Nonbuilt %
Respondents		74	65	40	35
Years of working experience	Less than 1 year	5	4.4	None	0
	1–5 years	33	29	None	0
	6–10 years	30	26.4	None	0
	11–15 years	6	5.3	None	0
	More than 20 years	0	0	None	0
House living type	Bungalow (detached house)	14	12.3	5	4.4
	Semi-D house	6	5.3	7	6.1
	Terrace house	26	22.8	19	16.6
	Low-rise apartment	10	8.8	3	2.6
	High-rise apartment	17	14.9	5	4.4
	Other	1	0.9	1	0.9
Years of living in current house	Less than 1 year	16	14.1	5	4.4
	2–5 years	18	15.8	16	14
	More than 5 years	11	9.7	10	8.8
	More than 10 years	29	25.5	9	7.9
Location	Northern region (Perlis, Kedah, Penang, Perak)	17	14.9	5	4.4
	East Coast Region (Kelantan, Terengganu, Pahang)	5	4.4	15	13.1
	Central Region (Selangor, Kuala Lumpur, Putrajaya)	16	14.1	13	11.4
	Southern Region (Negeri Sembilan, Melaka, Johor)	21	18.4	1	0.9
	East Malaysia (Sabah, Sarawak, Labuan)	15	13.2	6	5.3
Household income	Below RM2,500	4	3.5	5	4.4
	RM2,501–RM5,000	27	23.7	14	12.3
	RM5,001–RM7,500	20	17.6	8	7
	RM7,501–RM10,00 0	15	13.2	3	2.6
	RM10,001–RM12,500	6	5.3	5	4.4
	More than RM12,500	2	1.8	5	4.4

Table 2. Respondent profile

used (Pallant, 2016). The Cronbach's alpha values range from 0 to 1. A satisfactory value of 0.8 or higher signifies good consistency (Pallant, 2016). Cronbach's alpha values for the collected data are 0.988. As a result, the collected data have excellent reliability at the 5% significance level and are appropriate for further analyses.

Next, the two-standard deviation (SD) techniques were used to filter out potential outliers. Outliers are data that deviate from the norm and might impact the results. To identify outliers, the technique involves calculating the means, SD and two SD intervals of the design criteria. Any variables with mean values outside the two SD intervals are considered outliers (Tan *et al.*, 2023). Consequently, "pet policy" and "water feature landscape" were identified as outliers and excluded from further analysis.

Design criteria that affect WELL collectively

Agreement analysis. As the respondents in this study are from two groups (nonbuilt environment professionals living in multistory residential buildings and built environment professionals), the Mann–Whitney U-test was used to detect any statistically significant differences in the means of the design criteria between the two respondent groups. The test revealed that 23 out of the 49 design criteria (approximately 47%) have statistically significant different means between the two respondent groups. Therefore, the CDC were analyzed from the perspective of these two respondent groups.

Normalized mean analysis. Next, normalized mean analysis was used to transform the minimum mean value to a normalized value (NV) of 0 and the maximum mean value to an NV of 1. The remaining mean values were transformed into NVs ranging from 0 to 1. The calculation of NV involves the subsequent formula: NV = (mean − minimum mean) / (maximum mean − minimum mean). Design criteria with NVs of at least 0.50 (NV $\geq$ 0.50) are considered critical (Zamani *et al.*, 2024). The data of the means, SDs and NVs of the design criteria are presented in Table 3. The results show 33 and 20 design criteria with NV $\geq$ 0.50 for the built and nonbuilt environment professionals. These are the CDC from the perspective of these two respondent groups.

Overlap analysis. An overlap analysis was conducted to identify the CDC relevant to the built and nonbuilt environment professionals. This technique is used to evaluate similarities and differences between distinct groups. The shared characteristics and distinctions between multiple groups can be identified within the variables where two or more circles intersect. The results of the overlap analysis are shown in Figure 3, which indicates that 16 CDC overlap between the two respondent groups. In other words, these are the CDC that affect WELL collectively for residential buildings in developing countries.

