An analysis of indoor environment evaluation for The Springs development in Dubai, UAE

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Abstract

Purpose – This study aims to evaluate The Springs' indoor environment, one of the iconic townhouse-type residential buildings in Dubai, more efficiently for the integrated evaluation of the indoor environment with the weights of indoor environmental factors such as thermal, indoor air, lighting and acoustic.

Design/methodology/approach – The weights of the indoor environment factors were derived for the integrated evaluation to reflect the residents' preferences. Based on the post-occupancy evaluation (P.O.E.) survey, the weights according to the gender, age group and indoor spaces followed a comparison and analytical processes.

Findings – This paper had found the priority of residents' needs for each space in The Springs project. In summer, thermal comfort was the most important factor for living room and the master bedroom. In winter, the priority for living room and kitchen was the indoor air quality.

Research limitations/implications – As it is the first research survey for housing project in Dubai, it needs to be extended to other housing projects in Dubai. To increase the reliability of the weights calculated through this study and the applicability of the integrated indoor environmental evaluation, more in-depth P.O.E. survey is needed with wide range of survey participants.

Social implications – This paper will help developing guidelines for future renovation based on the comparative analysis among thermal comfort, acoustic comfort, lighting comfort and indoor air comfort.

Originality/value – This paper is the first attempt to analyze the condition of early housing projects in Dubai. The data can be used to increase not only the design quality and marketability of housing projects in Dubai but also the condition of residents' health status to avoid sick building syndrome from approximately 20 years old buildings.

Keywords Dubai, The Springs, Indoor environment evaluation, Weight factors, P.O.E., Socially and culturally sustainable architecture and urban design

Paper type Research paper

1. Introduction

In recent residential building design, various eco-friendly architectural planning factors have been developed as demand for a comfortable and healthy life increases within the sustainable architecture paradigm (Maclay, 2014). Within the trend of sustainable architecture, the indoor environmental factors in residential buildings are recognized as one of the most critical factors affecting the quality of the residents'

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life (Lee and Shepley, 2018). The importance of indoor environment evaluation for the improvement of residents' indoor living quality and sustainable design is becoming more prominent (Tucker, 2014). A residential building is a house where residents spend 90% of their indoor activities and 70% of the total time (Samuelson *et al.*, 2020). Low quality of indoor environment could affect the residents' mental and physical health, productivity at work, the level of life satisfaction and the level of wellbeing as a family due to sick house syndrome (Kamaruzzaman *et al.*, 2017). Therefore, the quality of life and the physical conditions of the residents' interiors become a main concern (Lee and Shepley, 2018). The indoor environmental evaluation factors in a residential building are composed of four elements: thermal environment, acoustic environment, light environment and indoor air environment (Serrano-Jiménez *et al.*, 2021). Lack of these four indoor environmental comforts could cause various health risks such as headache, migraine headache, fatigue, continuous sneezes and sleeping disorder (Lai *et al.*, 2009).

The building's environmental quality can be determined via the appropriate combination of four indoor environmental factors to improve residents' satisfaction (Allen and Macomber, 2020). Till date, the evaluation of the indoor environment has been conducted for specific factors, independently, such as thermal environment and environmental lighting (Sun *et al.*, 2020). While taking into considerations the residents' perspective, research on the integrated indoor environment evaluation of the thermal environment, acoustic environment, light environment and indoor air environment is relatively few (Tae *et al.*, 2007). Therefore, this study with the deliberation of the weight of the indoor environmental factors reflecting the relative evaluation priority and importance of the four indoor environmental factors is needed for more effective integrated evaluation of the indoor environment in a residential space. In this paper, the target building is limited to The Springs three-bedrooms unit in Dubai, developed by Emaar. It is one of Dubai's most notable residential developments for a family-oriented lifestyle (Blanchard, 2019). Based on the post-occupancy evaluation (P.O.E.) survey on the residents' indoor environment, the weights of indoor environmental factors for integrated evaluation will be extracted. Worth to mention that the P.O.E. evaluation started by "one-off case study evaluations" late 1960s and progressed into "system wide and cross-sectional evaluation efforts" in the 1980s and 1990s, focusing on the building's performance (Meir *et al.*, 2009). The study follows a weight calculation process according to age, gender and indoor space to identify values and analyze the residents' indoor environment's perception and characteristics.

2. Housing in Dubai

His Highness Sheikh Mohammed Bin Rashid Al Maktoum, Vice President and Prime Minister of the U.A.E. and Ruler of Dubai, had declared the freehold rights for property ownership for expatriates in Dubai in 2002. It led to the modern housing development of Dubai and drawn attention and attracted more than 200 nationality investors worldwide (Rashid, 2018). The significant difference between freehold and leasehold property in Dubai is the granted rights to the property owner. Leasehold ownership means the owner has the rights for a maximum of 99 years, but freehold ownership implies the owner has all the legal rights regarding his/her property to sell, lease, or occupy (Khan and Townsend, 2019). Based on 2002 Dubai Statistics in Gulf News, Dubai's population was 1,010,751 and 85% were expatriate (Kawach, 2003).

