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OCCUPANT SATISFACTION OF INDOOR ENVIRONMENT IN LIGHT OF INTEGRATED GREEN & WELL REQUIREMENTS

Wael Kamel Professor, Department of Construction and Building Engineering,
Arab Academy for Science, Technology & Maritime Transport, Egypt, wael_kamel@yahoo.com

Sherine Shafik Professor, Department of Architecture – Engineering & Environmental Design
Arab Academy for Science, Technology & Maritime Transport, Egypt, sherry_aly@yahoo.com

Esraa Elgezery M.Sc. Researcher, Department of Architecture – Engineering & Environmental Design
Arab Academy for Science, Technology & Maritime Transport, Egypt, esraa.elgezery@hotmail.com

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Abstract

Buildings are the foundations of modern cities urban planning. People spend about 80-90% of their life in buildings "indoor environment / closed places". Most successful models in developing countries set the people's health and wellbeing in the center of focus of their Sustainable Development Planning Process (SDPP). Building architecture and design techniques developed across the time reached to the GREEN and WELL Buildings Architecture to be the cornerstone and key element of human health, accommodating and ensuring a high quality of life and wellbeing for all people at all ages. A thorough Literature review showed a gap between the Rated (LEED Certified) buildings and the occupants' satisfaction. The research aims to address a proposal for a potential improvement of occupant health and wellbeing when simultaneously implementing the indoor performance requirements "rating systems" of the Leadership in Energy and Environmental Design (LEED) and the (WELL) Building Standard. The research proposal is based on the inferential analysis of the database survey of the Center of Built Environment (CBE) reflecting the individual occupant responses and the rating systems of the LEED and WELL standards. The research concludes that integrating the features of both systems significantly helps to improve the Indoor Environmental Quality (IEQ); leading to a better occupants' health, wellbeing, and productivity.

Keywords

Occupant, indoor, environment, GREEN, WELL

OCCUPANT SATISFACTION OF INDOOR ENVIRONMENT IN LIGHT OF INTEGRATED GREEN & WELL REQUIREMENTS

Wael KAMEL¹, Sherine SHAFIK², and Esraa ELGEZERY³

¹ Professor, Department of Construction and Building Engineering, Arab Academy for Science, Technology & Maritime Transport, Egypt

² Professor, Department of Architecture – Engineering & Environmental Design, Arab Academy for Science, Technology & Maritime Transport, Egypt

³ M.Sc. Researcher, Department of Architecture – Engineering & Environmental Design, Arab Academy for Science, Technology & Maritime Transport, Egypt

ABSTRACT: *Buildings are the foundations of modern cities urban planning. People spend about 80-90% of their life in buildings “indoor environment / closed places”. Most successful models in developing countries set the people’s health and wellbeing in the center of focus of their Sustainable Development Planning Process (SDPP). Building architecture and design techniques developed across the time reached to the GREEN and WELL Buildings Architecture to be the cornerstone and key element of human health, accommodating and ensuring a high quality of life and wellbeing for all people at all ages. A thorough Literature review showed a gap between the Rated (LEED Certified) buildings and the occupants’ satisfaction. The research aims to address a proposal for a potential improvement of occupant health and wellbeing when simultaneously implementing the indoor performance requirements “rating systems” of the Leadership in Energy and Environmental Design (LEED) and the (WELL) Building Standard. The research proposal is based on the inferential analysis of the database survey of the Center of Built Environment (CBE) reflecting the individual occupant responses and the rating systems of the LEED and WELL standards. The research concludes that integrating the features of both systems significantly helps to improve the Indoor Environmental Quality (IEQ); leading to a better occupants’ health, wellbeing, and productivity.*

KEYWORDS: *Occupant, indoor, environment, GREEN, WELL*

1. INTRODUCTION

Buildings are the foundations of modern cities, People spend about 80-90% of their life in buildings “indoor environment / closed places” (Kolozali, 2016). Most successful models in developing countries set the people’s health and wellbeing in the center of focus of their Sustainable Development Planning Process (SDPP).

Many factors combine together to affect the health of individuals and communities. Whether people are healthy or not, is determined by their circumstances and environment. To a large extent, factors such as where we live, the state of our environment, genetics, our income and education level, and our relationships with friends and family all have considerable impacts on health, whereas the more commonly considered factors such as access and use of health care services often have less of an impact. The World Health Organization (WHO) defined health with a phrase, "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.". Health and wellbeing are determined by a range of factors, many of them linked to the quality, accessibility and sustainability of our built environment (World Health Organization, 2018).

The wellbeing triple bottom line are “health, comfort and happiness”, they are linked to the triple bottom line of the sustainable development “physical, economic and social”. Health; is referred to absence of disease

with terms of symptoms such as body temperature or blood chemistry. Comfort; is widely understood to be a “condition of mind which expresses satisfaction” with the environment, whether thermal, visual, acoustic, etc. and thus incorporates both qualitative psychological considerations (e.g. expectation, control) and quantitative physical parameters (e.g. temperature, air movement). Happiness; colloquially refers to emotions experienced, potentially ranging from contentment to joy, therefore it is primarily a subjective and qualitative consideration (International VELUX Award, 2018).