Critical decision criteria that affect health, well-being and productivity simultaneously

Analytic hierarchy process. To determine the critical decision criteria that affect health, well-being and productivity simultaneously, first, the AHP was used to compute the relative weightage of the three WELL categories. AHP emerged in 1980 by Saaty as a prevalent technique for multicriteria decision-making in the construction industry (Tan *et al.*, 2023). The AHP data analysis, involving pairwise comparison and consistency index, was used to calculate the weightage of each WELL category using the survey data in Section C. Finally, the weighted means (three means for each criterion – one each for health, well-being and productivity) for the design criteria were calculated.

Agreement analysis. Subsequently, the Kruskal–Wallis H test was used to identify any significant differences in the means of the design criteria between health, well-being and productivity. In this analysis, variables with p-values > 0.05 suggest significant differences between groups (Pallant, 2016). Table 4 shows the p-values derived from the Kruskal–Wallis H test. The results show no significant differences in the means of the design criteria between the three WELL categories.

Normalized mean analysis. Next, the normalized mean analysis was used to identify the CDC that affect health, well-being and productivity. The NV is calculated to identify the CDC for each category. Table 4 presents the mean, SD and NV values. The results indicate that seven design criteria for health, seven for well-being and eight for productivity have NV $\geq$ 0.50. In other words, these are the CDC that affect health, well-being and productivity for residential buildings in developing countries.

Overlap analysis. Then, the overlap analysis was used. The results of the overlap analysis show that six CDC overlap between health, well-being and productivity: "property price," "water flow and supply," "water treatment," "pest management," "management services" and "waste management." In other words, these are the CDC that affect health, well-being and productivity simultaneously for residential buildings in developing countries.

Interrelationship between critical design criteria

Finally, the Spearman correlation analysis was used to analyze the interrelationship between the CDC identified in the previous two subsections. The analysis assesses the degree of association