The housing supply of Dubai had accelerated not only in the Dubai Creek area, the most developed area at that time but also Emirates Living. Three thousand four hundred housing units were provided in Emirates Living in 2003. It had expanded with 6,000 housing units, including The Meadows, The Springs and The Emirates Hills, in 2006 (Hutton, 2019). Dubai

Marina had started to sell 654 apartment housing units from five new projects in 2004, 319 apartment housing units in 2004, 3,555 apartment housing units in 2006, 2,153 apartment housing units in 2007. It had become the catalyst for the housing market in Dubai. After 15 years, Dubai Marina is almost completed in 2019 and became an entire community (Gillett, 2019). Suburban type community, Arabian Ranches project, had ended and sold 829 housing units in 2005 and 1,393 more housing units in 2007. Jumeirah Lake Tower had introduced 2,665 new apartment units in 2007 and 6,250 new apartment units in 2009 in Jumeirah Lake Towers.

Between 2008 and 2009, 2,400 housing units were provided in Palm Jumeirah, 1,425 housing units in Silicon Oasis and 25,400 housing units in Discovery Gardens. A total number of 52,300 housing units were delivered in Dubai between 2008 and 2009 (Adams, 2019). During 2007, the highest point of Dubai's real estate boom. The Real Estate Regulatory Authority (R.E.R.A.) was established to set up the regulation regarding real estate transactions and registration of ownership of land and properties in Dubai (Peacock, 2019).

Based on the economy and population growth, Dubai needs 15,000–20,000 housing units per year. Still, the oversupply of housing has been dropping the housing values by 25% since 2014 (Murphy, 2019). Even though Dubai is one of the most stable and robust economies in the Middle East and North Africa (M.E.N.A.), there is one housing category problem. The deficiency of affordable housing will be the barrier to Dubai's sustainable development (Plumb, 2018). Dubai leader, H.H. Sheikh Mohammed Bin Rashid Al' 'Maktoum's diverse strategies had made the city's economy independent from crude oil and gross domestic product (G.D.P.) from USD 11bn in 1995 to USD 405.7bn in 2019. Dubai's population was dramatically changed from 680,000 in 1995 to 2,800,000 in 2019, and 90.7% are expatriates. However, the need for more affordable housing units for the growing middle class is also increasing (Al Mehairi, 2018).

The major problem of Dubai's housing market is that it was driven not by the homeowners' real needs but by the speculators. From 2003 to 2015, the price of villa went up five times, and the cost of an apartment went up three times. The fact that made the actual owners and tenants in significant difficulties, without any affordable choices, to spend more than 40% of their income on their housings (Issa, 2019). Assumed from the Gallup survey on the housing satisfaction rate in Dubai in 2015, only 49% was satisfied, and 58% of the expatriates were paying unaffordable rent in Dubai. This is why Dubai has only 30% homeownership because only 20% of the housing market is affordable while the needs for affordability are over 40% (Burke, 2019). This social phenomenon made low salary expatriates commute to the cheaper Emirates like Sharjah and Ajman to create additional infrastructure and environmental problems (Ramahi, 2018). Singapore had faced similar issues, but the government changed its long-term masterplan to create more affordable housing with priority to affordable housing in land use plan, giving inclusionary zoning, tax incentives and land subsidies (Majendie, 2020). Dubai's top-down development model should be adjusted because private-sector developers do not have any tools or interests for affordable housing units but only developing high-end luxury housing units. It is against the supply–demand approach and only attracts international speculators to drive the Dubai housing market in an undesirable direction (Kumar, 2008). With a profit-driven land management policy, the Dubai Government sells lands at a high price to small developers. It leaves them no choice but to develop luxury housing units to recover their high cost. Instead of this chain reaction, the Dubai government should implement inclusionary zoning with an extra Gross Floor Area (G.F.A.) ratio. In this condition, investigators compensate their land cost and give more incentive to build affordable housing units (Alawadi and Khanal, 2018). The Dubai Government announced an innovative technology plan to build an affordable

housing unit with 3D printing by reducing 30% of construction cost, and 25% of total construction will be built by 3D printing by 2025 (Malone, 2019). Furthermore, the Dubai government takes 29.8% of a single household into serious consideration when they develop an affordable housing unit.