Buildings have extensive direct and indirect impacts on the environment. During their construction, occupancy, renovation, repurposing, and demolition, buildings use energy, water, and raw materials, generate waste, and emit potentially harmful atmospheric emissions. These facts have prompted the creation of green building standards, certifications, and rating systems aimed at mitigating the impact of buildings on the natural environment through sustainable design. The continuous improvement of green building standards and rating systems are the key elements of human health to ensure a high quality of life and wellbeing for all people at all ages (WBDG, 2018).

There is now a proliferation of standards, rating, and certification programs in the marketplace to help guide, demonstrate, and document efforts to deliver sustainable, high-performance buildings. It is estimated that there are nearly 600 green product certifications in the world with nearly 100 in use in the U.S., and the numbers continue to grow. The most commonly used and respected green building international programs in the marketplace are: “U.S. Green Building Council-The Leadership in Energy and Environmental Design (LEED)”, “International WELL Building Institute™ (IWBI)-WELL Building Standard (WELL)”, “BCA Green Mark Scheme (Singapore)-Building and Construction Authority (BCA)”, “Beam (Hong Kong)-Business Environment Council”, “BREEAM (UK, EU, EFTA member states, EU candidates, as well as the Persian Gulf)-BRE Global”, “CASBEE (Japan)-JSBC (Japan Sustainable Building Consortium) and its affiliated sub-committees”, “EDGE-International Finance Corporation (IFC), a member of the World Bank Group”, “Green Star SA (South Africa)-Green Building Council of South Africa administers program independent assessors to assess and score projects”, “Pearl Rating System for Estidama (UAE)-Abu Dhabi Urban Planning Council” (WBDG, 2018).

In this research the most updated versions of LEED and WELL will be considered: LEED v4 for Building Design and Construction (April 6, 2018), LEED v4 for Interior Design and Construction (April 6, 2018), LEED v4 for Building Operations and Maintenance (January 5, 2018), LEED v4 for Neighborhood Development (January 5, 2018), LEED v4 for Homes Design and Construction (January 5, 2013), and The WELL Community Standard™ v1 with Q1 2018 addenda.

The LEED v4 (2018) consists of credits which earn points in eight categories: “Location and Transportation, Sustainable Cities, Water Efficiency, Energy and Atmosphere, Material and Resources, Indoor Environmental Quality, Innovation, and Regional Priority”. One hundred points are available across these categories with mandatory prerequisites such as minimum energy and water-use reduction, recycling collection, and tobacco smoke control. Within each category are credits that pertain to specific strategies for sustainability, such as the use of low-emitting products, reduced water consumption, energy efficiency, access to public transportation, recycled content, renewable energy, and daylighting. Since its inception, LEED standards have become more stringent as the market has changed and expanded to include distinct rating systems that address different building types: New Construction, Existing Buildings, Commercial Interiors, Core & Shell, Schools, Retail, Healthcare, Homes, and Neighborhood Development (LEED v4, 2018).

The WELL Community Standard™ v1 (2018) is a performance-based system for measuring, certifying, and monitoring features of the built environment that impact human health and well-being by looking at credits which earn points in eleven factors, or concepts: “Air, Water, Nourishment, Light, Fitness, Temperature, Sound, Material, Mind, Community, and Innovation” (WELL v1, 2018).

2. OCCUPANT SATISFACTION OF INDOOR ENVIRONMENT

2.1 CBE's Questionnaires-Features Measuring The Occupants' Satisfaction

The Center for the Built Environment (CBE) was founded in 1997 under the National Science Foundation (NSF) Industry/University Cooperative Research Center (IUCRC) program. The center aims to improve the environmental quality and energy efficiency of buildings by providing timely, unbiased information on building technologies and design and operation techniques through an extensive occupant-survey program to “take the pulse” of buildings in operation: measuring the occupants’ responses to their indoor environments, and linking them to improved physical measurements of indoor environmental

quality. This feedback is directed variously at those who manage, operate, and design buildings (CBE, 2018).

CBE has developed methods to measure the performance of occupied buildings in terms of occupant comfort and productivity, energy efficiency, and operations. For example, CBE's Web-based Occupant IEQ Survey quantifies how a building is performing from the perspective of its occupants. This provides immediate feedback for building owners and operators, and assists architects, engineers, and builders in the development of future buildings (CBE, 2018).

The CBE projects related to IEQ in buildings included surveys features of occupants' satisfaction, for instant Goins (2011) applied the (office layout, office furnishings, thermal comfort, air quality, lighting, acoustic quality, cleanliness, energy, potable water quantity, biodiversity, life-cycle costs, and operations costs) as survey features.