Code	Criteria	All MI	All SD	All NV	Built environment MI	Built environment SD	Built environment NV	Nonbuilt environment MI	Nonbuilt environment SD	Nonbuilt environment NV	Mann–Whitney *p*-value
C1	Increased ventilation	3.281	1.320	0.507[a]	3.581	1.239	0.682[a]	2.725	1.301	0.172	0.001[b]
C2	Air filtration	3.325	1.300	0.580[a]	3.568	1.240	0.667[a]	2.875	1.305	0.379	0.007[b]
C3	Combustion minimization	3.123	1.242	0.246	3.311	1.260	0.379	2.775	1.143	0.241	0.031[b]
C4	Ventilation design	3.386	1.334	0.681[a]	3.716	1.255	0.833[a]	2.775	1.271	0.241	0.000[b]
C5	Air quality	3.386	1.442	0.681[a]	3.689	1.423	0.803[a]	2.825	1.318	0.310	0.002[b]
C6	Operable windows	3.219	1.550	0.406	3.527	1.572	0.621[a]	2.650	1.350	0.069	0.002[b]
C7	Building amenities	3.105	1.319	0.217	3.230	1.400	0.288	2.875	1.137	0.379	0.148
C8	Property price	3.518	1.345	0.899[a]	3.622	1.421	0.727[a]	3.325	1.185	1.000[a]	0.162
C10	Beauty and design/ aesthetic	2.982	1.255	0.014	2.973	1.303	0.000	3.000	1.177	0.552[a]	0.959
C11	Biophilia (nature and living things)	3.035	1.226	0.101	3.122	1.271	0.167	2.875	1.137	0.379	0.250
C12	Location	3.219	1.550	0.406	3.500	1.510	0.591[a]	2.700	1.506	0.138	0.007[b]
C13	Coverage	3.281	1.442	0.507[a]	3.486	1.417	0.576[a]	2.900	1.429	0.414	0.038[b]
C14	Social outdoor spaces	3.149	1.453	0.290	3.311	1.470	0.379	2.850	1.388	0.345	0.095
C15	Social interaction	3.026	1.353	0.087	3.257	1.335	0.318	2.600	1.297	0.000	0.014[b]
C16	Neighborhood	3.202	1.477	0.377	3.446	1.416	0.530[a]	2.750	1.498	0.207	0.018[b]
C17	Outdoor environment	3.211	1.478	0.391	3.378	1.505	0.455	2.900	1.392	0.414	0.074
C18	Indoor place	3.246	1.399	0.449	3.432	1.405	0.515[a]	2.900	1.336	0.414	0.046[b]
C19	Building structure	3.333	1.437	0.594[a]	3.500	1.483	0.591[a]	3.025	1.310	0.586[a]	0.061
C20	Parcel room	2.974	1.258	0.000	3.054	1.302	0.091	2.825	1.174	0.310	0.360
C22	Water management	3.456	1.415	0.797[a]	3.662	1.388	0.773[a]	3.075	1.403	0.655[a]	0.028[b]
C23	Water flow and supply	3.544	1.506	0.942[a]	3.770	1.495	0.894[a]	3.125	1.453	0.724[a]	0.018[b]
C24	Water treatment	3.579	1.336	1.000[a]	3.797	1.324	0.924[a]	3.175	1.279	0.793[a]	0.011[b]
C25	Moisture management	3.289	1.253	0.522[a]	3.514	1.295	0.606[a]	2.875	1.067	0.379	0.007[b]
C26	Local technology and materials	3.096	1.317	0.203	3.176	1.318	0.227	2.950	1.319	0.483	0.385
C27	Nonallergic finishes material	3.035	1.363	0.101	3.122	1.414	0.167	2.875	1.265	0.379	0.328
C28	Pest management	3.553	1.331	0.957[a]	3.757	1.301	0.879[a]	3.175	1.318	0.793[a]	0.019[b]
C29	Home appliance	3.096	1.296	0.203	3.297	1.311	0.364	2.725	1.198	0.172	0.019[b]
C30	Construction technology	3.193	1.303	0.362	3.338	1.348	0.409	2.925	1.185	0.448	0.085
C31	Thermal comfort/ room temperature	3.412	1.329	0.725[a]	3.689	1.323	0.803[a]	2.900	1.194	0.414	0.002[b]
C32	Accessible design	3.298	1.389	0.536[a]	3.500	1.407	0.591[a]	2.925	1.289	0.448	0.026[b]
C33	Security features (e.g. CCTV, access card and boom gate)	3.342	1.329	0.609[a]	3.459	1.357	0.545[a]	3.125	1.265	0.724[a]	0.154
C34	Building density	3.254	1.342	0.464	3.432	1.415	0.515[a]	2.925	1.141	0.448	0.044[b]
C35	Parking (design and facilities)	3.386	1.424	0.681[a]	3.527	1.501	0.621[a]	3.125	1.244	0.724[a]	0.062
C36	Population	3.211	1.398	0.391	3.459	1.397	0.545	2.750	1.296	0.207	0.008[b]
C37	Management services	3.351	1.439	0.623[a]	3.459	1.510	0.545[a]	3.150	1.292	0.759[a]	0.168
C38	Waste management	3.553	1.446	0.957[a]	3.865	1.368	1.000[a]	2.975	1.423	0.517[a]	0.002[b]
C39	Maintenance cost	3.175	1.384	0.333	3.284	1.429	0.348	2.975	1.291	0.517[a]	0.242
C40	Mechanical and electrical services	3.307	1.364	0.551[a]	3.514	1.367	0.606[a]	2.925	1.289	0.448	0.020[b]
C41	Maintenance services	3.307	1.409	0.551[a]	3.514	1.426	0.606	2.925	1.309	0.448	0.024[b]
C42	Recycle practice	3.386	1.259	0.681[a]	3.514	1.295	0.606[a]	3.150	1.167	0.759[a]	0.110
C43	Legal	3.202	1.371	0.377	3.324	1.336	0.394	2.975	1.423	0.517[a]	0.201
C44	Garbage management	3.439	1.451	0.768[a]	3.703	1.450	0.818[a]	2.950	1.339	0.483	0.006[b]

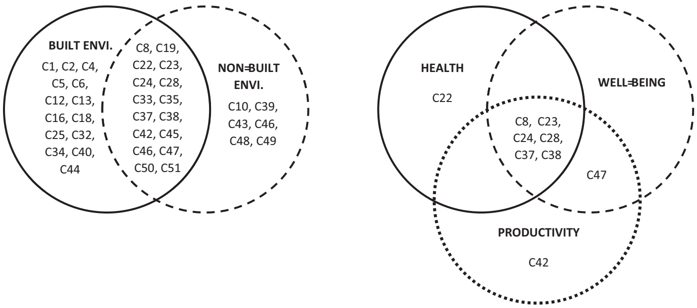
(*continued*)

Table 3. Results of normalized mean and Mann–Whitney analysis for built and nonbuilt environment professionals