The other problem in Dubai housing is that housing units are getting old and need to be renovated to keep up with the market values (Joslin, 2019). Thus, this paper aims to analyze the indoor environment of one of The Emirates Living projects, The Springs, which is 16 years old. The resident's perspectives and the expert's points of view are the main stakeholders whom their involvements contribute to the achievement and credibility of the data to reach (Qtaishat, 2020). The real estate agent's perspective, The Springs in Emirates Living, needs appropriate renovation. The cost of the villa of Arab Emirates Dirhams (A.E.D.) 1.2m two-bedroom villa can be sold up to A.E.D. 1.45m. And A.E.D. 1.8m three-bedroom villa in The Springs could be sold up to A.E.D. 2.2m with the adequate renovation (Locke, 2015). Especially Dubai's early projects, like the Emirates Living, require renovation. Our interview with the interior design company specialized in refurbishment in The Springs area states that their clients do not hesitate to renovate their older villas in The Springs. They had witnessed a dramatic increase in interest for home renovation in the Emirates Living area because clients know they will take advantage of the convenient location of the Spring when selling their properties, so they want to increase the values with optimal investment for maximum returns (Allsopp, 2019).

2.1 The Springs, Dubai

The resident survey was conducted during July–August and November–December 2019 among those who live in three bedrooms units of the Springs in Dubai. As Dubai has hot desert weather, summer is sweltering, humid and windy, with an average of 40 degrees. In the hottest month, August, the temperature can go up to 48.8 degrees. Winter is heavenly mild with 24 degrees and can go down to 14 degrees at night. The P.O.E. survey was conducted during pick summer and winter. Emaar Properties, a leading developer in Dubai, built The Springs and other high-profile projects. The Springs is part of the Emirates Living project with The Meadows, The Lakes and the Emirates Hills. The family-oriented project with a serene lifestyle and gated community attracts many Dubai residents (Lucas, 2008). The Springs consists of 4,856 townhouses and villas between two and five bedrooms and has a wealth of landscaped common areas such as 24 pocket parks, 15 swimming pools, 19 outdoor children's play areas, 14 basketball courts, 34 barbecue areas and 28 lakes (Figure 1).

Moreover, the Springs ranks fifth as the most popular area to rent and full ownership, from the expatriates, in Dubai due to the family and friendly local atmosphere (Blanchard, 2019) (Table 1). Figure 1 shows the plan view of The Springs' three-bedroom villa for the research's weight calculation.

The first floor has a living room, kitchen, guest bathroom, study room and backyard. The second floor has a master bedroom, two children's bedrooms and bathrooms. The flooring is tile and has a central air conditioner that the occupants can control. To increase the study's reliability and facilitate the comparative analysis, the P.O.E. survey was limited to residents living in the same plan layout of the 254 m^2 (2,734 ft^2) three-bedroom unit.

The total number of samples of survey participants is four hundred, the winter (November–December 2019) survey sample number was two hundred and the summer (July–August 2019) survey sample number was two hundred.

3. Methodology

P.O.E. survey was conducted on The Spring residents of Dubai to obtain primary data for calculating the weight of indoor environmental factors for the integrated evaluation of the

Source: Authors

Figure 1.
Streets of The Springs community and The Springs three-bed plans

indoor environment in July–August and November–December 2019. As it is essential to investigate the priorities and perceptions of the importance of the residents' indoor environmental factors for weight calculation, a questionnaire was created using the Paired Comparison Method (P.C.M.), was used (D' Orazio and Maracchini, 2019). P.C.M. refers to a method of investigating a pair to be compared and inferring using the difference within each pair (Brown and Peterson, 2012). The P.C.M. targets to increase the effectiveness of comparing indoor environmental factors. A pair of indoor environmental factors were made and compared in a homogeneous experimental unit. Six equivalent combinations between the four indoor environmental factors are possible (De Korte *et al.*, 2015). The first pair is between the thermal environment and the indoor air environment. The second pair is among the indoor air environment and the light environment. The third pair is amongst the light environment and the acoustic environment. The fourth pair is among the acoustic environment and the thermal environment. The fifth pair is between the thermal environment and the light environment. While the sixth pair is amongst the indoor air environment and the acoustic environment. Each combination resulting in the relative importance and the priority of the indoor environmental factors can be extracted via a comparative questionnaire that