Kamaruzzaman (2017) classified the survey features to 1. Visual Comfort; including the amount of light (daylight/artificial light), electric light (artificial light), sight, view, glare illumination level, the uniformity of light, the rendering quality of light, colors effect, attractiveness, and outward appearance. 2. Thermal Comfort; including temperature (mean radiant temperature), indoor temperature, control environment performance, relative humidity, Air movement (air velocity/air exchange), ventilation systems, ventilation rate, air permeability. 3. Acoustic Comfort; including noise level, sound privacy, outdoor noise (road traffic, aircraft, railway, construction work, commercial, above apartment, within apartment), housing crowding sound, pressure level, sense of crowding, indoor noise, and outdoor noise. 4. Indoor Air Quality; including particulate matters: (PM_{2.5} and PM₁₀) nitrogen dioxide (NO₂), Carbon dioxide (CO₂), carbon monoxide (CO), sulfur dioxide (SO₂), total volatile organic compound (TVOCs), formaldehyde (HCHO), benzene and other aromatic hydrocarbons (building materials, furniture, paints, consumer products, tobacco smoke), ventilation air exchange, cleanliness, smell/odorant, dust or dirtiness, cleanliness of the building, indoor sources of pollutants (gas cookers, stoves, fireplaces, building and furnishing materials), indoor combustion, relative humidity (RH), molds, bacteria, allergens, particles, VOCs, formaldehyde, chlordane, naphthalene, polycyclic aromatic hydrocarbons. 5. Building Characteristics and Design; including design or technical flaw in the building system, building envelope, space of the housing, housing size (room per person), housing condition (age of house), basic amenities (shower), room interior, control over the environment, acoustics materials properties, sound insulation and absorption, types of building (a single housing, multiple housing), location of the building, orientation and direction of the building. 6. Occupants' Features; including activities human thermoregulation, behavior / lifestyle, selection of garment, job typology, gender occupant factors (lifestyle, economic status, adaptive behavior), the thermal resistance of clothing, partial water vapors pressure, heat production of the human body and human thermos-regulation, age, country origin, and behavior.

2.2 Occupants Responses Vs LEED

Carbonnier et al. (2017) through a previous study by Schiavon and Altomonte (2014), analyzed the occupant satisfaction in LEED and non-LEED certified buildings on a subset of the Center for the Built Environment survey database featuring 21,477 responses from 144 buildings (65 LEED-rated). The data suggested that, when evaluated comprehensively, there is not a practically significant influence of LEED certification on occupant satisfaction. Also investigated the impact on users' satisfaction in LEED and non-LEED certified buildings of factors unrelated to environmental quality, including consideration of office type, spatial layout, distance from window, building size, gender, age, type of work, time at workspace, and weekly working hours. The results showed that LEED-rated buildings may be more effective in providing higher satisfaction in open spaces rather than in enclosed offices, in small rather than in large buildings, and to occupants having spent less than one year at their workspace rather than to users that have occupied their workplace for longer. The findings suggest that the positive value of LEED certification from the point of view of occupant satisfaction may tend to decrease with time.

Bauman et al. (2017) showed that commercialization might be accelerated for HVAC control based on occupant requests by advancing building labeling credit of LEED for occupant control and/or monitoring in a way that takes advantages of adding the comfort feathers to the energy efficiency.

Talami et al. (2017) showed that the seven performance categories "Place, Water, Energy, Health & Happiness, Materials, Equity and Beauty" of the international sustainable building certification of the

International Living Future Institute are more developed than the LEED and BREAM, especially for the features “Health & Happiness, Equity and Beauty”.

Altomonte and Schiavon (2013) studied if LEED certified buildings lead to a higher, equal or lower satisfaction with indoor environmental quality than non-LEED rated buildings. Occupant satisfaction has been evaluated on a subset of the Center for the Built Environment Occupant Indoor Environmental Quality Survey database featuring 144 buildings (65 LEED certified) and 21,477 individual occupant responses (10,129 in LEED buildings). The results showed that there is not a significant influence of LEED certification on occupant satisfaction with indoor environmental quality, although the analysis of mean votes of satisfaction reveals that occupants of LEED buildings tend to be slightly more satisfied with air quality, and slightly more dissatisfied with amount of light.

Brager and Baker (2008) showed that there was not necessarily a correlation between buildings with a large number of LEED IEQ points, and the IEQ performance from the occupants’ perspective. And it was found that satisfaction with both thermal comfort and air quality increases significantly in buildings that provide people with some means of personal control over their environment, such as thermostats or operable windows.

Abbaszadeh and Zagreus et al. (2006) summarized the results of a large indoor environmental quality survey in office buildings, comparing green with non-green buildings. On average, occupants in green buildings were more satisfied with thermal comfort and air quality in their workspace. However, the average satisfaction scores in green buildings for lighting and acoustic quality were comparable to the non-green average. Comparing complaint profiles of those dissatisfied with lighting and acoustic quality, a higher percentage of occupants were dissatisfied with light levels and sound privacy in green buildings. The results suggested a need for improvements in controllability of lighting, and innovative strategies to accommodate sound privacy needs in open plan or cubicle office layouts in both comparison groups.