Code	Criteria	All MI	All SD	All NV	Built environment MI	Built environment SD	Built environment NV	Nonbuilt environment MI	Nonbuilt environment SD	Nonbuilt environment NV	Mann–Whitney *p*-value
C45	Emergency evacuation plans	3.351	1.408	0.623[a]	3.419	1.462	0.500[a]	3.225	1.310	0.862[a]	0.387
C46	Fire safety	3.456	1.421	0.797[a]	3.595	1.452	0.697[a]	3.200	1.344	0.828[a]	0.125
C47	Sound barriers	3.456	1.358	0.797[a]	3.554	1.435	0.652[a]	3.275	1.198	0.931[a]	0.177
C48	Positive sound	3.228	1.283	0.420	3.351	1.297	0.424	3.000	1.240	0.552[a]	0.141
C49	Solar glare control	3.237	1.391	0.435	3.365	1.439	0.439	3.000	1.281	0.552[a]	0.166
C50	Daylight design strategies Natural lighting	3.368	1.403	0.652[a]	3.554	1.444	0.652[a]	3.025	1.271	0.586[a]	0.034[b]
C51	Physical activity spaces	3.298	1.420	0.536[a]	3.459	1.473	0.545[a]	3.000	1.281	0.552[a]	0.067

Notes: MI = Mean index; SD = standard deviation; NV = normalized value = (mean − minimum mean)/(maximum mean − minimum mean); [a]Indicate the criteria is a critical WELL criteria (normalized value ≥ 0.50); [b]Indicate the Mann–Whitney result is significant at the 0.05 significance level (significance level < 0.05)

Table 3.



Notes: C1 = Increased ventilation; C2 = air filtration; C4 = ventilation design; C5 = air quality; C6 = operable windows; C8 = propertyprice; C10 = beauty and design/aesthetic; C12 = location; C13 = coverage; C16 = neighborhood; C18 = indoor place; C19 = building structure; C22 = water management; C23 = water flow and supply; C24 = water treatment; C25 = moisture management; C28 = pest management; C32 = accessible design; C33 = security features; C34 = building density; C37 = management services; C38 = waste management; C39 = maintenance cost; C40 = mechanical and electricalservices; C42 = recycle practice; C43 = legal; C44 = garbage management; C45 = emergency evacuation plans; C46 = fire safety; C47 = sound barriers; C48 = positive sound; C49 = solar glare control; C50 = daylight design strategies / Natural lighting; C51 = physical activity spaces

Figure 3.
Critical analysis of WELL criteria

between two variables measured on an ordinal scale. The correlation coefficients' value can be categorized as follows: 0.00–0.29 represents no correlation, 0.30–0.49 represents low correlation, 0.50–0.69 represents moderate correlation, 0.70–0.89 represents strong correlation and 0.90–1.00 represents extremely high correlation (Asuero *et al.*, 2006)

Table 4. Result of mean score ranking, normalization and Kruskal–Wallis analysis for health, well-being and productivity