	3 bed villa		4 bed villa		5 bed villa	
Popular area	Annual rent	From 2018 (%)	Annual rent	From 2018 (%)	Annual rent	From 2018 (%)
Mirdif	105,000	−12.5	120,000	−8.4	130,000	−7.1
Jumeirah	155,000	−11.4	180,000	−10.0	220,000	−12.0
Al Barsha	155,000	−6.1	180,000	−10.0	210,000	−4.5
Arabian Ranches	140,000	−15.2	215,000	−2.3	240,000	−5.9
The Springs	*145,000*	*-3.3*	167,000	−4.6	215,000	−11.3
Umm Suqeim	160,000	−11.1	180,000	−10.0	230,000	−8.0
DAMAC Hills The Villa	110,000	−15.4	165,000	N/A	180,000	−14.3
The Villa	145,000	−9.4	170,000	−5.6	174,900	−7.9
JVC	115,000	−14.8	130,000	−10.3	140,000	−3.4.3
Reem	110,000	−16.7	125,500	−15.8	N/A	N/A

Source: Khan@Bayut.com (2019)

Table 1.
Top 10 areas for villa rent in Dubai 2019

displays the degree of importance of indoor environmental factors that residents consider more important.

3.1 Need of a weighted evaluation model for integrated evaluation

The importance of the indoor environment is getting increased for the well-being and healthy life of residents. Accordingly, the indoor environment's integrated evaluation must have a more efficient evaluation of their residential space from the residents' perspectives (Bluyssen, 2013). A pleasant indoor environment results from the individual relationships between residents and their thermal, light, acoustic and indoor air environments factors (Kong *et al.*, 2018). This enjoyment can be achieved via providing a balanced level of indoor environmental factors that can be optimized for the indoor activities and a complex interaction process with the residents (Sternberg, 2010). Moreover, indoor environment evaluation factors differ from the consider ranking of the integrated evaluation according to the age, gender, within each residential space in the building (Choi and Lee, 2018). Therefore, an evaluation model that does not consider the application of weights is bound to show limitations in terms of efficiency and reliability of integrated indoor environmental evaluation (Bluyssen, 2019).

3.2 Importance among indoor environmental factors

To calculate the weight, it is essential to define the importance and evaluation priority of the indoor environmental factors according to gender, age and residential space. The researchers examined not only the relative importance of indoor environmental factors and the priorities of indoor environmental factors in the entire residential building, but also the individual indoor spaces such as the living room, kitchen, master bedroom, small bedrooms and toilets of the three-bedroom units.

With P.C.M. (using pairs of six combinations of indoor environmental factors, the research investigated the degree of comparable importance to be perceived by residents. The questionnaire used the P.O.E. as shown in Table 2.

As in the example of the questionnaire shown in Table 2; the first question comparing the relative importance between the thermal environment and the indoor air environment. If surveyor thinks it is equally important, he/she marks under Neutral "0." On the other hand, if he/she considers the thermal environment more critical, depending on the degree of importance to be considered, he/she can mark from "3: Very Important" to "1: Slightly Important."

3.3 Weight calculation process

The process of calculating the weight of indoor environmental factors for integrated indoor environmental evaluation from the data identified through the P.O.E. survey is shown in Table 3.

Table 2.
Example of the POE survey for the relative importance of indoor environmental factors

Question: Which indoor environmental factors should be considered more critical for the living room?

		Important <<<<			Neutral	>>>> Important			
		3	2	1	0	1	2	3	
1	Thermal environment	()	()	()	(○)	()	()	()	Indoor air environment
2	Indoor air environment	()	()	()	()	()	(○)	()	Light environment
3	Light environment	()	()	(○)	()	()	()	()	Acoustic environment
4	Acoustic environment	()	()	()	()	()	(○)	()	Thermal environment
5	Thermal environment	()	()	(○)	()	()	()	()	Light environment
6	Indoor air environment	()	(○)	()	()	()	()	()	Acoustic environment

4. Analysis

4.1 General characteristics of P.O.E. surveyors

The questionnaire's necessary information, such as gender, age and family composition, is shown in Table 4. The survey participants were 100 men and 100 women in the winter survey and 100 men and 100 women in the summer survey. The survey participants, who were between 30–39, were 143 in winter (71.5%) and 135 in summer (67.5%). In terms of marital status, 95.5% (191 people) in the winter survey and 94.5% (189 people) in the summer survey. Most of them are married and have children, such as 69% (138 people) of four-person family in the summer survey and 72.5% (145 people) in the winter survey.