3. THEORETICAL ANALYSIS

3.1 Gap Analysis

The Gap Analysis involved the comparison of the actual building performance reflecting the occupants needs (assessment done by responses of the CBE Occupant Satisfaction Surveys) with the potential or desired building performance (assessment done by the credits / features of the rating systems of LEED and WELL). The Gap Analysis identified the gaps between the features requested by the occupants represented their needs for better “health, wellbeing and satisfaction” and the credits / features included in the rating systems of LEED and WELL. This may reveal areas that can be improved and challenging improved the potential occupant satisfaction of visual comfort to want to go in the future. The Gap Analysis Results tabulated in 12 Tables, Tables (1 - 6) under the title “occupants satisfaction surveys features Vs features of LEED and WELL”, showed the expectation of performance of the LEED and WELL rating systems related to occupants satisfaction, and Tables (7 - 12) under the title “suggested integrated features for occupants satisfaction of indoor environment”, collected and integrated all the features of “CBE, LEED, WELL, to minimize this gap when all features simultaneously implemented for better occupants health, wellbeing and satisfaction.

3.2 Occupants Satisfaction Surveys Features Vs Features of LEED / WELL

The 6 categories (visual comfort, thermal comfort, acoustic comfort, indoor air quality, building characteristics, and occupants’ features) of the CBE’s occupants’ satisfaction surveys were presented in the Tables (1 - 6), their features included in these 6 Tables represented the basis (100% occupants’ satisfaction) for the gap analysis Vs the features of LEED and WELL.

In Table 1, the LEED’s features covered 3 features of the 10 visual comfort features (30% visual comfort), the WELL’s features covered 4 features of the 10 visual comfort features (40% visual comfort), and the WELL covered the feature “amount of light” by 2 WELL’s features.

In Table 2, the LEED’s features covered 3 features of the 9 thermal comfort features (33.3% thermal comfort), and the WELL’s features covered 1 features of the 9 thermal comfort features (11% thermal comfort).

In Table 3, the LEED's features didn't cover any of the 7 acoustic comfort features (0% acoustic comfort), the WELL's features covered 4 features of the 7 acoustic comfort (57% acoustic comfort), and the feature "noise level" covered by 4 WELL's features.

Table 1: Visual Comfort - Occupants satisfaction surveys features Vs features of LEED / WELL
Reference: The author

Occupants Satisfaction Surveys Features	LEED / WELL		
	Categories / Concepts	Credits / Features	References
amount of light	Light	obtrusive light control / Mass Transit Lighting	WELL v1
daylight	Indoor Environmental Quality	daylight	LEED v4
artificial light	n/a	n/a	n/a
sight and view	Indoor Environmental Quality	quality views	LEED v4
glare illumination level	Light	obtrusive light control	WELL v1
uniformity of light	Light	right-of-way lighting	WELL v1
rendering quality of light	Indoor Environmental Quality	interior lighting	LEED v4
	Light	visibility facilitation	WELL v1
colors effect	n/a	n/a	n/a
attractiveness	n/a	n/a	n/a
outward appearance	n/a	n/a	n/a

Table 2: Thermal Comfort - Occupants satisfaction surveys features Vs features of LEED / WELL
Reference: The author

Occupants Satisfaction Surveys Features	LEED / WELL		
	Categories / Concepts	Credits / Features	References
mean radiant temperature	n/a	n/a	n/a
indoor temperature	Temperature	extreme weather warnings	WELL v1
control environment performance	Indoor Environmental Quality	balancing of heating and cooling distribution systems	LEED v4
relative humidity	n/a	n/a	n/a
air velocity	n/a	n/a	n/a
air exchange	n/a	n/a	n/a
ventilation systems	Indoor Environmental Quality	enhanced ventilation	LEED v4
ventilation rate	Indoor Environmental Quality	ventilation	LEED v4
air permeability	n/a	n/a	n/a

Table 3: Acoustic Comfort - Occupants satisfaction surveys features Vs features of LEED / WELL
Reference: The author

Occupants Satisfaction Surveys Features	LEED / WELL		
	Categories / Concepts	Credits / Features	References
noise level	Sound	sound planning / community sound mapping / noise ordinance / hearing health education	WELL v1
sound privacy	n/a	n/a	n/a
outdoor noise	Sound	planning for acoustics	WELL v1
housing crowding sound	n/a	n/a	n/a
noise pressure level	n/a	n/a	n/a
sense of crowding	Sound	noise level limit	WELL v1
indoor noise	Sound	community sound mapping	WELL v1

In Table 4, the LEED's features covered 6 features of the 16 indoor air quality features (37.5% indoor air quality), the feature "particulate matters (PM2.5 and PM10)" covered by 4 LEED's features, the feature "carbon dioxide (CO2)" covered by 2 LEED's features, the feature "carbon monoxide (CO)" covered by 2 LEED's features, the WELL's features covered 1 features of the 16 indoor air quality features (6.3% indoor air quality), and the feature "indoor sources of pollutants" covered by both LEED and WELL rating systems, 4 LEED's features, and 3 WELL's features.

In Table 5, the LEED's features covered 5 features of the 11 building characteristics features (45.5% building characteristics), the feature "design" covered by 15 LEED's features, the feature "control over the environment" covered by 32 LEED's features, the feature "location of the building" covered by 38 LEED's features, and the WELL's features didn't cover any of the 11 building characteristics features (0% building characteristics).

In Table 6, both LEED and WELL rating systems didn't cover any of the 8 occupants' features (0% occupants' features).