Code	Criteria	*N*	Health MI	Health SD	Health NV	Health Rank	Well-being MI	Well-being SD	Well-being NV	Well-being Rank	Productivity MI	Productivity SD	Productivity NV	Productivity Rank	Kruskal–Wallis *p*-value
C8	Property price	65	1.210	0.672	0.726[a]	5	1.101	0.530	1.000[a]	1	1.094	0.576	1.000[a]	1	0.706
C19	Building structure	65	1.122	0.773	0.015	15	0.977	0.529	0.000	16	0.969	0.534	0.000	16	0.760
C22	Water management	65	1.193	0.789	0.589[a]	7	1.033	0.530	0.454	9	1.026	0.550	0.457	11	0.758
C23	Water flow and supply	65	1.241	0.814	0.974[a]	3	1.072	0.571	0.765[a]	5	1.047	0.562	0.621[a]	7	0.709
C24	Water treatment	65	1.226	0.666	0.852[a]	4	1.097	0.544	0.972[a]	2	1.081	0.542	0.898[a]	2	0.634
C28	Pest management	65	1.244	0.739	1.000[a]	1	1.088	0.530	0.898[a]	3	1.073	0.531	0.830[a]	3	0.556
C33	Security features (e.g. CCTV, access card and boom gate)	65	1.127	0.590	0.057	14	1.020	0.500	0.350	12	1.028	0.532	0.473	10	0.779
C35	Parking (design and facilities)	65	1.158	0.679	0.302	11	1.021	0.511	0.356	11	1.012	0.518	0.340	14	0.487
C37	Management services	65	1.208	0.691	0.707[a]	6	1.062	0.522	0.685[a]	7	1.059	0.535	0.720[a]	5	0.528
C38	Waste management	65	1.242	0.745	0.979[a]	2	1.077	0.566	0.806[a]	4	1.056	0.545	0.695[a]	6	0.394
C42	Recycle practice	65	1.161	0.661	0.324	10	1.039	0.477	0.496	8	1.038	0.527	0.553[a]	8	0.594
C45	Emergency evacuation plans	65	1.120	0.670	0.000	16	0.998	0.532	0.171	15	0.997	0.556	0.220	15	0.729
C46	Fire safety	65	1.163	0.726	0.344	9	1.014	0.513	0.294	14	1.015	0.541	0.364	12	0.670
C47	Sound barriers	65	1.173	0.655	0.421	8	1.064	0.550	0.705[a]	8	1.061	0.564	0.740[a]	4	0.734
C50	Daylight design strategies/ natural lighting	65	1.142	0.642	0.178	13	1.033	0.545	0.452	10	1.031	0.583	0.498	9	0.703
C51	Physical activity spaces	65	1.148	0.715	0.223	12	1.016	0.507	0.314	13	1.012	0.520	0.343	13	0.762

Notes: MI = Mean index; SD = standard deviation; NV = normalized value = (mean − minimum mean) / (maximum mean − minimum mean); [a]Indicate the criteria is a critical WELL criteria (normalized value ≥ 0.50); [b]Indicate the Kruskal–Wallis result is significant at the 0.05 significance level (significance level < 0.05)

The analysis showed that "water treatment" and "water management" are very highly correlated for health and productivity. "Water treatment" is also very highly correlated with "water flow and supply" for health, well-being and productivity. In addition, "waste management" and "management services" are very highly correlated for health and well-being. Finally, "fire safety" and "emergency evacuation plans" are very highly correlated for health, well-being and productivity. These results indicate that these design criteria (e.g. "water treatment" and "water management" or "water flow and supply") should be designed together for residential buildings in developing countries.

Discussion

Critical design criteria that affect health, well-being and productivity

Property price. Property prices can affect residents' health, well-being and productivity. Higher property prices can lead to a higher cost of living (Adabre *et al.*, 2020). Urban areas generally have higher property prices due to higher land costs than suburban areas (Wu, 2022). Spending a significant amount of income on housing costs may limit money for other necessities, impacting the financial well-being and financial stress for individuals and families (Soundarya Priya *et al.*, 2023). As a result, some individuals prefer to lease residential properties because rental is more economical than buying new urban apartments (Guo *et al.*, 2021). In another case, property prices also affect residents' health and well-being through limited access to quality housing (Adabre *et al.*, 2020). High property prices may limit residents to live in substandard and crowded conditions. Living in poor housing conditions may affect human health as they are frequently accompanied by various challenges. Finally, property prices affect residents' health, well-being and productivity through geographical proximity. In some cases, individuals may be forced to live in areas with more affordable housing, but that may be far from job opportunities or essential services (Wu, 2022). Long commutes and exposure to traffic congestion can lead to stress, fatigue and reduced overall well-being (Telfar-Barnard *et al.*, 2017).

Water flow and supply. The water flow and supply can affect health and well-being in many ways, including water availability. Inconsistent or unreliable water supply can contribute to stress and anxiety among residents (Adams *et al.*, 2020). The uncertainty of water availability can affect daily life, affecting well-being. The water flow and supply also affect residents' well-being and productivity through the diminished water pressure challenges (Enshassi *et al.*, 2017). The consequences of these challenges are affecting the residents' operational efficacy and productivity in their daily lives. The persistence of water-related issues requires residents to identify supplementary water sources, which is particularly difficult for senior adult residents. A robust water supply pressure is indispensable to facilitate a conducive and productive living (Hall *et al.*, 2014). Finally, the water flow and supply can affect residents' health and well-being through sanitation and hygiene. Limited water supply or inconsistent water flow can hinder proper hygiene practices, including handwashing and sanitation (Bradley and Bartram, 2013). Consequently, residents are susceptible to health consequences precipitated by the lack of contentment from suboptimal water conditions within their residences.