4.2 Analysis of tde weight value

4.2.1 Weight of indoor environmental factors in summer. The weights for indoor environmental factors in summer were in the order of thermal environment (3.04), indoor air

#	Process	Description
1	Raw data	Survey data to evaluate the importance of indoor environment factors through P.C.M.
2	Assigned value	Applying assigned values according to the importance
3	Raw score	The sum of the values after the assigned values were applied for each factor
4	Assigned weight	Setting the highest value among the scores as 10 and convert the rest with the same ratio
5	Average of assigned weight	The average value of each calculated assigned weight value
6	Weight calculation	The weight formula of each indoor environment factor is as follows: the sum of the four indoor environment factors weights is 10 [(Average value of the assigned weight of each indoor environment factor/4 average value of the assigned weight of indoor environment factor) × 10]

Table 3. Weight calculation process for indoor environmental factors

Category	Summer 2019	Winter 2019
Gender		
Male	107 (53.5%)	95 (47.5%)
Female	93 (46.5%)	105 (52.5%)
Age group		
30–39	135 (67.5%)	143 (71.5%)
40–49	59 (29.5%)	48 (24.0%)
50–59	6 (3.0%)	9 (4.5%)
Marital status		
Married	189 (94.5%)	191 (95.5%)
Not married	11 (5.5%)	9 (4.5%)
Family type		
2 persons family	1 (0.5%)	1 (0.5%)
3 persons family	59 (29.5%)	51 (25.5%)
4 persons family	138 (69.0%)	145 (72.5%)
5 persons family	2 (1.0%)	3 (1.5%)

Table 4. General characteristics of POE surveyors

environment (2.87), light environment (2.48) and acoustic environment (2.30). Due to Dubai's sweltering and humid weather, the thermal environment shows a high weight. As indoor cooling generally depended on air conditioning in most residential buildings in summer, residents perceive the indoor air quality as very important (Table 5). Based on the age group analysis, the indoor air environment (3.12) was relatively higher in the 30 s compared to other age groups. The higher the age group is, the more sensitive were the interior and outdoor noises and the weight for the sound environment was (2.66) in the 50 s, which was higher than the weight for the acoustic environment in the 30 s (2.13). Considering the thermal environment importance, which decreases in summer while the age group increases. The weight of the 40 s (3.12) and the 50 s (2.83) increase comparing the weight of 30 s (3.26) (Table 5). Therefore, the thermal environment weight shows that the younger residents are more sensitive to temperature and humidity indoors and outdoors in summer. Compared to male residents (1.99), female residents (2.11) had higher weights for the acoustic environment. While if compared to male residents, the female residents have a relatively long average dwelling time in residential spaces, which reflects a more sensitive reaction to living noise from indoors and outdoors.

4.2.2 Weight of indoor environmental factors in winter. The weights for indoor environmental factors in winter were in the order of indoor air environment (2.86), light environment (2.59), acoustic environment (2.45) and thermal environment (2.39). In particular, due to the importance of ventilation in winter and the characteristics of the mild winter weather in Dubai, it shows the perception of the indoor environmental factors of residents who frequently open windows for ventilation and refrain from air conditioning as much as possible to realize a pleasant indoor environment. Examining the difference by gender, for males, the weights of indoor environmental factors were indoor air environment (2.85), light environment (2.54), thermal quality (2.36) and acoustic quality (2.35). For females, the order was indoor air environment (2.78), light environment (2.53), acoustic quality (2.51) and thermal quality (2.31) (Table 6). Due to the characteristics of the residential pattern of female residents who spend a relatively large amount of time at home, the acoustic environment weight for the indoor noise or outdoor noise was calculated relatively high. Notably, The Springs is a townhouse-type, the two-story flat slab concrete structure building reflects the characteristics of the acoustic environment of the residential building. If exposed to T.V., music, children's cries from neighbors and living noise caused by the use of air conditioning pipes or toilets, the acoustic augments. Based on examining the weight by the age group, the ranking of indoor environmental factors was different. In the case of 30 s, residents of 3–4 family members with 1 or 2 children show relatively high consideration and

Table 5. Weight for indoor environment evaluation for summer

Category	Thermal quality	Indoor air quality	Lighting quality	Acoustic quality
Average	3.04	2.87	2.48	2.30
Gender				
Male	3.13	2.88	2.11	1.99
Female	2.89	2.97	2.25	2.11
Age group				
30s	3.26	3.12	2.87	2.13
40s	3.12	2.85	2.05	2.63
50s	2.83	2.53	3.12	2.66

interest in the indoor air environment and light environment directly related to indoor health in winter.

4.2.3 Weight analysis of indoor environmental factors for residential spaces. The Springs' three-bedroom unit is 254 m^2 and has the preferable floor plan for the expatriate family in Dubai. As described earlier, The Springs is a two-story concrete townhouse with a living room and kitchen on the first floor where family members spend their time together and master bedroom, two small bedrooms and a toilet on the second floor. Based on the P.O. E. survey, Tables 7 and 8 show the weights of indoor environmental evaluation factors for each space according to the season.