Table 4: Indoor Air Quality - Occupants satisfaction surveys features Vs features of LEED / WELL
Reference: The author

Occupants Satisfaction Surveys Features	LEED / WELL		
	Categories / Concepts	Credits / Features	References
particulate matters (PM _{2.5} and PM ₁₀)	Indoor Environmental Quality	green cleaning policy / green cleaning-custodial effectiveness assessment / green cleaning-equipment / air filtering	LEED v4
nitrogen dioxide (NO ₂)	n/a	n/a	n/a
carbon dioxide (CO ₂)	Energy and Atmosphere	green power and carbon offsets / renewable energy and carbon offsets	LEED v4
carbon monoxide (CO)	Energy and Atmosphere	green power and carbon offsets / renewable energy and carbon offsets	LEED v4
sulfur dioxide (SO ₂)	n/a	n/a	n/a
total volatile organic compound (TVOCs)	n/a	n/a	n/a
formaldehyde (HCHO)	n/a	n/a	n/a
benzene and other aromatic hydrocarbons	n/a	n/a	n/a
ventilation air exchange	Indoor Environmental Quality	environmental tobacco smoke control	LEED v4
Cleanliness	n/a	n/a	n/a
smell/odorant	n/a	n/a	n/a
dust or dirtiness	n/a	n/a	n/a
indoor sources of pollutants	Indoor Environmental Quality	Garage Pollutant Protection / Compartmentalization / Enhanced Compartmentalization / Enhanced Garage Pollutant Protection	LEED v4
	Air	long-term air quality / short-term air quality / enhanced short-term air quality	WELL v1
indoor combustion	Indoor Environmental Quality	combustion venting / enhanced combustion venting	LEED v4
molds, bacteria, allergens	n/a	n/a	n/a
VOCs	n/a	n/a	n/a

Table 5: Building Characteristics - Occupants satisfaction surveys features Vs features of LEED / WELL
Reference: The author

Occupants Satisfaction Surveys Features	LEED / WELL		
	Categories / Concepts	Credits / Features	References
Design	Energy and Atmosphere / Green Infrastructure & Buildings / Innovation / Materials and Resources	06 features / 04 features / 03 features / 02 features	LEED v4
building envelope	n/a	n/a	n/a
space of the housing	n/a	n/a	n/a
housing size	Energy and Atmosphere	Home Size	LEED v4
housing condition	n/a	n/a	n/a
basic amenities	n/a	n/a	n/a
control over the environment	Visual Comfort / Thermal Comfort / Indoor Air Quality	09 features / 03 features / 20 features	Tables 1, 2, and 4
acoustics materials insulation and absorption	Indoor Environmental Quality	Acoustic Performance	LEED v4
types of building	n/a	n/a	n/a
location of the building	Location and Transportation / Sustainable Sites	20 features 18 features	LEED v4
orientation and direction	n/a	n/a	n/a

Table 6: Occupants' Features - Occupants satisfaction surveys features Vs features of LEED / WELL
Reference: The author

Occupants Satisfaction Surveys	LEED / WELL		
	Categories / Concepts	Credits / Features	References
activities human thermoregulation	The 8 features are n/a in LEED v4 or WELL v1		
behavior / lifestyle			
selection of garment			
job typology			
economic status			
thermal resistance of clothing			
human thermos-regulation			
age			

3.3 Suggested Integrated Features for Occupants Satisfaction of Indoor Environment

The Tables (7 - 12) included 6 groups of integrated assessment features, represented the upgraded basis for occupants satisfaction assessment (100% occupants' upgraded satisfaction), these integrated assessment features combined the features of the CBE, LEED, and WELL mentioned in the Tables (1 - 6), in addition to more features selected from the 5 standards of LEED v4 and the WELL v1 standard and added to Tables (7 - 12) to improve directly and indirectly the potential of the suggested integrated features to accomplish the occupant health, wellbeing and satisfaction.

Table 7 included 16 visual comfort integrated assessment features, the CBE's features covered 10 features representing (62.5%), the LEED's features covered 5 features representing (31.3%), and the WELL's features covered 8 features representing (50%).

Table 7: Visual Comfort - Integrated Assessment Features
Reference: The author

Integrated Assessment Features	CBE	LEED	WELL	References
amount of light	√	n/a	√	WELL v1
daylight	√	√	n/a	LEED v4
artificial light	√	n/a	n/a	CBE
sight and view	√	√	n/a	LEED v4
glare illumination level	√	n/a	√	WELL v1
uniformity of light	√	n/a	√	WELL v1
rendering quality of light	√	√	√	LEED v4/WELL v1
colors effect	√	n/a	n/a	CBE
attractiveness	√	n/a	n/a	CBE
outward appearance	√	n/a	n/a	CBE
lighting	n/a	√	n/a	LEED v4
light pollution reduction	n/a	√	n/a	LEED v4
light trespass mitigation for sleep	n/a	n/a	√	WELL v1
lighting master plan	n/a	n/a	√	WELL v1
lighting control schedule	n/a	n/a	√	WELL v1
community-wide emittance caps	n/a	n/a	√	WELL v1

Table 8 included 10 thermal comfort's integrated assessment features, CBE's features covered 9 features representing (90%), the LEED's features covered 4 features representing (40%), and the WELL's features covered 1 features representing (10%).