Water treatment. The water treatment can affect residents' health and well-being in many ways through water quality. The availability of clean water can mitigate the spread of hazardous maladies and infectious diseases in daily life that eventually affect the health and well-being of residents (Adams *et al.*, 2020). Water treatment can also affect residents' health through filtration (Villanueva *et al.*, 2021). Water originates from diverse sources, undergoing several sequential phases of treatment and filtration before its distribution for domestic utilization. Filtration processes in water treatment remove suspended particles, sediment and other impurities. This not only improves the clarity and taste of the water but also reduces the risk of exposure to contaminants (Palansooriya *et al.*, 2020). The water treatment process is paramount in furnishing refined effluent, making it amenable to environmentally sustainable reuse for WELL living in residential buildings. In this context, incorporating a filtration mechanism for water treatment is a prerequisite for securing a clean water supply. In another case, the water treatment can also affect residents' health through the condition of the water piping (Khan *et al.*, 2013). Typically, aged residential buildings have recurrent issues with clogged and rusty piping. These clogged and rusty piping conduits invariably precipitate ramifications that extend to water quality, necessitating remediation that affects the health and productivity of residents.

Pest management. Pest management can affect residents' health by controlling the spread of disease. Pests have become one of the disasters that can affect residents' health. Many pests serve as carriers of pathogens that can cause illnesses, and controlling their populations reduces the risk of disease transmission. Proper pest control measures, such as eliminating vectors like mosquitoes and rodents, can help prevent the spread of diseases (Esu *et al.*, 2010). In addition, pest management regulates unsought insects and pests that can improve residents' health, well-being and productivity within residential buildings and areas through pest reduction and inspection (IWBI, 2022). Also, pest management can affect residents' health, well-being and productivity through a pest-free environment (Peek *et al.*, 2023). Living in pest-free environments can contribute to better mental health. Pests like bedbugs, rodents or cockroaches can cause stress, anxiety and sleep disturbances. Effective pest control can alleviate these mental health and well-being issues (Shah *et al.*, 2018). Less stress, anxiety and sleep disturbance can improve the productivity of residents. Finally, pest management can improve the indoor ventilation of residential buildings. Wang *et al.* (2016) agreed that pest management also involved maintaining a residential free from pests or insects by preventing dampness-related damage and improving indoor ventilation.

Management services. Management services can affect residents' health through prompt rules and regulations. Predominantly, the categories of residential buildings necessitating management services are characterized by multifamily residential building types. Within this context, the management services encompass the adept administration of the residential buildings and their precincts. This management service involves formulating and enforcing well-defined rules and regulations surrounding diverse facets such as visitor parking regulations, stipulated visiting hours and providing security services. Management must implement mitigation rules and practices for residents as a precautionary measure during emergencies and disasters (Murtagh *et al.*, 2019). Furthermore, the management services can affect residents' well-being and productivity through annual and up-to-date services. The managerial services extend to the annual reassessment of tenancy agreements, facilitating an up-to-date awareness of incumbent tenants. Finally, management services can affect residents' well-being and productivity by providing security services. The security services for residential areas like access cards, guards and surveillance cameras closed-circuit television (CCTV) can improve residents' safety, well-being and productivity. Guo *et al.* (2021) agreed that leadership in energy and environmental design-certified apartments affect health and well-being. However, there are concerns about running costs that will also increase the management services cost for residents. A quality management procedure during residential construction will reduce future defects (Tabet Aoul *et al.*, 2021).

Waste management. Waste management can affect residents' health through waste disposal patterns and behaviors. Waste disposal patterns and behaviors can affect waste management, affecting health and safety (Ikiz *et al.*, 2021). Also, waste management can affect residents' health, well-being and productivity by properly designing garbage disposal areas. The garbage disposal area location needs to be not too close to the block and should be well maintained to avoid smell, pests or dirty environmental issues that can affect the health and well-being of the residents. The waste collection points should also be appropriately arranged to reduce pedestrian exposure risks (Ma *et al.*, 2022). Incorporating a dedicated waste disposal room on each floor of the residential buildings, coupled with the garbage collection services, is an advantageous arrangement for waste management. This configuration is a productive system that obviates the need for residents to transport their trash through the elevator to the ground-floor receptacle area. Finally, waste management can affect residents' health, well-being and productivity through a systematic garbage collection system. The local council has arranged a garbage collection schedule and operation, which are effective and productive for residents. In other cases, residents renovating their property are not aware of the renovation waste from the construction. There should also be a waste management framework for renovation waste for residential development (Ding *et al.*, 2019).