4.2.3.1 Weight for indoor environment evaluation by residential space (summer). Table 7 shows the weight results of each space for the indoor environmental factors in summer. The weight values in each indoor area showed a similar weight pattern as the weight values of indoor environmental factors in winter. In the case of the living room, the weights for indoor environmental factors were in the order of Thermal Quality (3.06), Indoor Air Quality (2.67), Lighting Quality (2.65) and Acoustic Quality (1.67). In the 30 s, the indoor air environment (2.99) was higher than those of other age groups and the weights of the light environment and acoustic environment were higher in the 40 s and 50 s. The result suggests that younger residents in the living room prefer cool, bright and light spaces and that groups in their 40 s and 50 s consider indoor air environment elements more importantly in evaluation with high interest. In the case of the kitchen, the weights for indoor environmental factors in summer are in the order of thermal environment (3.73), indoor air environment (2.50), light environment (2.46) and acoustic environment (1.35). In the case of the master bedroom, the weights for indoor environmental factors are thermal environment (3.16), indoor air environment (2.83), acoustic environment (2.58) and light environment (1.48). The weights for the thermal environment and indoor air environment were high and the sound environment weight was also higher than that of other spaces (Figure 2).

4.2.3.2 Weight for indoor environment evaluation by residential space (winter). Based on the weights according to the residential space, as shown in Table 8, in the case of the living room located on the first floor of the building, the calculated weights for the indoor environmental factors are indoor air environment (2.95), light environment (2.67), acoustic environment (2.62) and thermal environment (1.80). If comparing spaces such as the kitchen and the bedroom, the living space weight, due to various activities of family members, was higher in the following order; indoor air environment, light environment and acoustic environment. While the weight for the thermal environment was relatively low due to the temperate weather condition of winter in Dubai. In the case of the kitchen, the weights for indoor environmental factors were indoor air environment (3.68), acoustic environment

Category	Indoor air quality	Lighting quality	Acoustic quality	Thermal quality
Average	2.86	2.59	2.45	2.39
Gender				
Male	2.85	2.54	2.35	2.36
Female	2.78	2.53	2.51	2.31
Age group				
30s	3.04	2.45	2.41	2.33
40s	2.95	2.56	2.39	2.41
50s	2.68	2.81	2.59	2.52

Table 6.
Weight for indoor environment evaluation for winter

Space	Category	Thermal quality	Indoor air quality	Lighting quality	Acoustic quality
Living room (GF)	Average	3.06	2.67	2.65	1.67
	Gender				
	Male	3.16	2.68	2.56	1.69
	Female	2.96	2.66	2.73	1.65
	Age group				
	30s	2.34	2.99	2.72	1.95
	40s	3.18	2.58	2.65	1.59
	50s	2.90	2.83	2.51	1.76
Kitchen (GF)	Average	3.73	2.50	2.46	1.35
	Gender				
	Male	3.79	2.45	2.54	1.30
	Female	3.67	2.55	2.39	1.39
	Age group				
	30s	3.26	2.92	2.15	1.67
	40s	3.83	2.39	2.51	1.28
	50s	3.50	2.37	2.82	1.31
Master bedroom (1F)	Average	3.16	2.83	1.48	2.58
	Gender				
	Male	3.31	2.84	1.38	2.55
	Female	3.02	2.82	1.57	2.60
	Age group				
	30s	2.78	2.49	1.71	3.03
	40s	3.25	2.87	1.39	2.49
	50s	2.79	2.92	1.72	2.58
Small bedrooms (1F)	Average	3.06	2.73	1.96	2.25
	Gender				
	Male	3.22	2.98	1.69	2.17
	Female	2.91	2.47	2.24	2.32
	Age group				
	30s	2.32	2.57	2.23	2.88
	40s	3.24	2.71	1.96	2.11
	50s	2.67	3.07	1.72	2.54
Bathroom (1F)	Average	3.22	2.83	2.10	1.86
	Gender				
	Male	3.23	2.84	1.98	1.98
	Female	3.21	2.82	2.15	1.76
	Age group				
	30s	2.96	3.37	2.06	1.61
	40s	3.19	2.74	2.13	1.94
	50s	3.63	2.82	1.94	1.61

Table 7.
Weight for indoor environment evaluation by residential space (summer)

(2.73), light environment (2.02) and thermal environment (1.61). The kitchen is a space that requires ventilation due to the food smell generated in the process of cooking food and the weight of the indoor air environment factor is relatively high compared to the weight of other indoor environmental factors. Compared with the living room and kitchen spaces on the first floor, the acoustic environment weight was relatively high in the master bedroom (2.85) and the small bedroom (2.81). The master bedroom and the small bedroom show higher consideration of the acoustic environment than other residential spaces. In winter, residents rarely operate air-conditioners, but due to the desert sand dust wind, there is a lack of natural ventilation. The interest in indoor air environment is getting higher in winter. The indoor air environment weight was also higher in the master bedroom (3.18) and the small