Table 9 included 7 acoustic comfort's integrated assessment features, CBE's features covered 7 features representing (100%), the LEED's features didn't covered any features representing 0%, and the WELL's features covered 4 features representing (57%).

Table 10 included 54 indoor environmental quality's integrated assessment features, CBE's features covered 16 features representing (29.6%), the LEED's features covered 32 features representing (59.3%), and the WELL's features covered 13 features representing (24%).

Table 8: Thermal Comfort - Integrated Assessment Features
Reference: The author

Integrated Assessment Features	CBE	LEED	WELL	References
mean radiant temperature	√	n/a	n/a	CBE
indoor temperature	√	n/a	√	WELL v1
control environment performance	√	√	n/a	LEED v4
relative humidity	√	n/a	n/a	CBE
air velocity	√	n/a	n/a	CBE
air exchange	√	n/a	n/a	CBE
ventilation systems	√	√	n/a	LEED v4
ventilation rate	√	√	n/a	LEED v4
air permeability	√	n/a	n/a	CBE
thermal comfort	n/a	√	n/a	LEED v4

Table 9: Acoustic Comfort - Integrated Assessment Features
Reference: The author

Integrated Assessment Features	CBE	LEED	WELL	References
noise level	√	n/a	√	WELL v1
sound privacy	√	n/a	n/a	CBE
outdoor noise	√	n/a	√	WELL v1
housing crowding sound	√	n/a	n/a	CBE
noise pressure level	√	n/a	n/a	CBE
sense of crowding	√	n/a	√	WELL v1
indoor noise	√	n/a	√	WELL v1

Table 10: Indoor Environmental Quality - Integrated Assessment Features
Reference: The author

Integrated Assessment Features	CBE	LEED	WELL	References
particulate matters (PM _{2.5} and PM ₁₀)	√	√	n/a	LEED v4
nitrogen dioxide (NO ₂)	√	n/a	n/a	CBE
carbon dioxide (CO ₂)	√	√	n/a	LEED v4
carbon monoxide (CO)	√	√	n/a	LEED v4
sulfur dioxide (SO ₂)	√	n/a	n/a	CBE
total volatile organic compound (TVOCs)	√	n/a	n/a	CBE
formaldehyde (HCHO)	√	n/a	n/a	CBE
benzene and other aromatic hydrocarbons	√	n/a	n/a	CBE
ventilation air exchange	√	√	n/a	LEED v4
cleanliness	√	n/a	n/a	CBE
smell/odorant	√	n/a	n/a	CBE
dust or dirtiness	√	n/a	n/a	CBE
indoor sources of pollutants	√	√	√	LEED v4/WELL v1
indoor combustion	√	√	n/a	LEED v4
molds, bacteria, allergens	√	n/a	n/a	CBE
VOCs	√	n/a	n/a	CBE
construction indoor air quality management plan	n/a	√	n/a	LEED v4
contaminant control	n/a	√	n/a	LEED v4
enhanced indoor air quality strategies	n/a	√	n/a	LEED v4
green cleaning-products and materials	n/a	√	n/a	LEED v4
indoor air quality assessment	n/a	√	n/a	LEED v4
indoor air quality management program	n/a	√	n/a	LEED v4
integrated pest management	n/a	√	n/a	LEED v4
low emitting products	n/a	√	n/a	LEED v4

low-emitting materials	n/a	√	n/a	LEED v4
minimum indoor air quality performance	n/a	√	n/a	LEED v4
occupant comfort survey	n/a	√	n/a	LEED v4
radon-resistant construction	n/a	√	n/a	LEED v4
active solar ready design	n/a	√	n/a	LEED v4
advanced energy metering	n/a	√	n/a	LEED v4
annual energy use	n/a	√	n/a	LEED v4
building orientation for passive solar	n/a	√	n/a	LEED v4
building-level energy metering	n/a	√	n/a	LEED v4
building-level water metering	n/a	√	n/a	LEED v4
efficient domestic hot water equipment	n/a	√	n/a	LEED v4
efficient hot water distribution system	n/a	√	n/a	LEED v4
high efficiency appliances	n/a	√	n/a	LEED v4
indoor water use reduction	n/a	√	n/a	LEED v4
minimum energy performance	n/a	√	n/a	LEED v4
space heating & cooling equipment	n/a	√	n/a	LEED v4
water metering	n/a	√	n/a	LEED v4
windows	n/a	√	n/a	LEED v4
fundamental air quality	n/a	n/a	√	WELL v1
smoking ban	n/a	n/a	√	WELL v1
enhanced long-term air quality	n/a	n/a	√	WELL v1
air quality education	n/a	n/a	√	WELL v1
drinking water quality	n/a	n/a	√	WELL v1
high quality drinking water	n/a	n/a	√	WELL v1
drinking water access	n/a	n/a	√	WELL v1
legionella control	n/a	n/a	√	WELL v1
hazardous waste management	n/a	n/a	√	WELL v1
site remediation and redevelopment	n/a	n/a	√	WELL v1
construction remediation	n/a	n/a	√	WELL v1
post-occupancy surveys	n/a	n/a	√	WELL v1

Table 11 included 22 building characteristics' integrated assessment features, CBE's features covered 11 features representing (50%), the LEED's features covered 16 features representing (72.7%), and the WELL's features didn't covered any features representing (0%).