Critical design criteria that affect well-being and productivity

Sound barriers. The sound barriers can affect residents' well-being and productivity through reduced noise disturbance and penetration. Noise exposure can affect human comfort and health. Sound barriers are mechanisms or devices that mitigate excessive or disruptive auditory disturbances from ambient surroundings. Reduced noise levels contribute to a quieter and more peaceful environment, promoting residents' well-being and enhancing the quality of life (Alonso *et al.*, 2020). Improving building façade and ventilation opening design criteria can avoid external noise intrusion (Torresin *et al.*, 2019). In another case, sound barriers can affect residents' well-being and productivity through building structure. Furthermore, the effect of noise can extend vertically through the different levels of a building structure. The effects of noise transmission patterns on a designated baseline floor can harm human well-being (Wu *et al.*, 2019).

Critical design criteria that affect health

Water management. Water management can affect residents' health by controlling the transmission of viruses or harmful particles. The transmission of viruses or harmful particles will affect residents' health if the water system is not managed correctly Zhang *et al.* (2021). A residential building should have proper water management as described in WELL multifamily residential pilot (WELL MRP); water management can be classified into two parts: exterior liquid water management and interior water management. External water management involves liquid water from exterior resources. In contrast, internal water management is from interior resources. ANSI/ASHRAE Standard 90.2–2007 applies to water management, such as heating equipment and systems, air-conditioning equipment and systems and domestic water-heating equipment and systems. Water management also can affect residents' health through water availability and quality. On the contrary, water management can also affect residents' well-being and productivity through water reuse. According to research by Opher *et al.* (2018), water reuse is the opportunity to save unpolluted grey water that benefits residents. Water reuse will benefit water saving, urban landscape, community engagement and household expenses.

Critical design criteria that affect productivity

Recycle practice. The recycling practice can affect residents' productivity through garbage categorizing. Recycle practices, such as categorizing garbage, should be practiced by residents to increase the productivity of individuals as well as the garbage collector. Waste disposal patterns and behaviors that include recycling, reuse and reduction practices of garbage disposal patterns also can reduce the effect on waste management and the environment (Ikiz *et al.*, 2021). Recycling practices can also increase productivity by efficient resource management. Efficient managing resources encourages responsible consumption and waste reduction. Residents who practice recycling are more likely to adopt other sustainable behaviors, leading to better management of resources and increased productivity in the long run.

Comparison with existing WELL building standards

This section compares the CDC to the current WELL Multifamily Residential Pilot (IWBI, 2020) and WELL Building Standard V2 (IWBI, 2022) as illustrated in Table 5. The comparison shows that "water management" is indicated in WELL MRP and WELL V2 as "water management" and "basic water management." Similarly, "pest management" is also available in both standards, as "pesticide management and pest control" in WELL MRP and "pest management and pesticide use" in WELL V2. Finally, "sound barriers" is also available as "sound barriers" in WELL MRP and WELL V2). However, "property price" is absent in the current WELL MRP but available in the WELL V2 as "housing equity." Furthermore, "water treatment" is available in WELL MRP as "water treatment" but absent from WELL V2 and "waste management" is available as "waste management" in WELL V2 but absent in WELL MRP. Finally, "water flow and supply," "management services," and "recycling practices" are absent in both WELL MRP and WELL V2. These findings can serve as a basis for policymakers to modify existing WELL Building Standards.