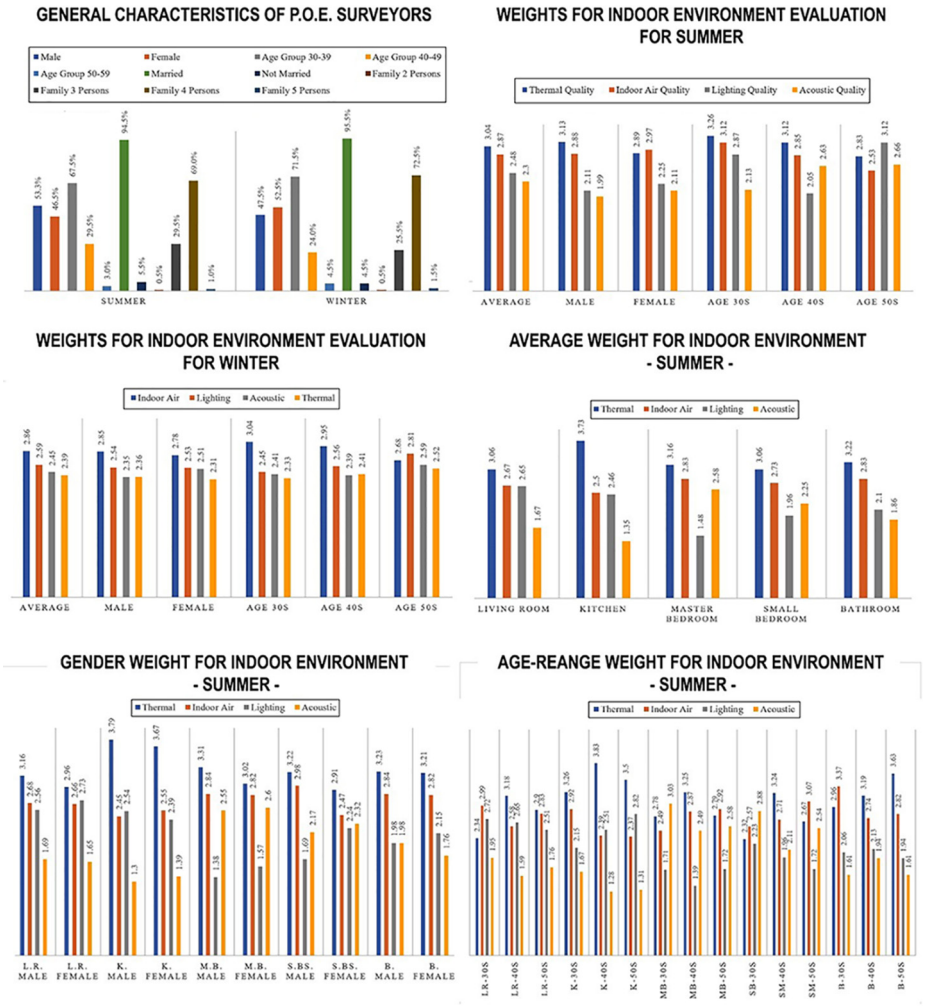

Figure 2.
Graph visualizations for Table 4 to Table 7

bedroom (3.07) than the weights of other indoor environmental factors. The weight of the light environment and small bedroom spaces was comparatively low.

5. Discussion

This study defines the weights for the integrated evaluation of the indoor environment, conducted for residents for a limited period at The Springs, one of Dubai's representative townhouse-type buildings. The results indicated that, based on the necessary information of the questionnaire, the concerned users should be men (summer – 53.5%) and women (winter – 52.5%), married in both conditions (summer 94.5% and winter 95.5%) at the age group (the 30 s) with results (summer – 67.5%) and (winter – 71.5%). Due to the active age, the interiors for the couples of 30 s, need special apprehensions. The increases in the urbanization and the technology developments concluded in an "indoor generation" (Kelly and Fussell, 2019)