Table 11: Building Characteristics - Integrated Assessment Features
Reference: The author

Integrated Assessment Features	CBE	LEED	WELL	References
design	√	√	n/a	LEED v4
building envelope	√	n/a	n/a	CBE
space of the housing	√	n/a	n/a	CBE
housing size	√	√	n/a	LEED v4
housing condition	√	n/a	n/a	CBE
basic amenities	√	n/a	n/a	CBE
control over the environment	√	√	n/a	Tables 1, 2, and 4
acoustics materials insulation and absorption	√	√	n/a	LEED v4
types of building	√	n/a	n/a	CBE
location of the building	√	√	n/a	LEED v4
orientation and direction	√	n/a	n/a	CBE
access to quality transit	n/a	√	n/a	LEED v4
high priority site	n/a	√	n/a	LEED v4
LEED for neighborhood development location	n/a	√	n/a	LEED v4
preferred locations	n/a	√	n/a	LEED v4
sensitive land protection	n/a	√	n/a	LEED v4
site improvement plan	n/a	√	n/a	LEED v4
site management	n/a	√	n/a	LEED v4
site management policy	n/a	√	n/a	LEED v4
site selection	n/a	√	n/a	LEED v4
smart location	n/a	√	n/a	LEED v4
surrounding density and diverse uses	n/a	√	n/a	LEED v4

Table 12 included 20 integrated assessment features of occupants' features, CBE's features covered 8 features representing (40%), the LEED's features didn't covered any features representing (0%), and the WELL's features covered 12 features representing (60%).

Table 12: Occupants' Features - Integrated Assessment Features
Reference: The author

Integrated Assessment Features	CBE	LEED	WELL	References
activities human thermoregulation	√	n/a	n/a	CBE
behavior / lifestyle	√	n/a	n/a	CBE
selection of garment	√	n/a	n/a	CBE
job typology	√	n/a	n/a	CBE
economic status	√	n/a	n/a	CBE
thermal resistance of clothing	√	n/a	n/a	CBE
human thermos-regulation	√	n/a	n/a	CBE
age	√	n/a	n/a	CBE
access to mental health services	n/a	n/a	√	WELL v1
access to primary healthcare	n/a	n/a	√	WELL v1
activity programming	n/a	n/a	√	WELL v1
alcohol environment	n/a	n/a	√	WELL v1
community health and wellness	n/a	n/a	√	WELL v1
fundamental housing quality	n/a	n/a	√	WELL v1
healthy food procurement	n/a	n/a	√	WELL v1
housing equity and affordability	n/a	n/a	√	WELL v1
mental health crisis support	n/a	n/a	√	WELL v1
nutrition education	n/a	n/a	√	WELL v1
substance abuse and addiction services	n/a	n/a	√	WELL v1
substance abuse and addiction services for at-risk populations	n/a	n/a	√	WELL v1

4. DISCUSSIONS

The research aimed to improve the health and wellbeing of occupants in the indoor environmental. The literature review showed a gap between the occupants' needs (occupants' satisfaction) and the features offered to them by building indoor environment, although some of these building were certified and earned a high score in LEED rating system (Platinum and Gold). The research reviewed the CBE's questionnaires / score sheets, collected the most factors (features) affecting the occupants' satisfaction, and tabulated these features in 6 categories in comparison of the related features of LEED and WELL Tables (1 - 6).

Tables (1 - 6), showed that the CBE's features of occupants' satisfaction were not fully covered by LEED and WELL features. on the other hand the research reviewed the "LEED v4 for Building Design and Construction, LEED v4 for Interior Design and Construction, LEED v4 for Building Operations and Maintenance, LEED v4 for Neighborhood Development, LEED v4 for Homes Design and Construction, and The WELL Community Standard™ v1" for additional features may improve the occupants' satisfaction. These additional features of LEED and WELL were added to the CBE's features represented the integrated assessment features in Tables (7 - 12). The potential improvement of the 6 categories are illustrated below:

Visual comfort, the 10 visual comfort features in Table 1, increased to 16 integrated assessment features in Table 7, improved the potential occupant satisfaction of visual comfort by 60%. The 16 integrated assessment features were all covered by the features of CBE, LEED and WELL, the CBE covered 62.5%, the LEED covered 31.3%, and the WELL covered 50%.

Thermal comfort, the 9 thermal comfort features in Table 2, increased to 10 integrated assessment features in Table 8, improved the potential occupant satisfaction of thermal comfort by 11.11%. The 10 integrated assessment features were all covered by the features of CBE, LEED and WELL, the CBE covered 90%, the LEED covered 40%, and the WELL covered 10%.

Acoustic comfort, the 7 acoustic comfort features in Table 3 were the same 7 integrated assessment features in Table 9. The 7 integrated assessment features were all covered by the features of CBE, LEED and WELL, the CBE covered 100%, the LEED covered 0%, and the WELL covered 57%.