Conclusion

This study explores the interrelationship between CDC that affect health, well-being and productivity (i.e. WELL) for residential buildings in developing countries, using Malaysia as a case study. Based on the results, "pest management" is the top CDC for health and "property price" is the top CDC for well-being and productivity. The overlapping analysis identifies six CDC that affects residents' WELL collectively as well as health, well-being and

Code	Critical design criteria	WELL multifamily residential pilot	WELL building standard V2
C8	Property price	–	● (Housing equity)
C22	Water management	● (Water management)	● (Basic water management)
C23	Water flow and supply	–	–
C24	Water treatment	●	–
C28	Pest management	● (Pesticide management and pest control)	● (Pest management and pesticide use)
C37	Management services	–	–
C38	Waste management	–	●
C42	Recycle practice	–	–
C47	Sound barriers	●	●

Notes: ● Indicate criteria that are available in the standard; – Indicate criteria that are absent in the standard

Table 5. Comparison with existing WELL standards

productivity simultaneously: property price, water flow and supply, water treatment, pest management, management services and waste management. Property price is the most critical design criterion as it impacts the living cost. When living costs increase, residents will be affected by society to move into more affordable houses, which may affect the quality of life. The finding also discovered differences in the CDC between built and nonbuilt environment professionals. It shows that we should always consider the public's thoughts when designing a building. Finally, the existing WELL Building Standard is a stakeholder guideline when designing residential buildings. Therefore, investigating additional CDC for residential buildings, specifically in developing countries, is important to updating the WELL Building Standard.

Theoretical implication

The study outcomes contribute to identifying the CDC that affect health, well-being and productivity for residential buildings in developing countries. This study introduces novel discoveries that encompass nine CDC that address concerns related to health, well-being and productivity: property price, water treatment, pest management, management services, waste management and water flow and supply. The six CDC augment the preexisting WELL building design criteria. Specifically, the findings suggest that "sound barriers" affects well-being and productivity Furthermore, "water management" affects health. Finally, "recycle practice" affects productivity. From an academic perspective, these findings offer potential for ongoing exploration. In addition future research encompassing various building types and countries could adapt the methodology used. Educationally, WELL design criteria and their application will prioritize educational value or awareness that can influence society by disseminating information, shaping opinions and promoting positive behaviors.

Practical implication

Looking at it pragmatically, the outcomes from applying WELL design criteria hold significant advantages for the industry. Notably, these outcomes extend to building owners and practitioners, who can leverage the findings to facilitate informed decision-making right from the initial design phase of a construction project. This nuanced grasp of WELL design criteria furnishes valuable information and offers a roadmap that can steer decision-makers toward refining building designs. The goal is to mitigate potential detriments to health, well-being and productivity, thereby ensuring a built environment that is truly conducive. Economically, applying WELL design criteria into practicality will optimize cost-effectiveness and scalability. It also can lead to more affordable and accessible residential buildings, improving economic conditions and access for a more significant segment of society. The WELL design criteria also have the potential to affect individuals, communities and society positively. Addressing various aspects of human life, from accessibility and safety to sustainability and cultural significance, will shape societal norms, values and behaviors.

Managerial implication

A notable void exists in developing countries concerning established building guidelines addressing WELL design criteria. Consequently, the outcomes derived from the investigation into WELL design criteria within this study hold profound implications that serve as the foundation to propel governmental initiatives toward crafting comprehensive guidelines for residential buildings. Nevertheless, the implication of these results is more comprehensive than policy and design circles. It permeates upwards, resonating with the top-tier decision-makers, including developers, designers and residents, elevating awareness. These results catalyze a transformative shift in their decision-making paradigms. As a direct consequence, organizations are spurred to adopt a proactive, forward-looking stance, one attuned to the intricate interplay between the physical environment and the holistic WELL of residents.

Limitations and future research directions

Despite the significance of the findings, this study has some limitations. Based on the Mann–Whitney test, it was found that there are significant differences in the criticality of the design criteria between the built environment and nonbuilt environment professionals. However, this study focused on investigating the CDC that affect WELL for residential buildings in developing countries. Therefore, future research can explore the possible reasons for such differences. In addition, the current WELL Building Standard for residential buildings does not include any design criteria related to neighborhood. As “neighborhood” was identified from the interviews and SLR as a criterion that affects residents’ health, well-being and productivity, this study included it during the data collection and analysis. However, the detailed design criteria related to neighborhood were not identified and investigated. Therefore, future research can investigate the effect of neighborhood design criteria on residents’ well-being, health and productivity. Furthermore, this study focuses on five residential building types that are common in Malaysia: detached, high-rise, low-rise, terrace and semi-detached houses. Different residential building types might exist in other countries to accommodate local needs. Therefore, future research should replicate this study to reflect the local residential building types. Finally, this study was limited to collecting data from Malaysia. Hence, it is recommended that future research explore the design criteria in different countries to facilitate global comparisons.

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