Space	Category	Indoor air quality	Lighting quality	Acoustic quality	Thermal quality
Living room (GF)	Average	2.95	2.67	2.62	1.80
	Gender				
	Male	3.05	2.51	2.72	1.79
	Female	2.85	2.86	2.52	1.81
	Age group				
	30s	2.50	2.57	3.24	1.70
	40s	3.21	2.66	2.39	1.74
	50s	2.19	2.80	2.72	2.29
Kitchen (GF)	Average	3.68	2.02	2.73	1.61
	Gender				
	Male	3.66	2.09	2.72	1.57
	Female	3.69	1.94	2.75	1.67
	Age group				
	30s	3.35	1.91	3.25	1.49
	40s	3.77	2.07	2.47	1.68
	50s	3.59	1.73	3.41	1.26
Master bedroom (1F)	Average	3.18	2.46	2.85	2.96
	Gender				
	Male	3.16	2.63	2.95	2.78
	Female	3.20	2.27	2.75	3.15
	Age group				
	30s	2.43	2.07	2.80	3.00
	40s	3.25	2.56	2.56	2.93
	50s	3.19	2.67	3.19	3.05
Small bedrooms (1F)	Average	3.07	2.38	2.81	2.55
	Gender				
	Male	3.05	2.50	2.71	2.46
	Female	3.09	2.24	2.91	2.66
	Age group				
	30s	2.10	2.34	3.01	2.54
	40s	3.07	2.42	2.81	2.50
	50s	3.51	2.12	2.71	3.03
Bathroom (1F)	Average	2.90	2.87	1.95	2.01
	Gender				
	Male	3.01	2.91	2.03	1.95
	Female	2.78	2.82	1.86	2.05
	Age group				
	30s	2.65	3.08	2.40	1.87
	40s	3.39	2.83	1.75	2.03
	50s	2.98	2.68	2.31	2.02

Table 8.
Weight for indoor environment evaluation by residential space (winter)

The indoor environmental factors within the residential satisfaction were positively associated, in correspondence with the related literature (Franco *et al.*, 2019), showing high responsivity in summer (thermal quality – 3.26) although in winter (indoor air quality – 3.04). The thermal quality in summer is high as the heat transmission distresses on residents. While the indoor air quality in winter is a main concern due to the lack of ventilation because the air-conditioners are switched off. The interior materials and their colors play role in such results (Zhang *et al.*, 2019).

In terms of interior spaces, the indoor environmental factors, which need focus based on the survey, are as follows; in summer, (living room – indoor air quality/2.99), (kitchen – thermal

quality/3.26), (master bedroom – acoustic quality/3.03), (small bedrooms – acoustic quality/2.88) and (bathroom – indoor air quality/3.37). These results follow the functions and their specific needs. The living rooms require clear indoor air as it is the place for socialization (Almusaed *et al.*, 2019). Whereas the kitchen is a place of cooking and heat production, the thermal condition is then the main concern. The bathroom needs high ventilation systems and the bedrooms require the noise less surrounds (Garland *et al.*, 2018).

In winter, the results show (living room – acoustic quality/3.24), (kitchen – acoustic quality/3.25), (master bedroom – thermal quality/3.00), (small bedrooms – acoustic quality/3.01) and (bathroom – indoor lighting quality/3.08). The acoustic quality is on the top of the factors, followed by the indoor air quality and the thermal quality, while the lighting quality is the least mentioned. The results of the winter differ due to the type of interior functions and, therefore, special focuses need to highlight (Soflaei *et al.*, 2020). The acoustic quality raises as more interior functions ensue while the windows are open to get benefits from the reasonable weather (Xue *et al.*, 2019).

The research in the next stage will be expanded to various types of residential building projects in Dubai, and this research data can be used as the fundamental data to increase not only the design quality and marketability but also the condition of residents' health (Sarkar and Bardhan, 2020). To increase the reliability of the weights calculated through this study and the applicability of the integrated indoor environmental evaluation in other residential buildings in Dubai, more in-depth P.O.E. survey is needed with wide range of survey participants.

6. Conclusion

Most of Dubai's early housing projects, such as The Meadows, The Springs and The Emirates Hills, were built in 2003. The projects' landscape had become perfect, but the housing unit itself became 18 years old, and the need for renovation is increasing dramatically. This paper aims to set up the guideline for this kind of renovation needs in Dubai, known as fast consuming city, based on the comparative analysis among thermal comfort, acoustic comfort, lighting comfort and indoor air comfort (Xikai *et al.*, 2019). Renovation is not only about raising the value of the property but also about maintaining the healthy condition of residents. Without this kind of guideline, the deteriorated building could cause sick building syndrome, which can cause various health risks such as headache, migraine headache, fatigue, continuous sneezes and sleeping disorder.

The purpose of this study is to evaluate the indoor environment more efficiently for the integrated evaluation of the indoor environment based on the weights of each of the derived indoor environmental factors. The weights of the indoor environment factors were derived for the integrated evaluation of the indoor environment, reflecting the preferences from the residents' perspectives. Based on the P.O.E. survey, the weights according to gender, age group and indoor were compared and analyzed using the weight calculation process. As residents' interest and demand to pursue a healthy life in a pleasant indoor environment increase, the importance of sustainable planning elements in residential buildings is also increasing. It is expected that it will be able to play a role as research data to develop integrated evaluation indicators of the indoor environment to plan and evaluate the residential building via the values of weights according to gender, age group and types of space. It will also be available as data for design to create an indoor environment for a more comfortable and healthy life for residents.

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