Indoor environmental quality, the category "indoor air quality" in Table 4 upgraded to category "indoor environmental quality" in Table 10, consequently the 16 features in Table 4, increased to 54 integrated assessment features in Table 10, improved the potential occupant satisfaction of indoor environmental quality

by 237.5%. The 54 integrated assessment features were all covered by the features of CBE, LEED and WELL, the CBE covered 29.6%, the LEED covered 59.3%, and the WELL covered 24%.

Building characteristics, the 11 building characteristics features in Table 5, increased to 22 integrated assessment features in Table 11, improved the potential occupant satisfaction of building characteristics by 100%. The 22 integrated assessment features were all covered by the features of CBE, LEED and WELL, the CBE covered 50%, the LEED covered 72.7%, and the WELL covered 0%.

Occupants' features, the 8 features of the category "occupants' features" in Table 6, increased to 20 integrated assessment features in Table 12, improved the potential occupant satisfaction of occupants' features by 150%. The 20 integrated assessment features were all covered by the features of CBE, LEED and WELL, the CBE covered 40%, the LEED covered 0%, and the WELL covered 60%.

- The Potential improvement of occupants' satisfaction when individually implementing the features of CBE, LEED, and WELL:
 - CBE's features covered the integrated assessment features of visual comfort by 62.5%, the thermal comfort by 90%, the acoustic comfort by 100%, the indoor environmental quality by 29.6%, the building characteristics by 50%, and the occupants' features by 40%. And covered the 6 categories by 47.3%.
 - LEED's features covered the integrated assessment features of visual comfort by 31.3%, the thermal comfort by 40%, the acoustic comfort by 0%, the indoor environmental quality by 59.3%, the building characteristics by 72.7%, and the occupants' features by 0%. And covered the 6 categories by 44.1%.
 - WELL's features covered the integrated assessment features of visual comfort by 50%, the thermal comfort by 10%, the acoustic comfort by 57%, the indoor environmental quality by 24%, the building characteristics by 0%, and the occupants' features by 60%. And covered the 6 categories by 29.5%.
- The potential improvement of occupants' satisfaction when implementing the integrated features of the CBE, LEED, and WELL:
 - (LEED and WELL)'s features together covered the integrated assessment features of visual comfort by 81.3%, the thermal comfort by 50%, the acoustic comfort by 57.1%, the indoor environmental quality by 83.3%, the building characteristics by 27.7%, and the occupants' features by 60%. And covered the 6 categories by 73.6%.
 - Suggested Integrated Assessment Features (integrated features of CBE, LEED and WELL) covered the occupants' satisfaction by 100% including the visual comfort, thermal comfort, acoustic comfort, indoor environmental quality, building characteristics, and occupants' features.

The research showed that integrating the features of LEED and WELL may improve the potential of occupants' satisfaction by 73.6%, and integrating the features of CBE, LEED and WELL may significantly improve the potential of occupants' satisfaction by 100%.

5. CONCLUSIONS

The research aimed to improve the occupants' satisfaction in the indoor environmental, the literature review showed a gap between the occupants satisfaction features of CBE's surveys and the features of the LEED rating system, the gap investigated with reference to the features of the two rating systems (LEED v4 and WELL v1) compared to the CBE's surveys features, the results indicated that:

- The CBE's features covered the 6 categories by overall percentage equal to 47.3%, in priorities "acoustic comfort by 100%, thermal comfort by 90%, visual comfort by 62.5%, building characteristics by 50%, occupants' features by 40%, and indoor environmental quality by 29.6%".

- The LEED's features covered the 6 categories by overall percentage equal to 44.1%, in priorities "building characteristics by 72.7%, indoor environmental quality by 59.3%, thermal comfort by 40%, visual comfort by 31.3%, acoustic comfort by 0%, and occupants' features by 0%".
- The WELL's features covered the 6 categories by overall percentage equal to 29.5%, in priorities "occupants' features by 60%, acoustic comfort by 57%, visual comfort by 50%, indoor environmental quality by 24%, thermal comfort by 10%, and building characteristics by 0%".
- Integrating the features of LEED and WELL improved covering the 6 categories by overall percentage equal to 73.6%. Overcame the 0% of both acoustic comfort and occupants' features by LEED, and the 0% of building characteristics by WELL. Which represents a potential improvement of occupant health and wellbeing when simultaneously implementing the features of both rating systems LEED and WELL.
- Integrating the features of CBE, LEED, and WELL improved covering the 6 categories by overall percentage equal to 100%, which represented the highest score for the occupants' upgraded satisfaction. These 6 categories in Tables (7 - 12) including the 129 integrated assessment features, may considered a guidelines for the diversity of the building industry, including manufacturers, building owners, facility managers, contractors, architects, engineers, government agencies, and utilities to improve the occupants health, wellbeing, and satisfaction in indoor environment. Also it may reveal areas that can be improved by LEED, WELL, and other rating systems through continuous developing and updating of their categories and credits features to match the occupant requirements for better health and wellbeing.

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