Green Hospital Implementation in Health Aspects: A Systematic Review

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***Abstract*—** A green hospital prioritizes health and sustainability by conserving energy, water, and materials. Improving structure siting, planning, development, service, repair, and disposal reduces health and environmental impacts. Hospitals save lives and promote health. Due to its mission, hospitals prioritize health. People go to hospitals because they want medical treatment, therefore, hospitals should be clean and comfortable. Previous researches state a well-designed hospital building may improve healing. Designers focus on green strategies to benefit hospital patients and staff. This paper is a systematic review of recent evidence on green hospitals and health aspects from Scopus, PubMed, EBSCO, and ProQuest databases. The data collection method was done through Zotero Reference Manager and searching for articles online with related keywords. The selected articles included studies that report on any elements of green design and health aspects in hospitals. 58 articles were found in this study that reported on green design aspects and health in a hospital setting. Green design aspects such as LEED, green building design, environmental sustainability, natural environment, green space, indoor air quality, thermal comfort, acoustic comfort, waste management, and water conservation are known to have a relationship with the staff comfort and satisfaction, patient comfort and satisfaction, productivity and performance, motivation, quality of care, quality of life, hospital-associated infection, physical health, physiological health, recovery, and safety. The green design aspects positively affect patient and staff health. Thus, implementing green design concepts in hospitals could enhance human health and the quality of care.

***Keywords*—** green hospital, green design, LEED, green aspects, hospital, health, wellbeing.

I. INTRODUCTION

Green building is a concept of building that reduces energy, water, and environmental disturbances. A green hospital prioritizes health and sustainability; thus, these types of hospitals must conserve energy, water, and materials. The implementation of green building in hospitals through improving structure siting, planning, development, service, repair, and disposal reduces health and environmental impacts.[1,2] The mission of hospitals is to save and enhance lives, meaning hospitals prioritize health the most. People come to hospitals to receive medical treatment, therefore hospitals should be clean and comfortable. According to previous research, a well-designed hospital building may improve the healing process. Designers must focus on green strategies to benefit hospital patients and staff. [3]

Natural habitats, especially green areas, are linked to a person's objective health and well-being standards. The health benefits that can be obtained from sustainable spaces may be due to vigorous exercise, reduced emotional stress, depression, and anxiety, and increased interpersonal relationships and coherence. [4]

People spend 90% of their time indoors in the wellness circle. The indoor environment affects people's health because it's where they spend most of their time and because indoor pollutants are higher than those outdoor.

Green buildings reduce environmental impacts by reducing on-site operations, conserving energy and water, and improving health. They also improve the indoor environment and reduce power use and emissions that cause heart disease, asthma, premature mortality, and global warming, in which these cases themselves have a cascade of adverse effects [2].

Previously, there wasn't enough information on how green hospital implementation can affect the health of hospital occupants. Therefore, this study aims to systematically review articles on green hospital implementation and health aspects to give hospital management a look at the green hospital concept and provide information about future research in this area.

II. MATERIAL AND METHOD

A. Study design

This study is a systematic review based on recent evidence of green hospitals and health, the method of this study was adopted according to the procedure used by Setyonugroho et al. (2015). [5]

B. Search Strategy

The Primary Investigator (PI) conducted the preliminary narrative literature review on green design and health to ensure that critical points and conceptual frameworks were covered for later search strategies. An extensive

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literature search was done using the keywords from this exercise. This research study tested 65 Green Hospital keywords and 35 Health Aspect keywords for relevancy (Tablw 1).

Table 1: *List of Keywords*

NO	Keywords
1.	"acoustic comfort"
2.	"BREEAM"
3.	"Building Research establishment environmental assessment method."
4.	OR 2-3
5.	"Building cooling"
6.	"building footprint"
7.	"building management system."
8.	"built environment"
9.	"construction industry"
10.	"emission reduction"
11.	"energy conservation"
12.	"Energy efficiency and conservation"
13.	"energy efficiency"
14.	"energy-intensive"
15.	"energy saving"
16.	"energy usage efficiency"
17.	"energy"
18.	"environmental performance"
19.	"environmental sustainability"
20.	"green assessment"
21.	"green BMI"
22.	"green building development"
23.	"Green building technologies"
24.	OR 5-23
25.	"green building"
26.	"green buildings"
27.	OR 25-26
28.	"green characteristics"
29.	"green cities"
30.	"green city"
31.	OR 28-30
32.	"green design"
33.	"green designs"
34.	OR 32-33
35.	"green hospital"
36.	"green hospitals"
37.	OR 35-36
38.	"green infrastructure"
39.	"green infrastructures"
40.	OR 38-39
41.	"green roof"
42.	"green roofs"
43.	OR 41-42
44.	"green space"
45.	"green spaces"
46.	OR 44-46
47.	“green star”
48.	"green technologies"
49.	"green technology"
50.	OR 47-49
51.	"greening financing"
52.	"greening healthcare"
53.	"greening room"
54.	"greening"
55.	"greenness"
56.	"GRIHA"
57.	"groundwater"
58.	"high-performance building"
59.	OR 51-58
60.	“LEED”
61.	"Leadership in energy and environmental design"
62.	OR 60-61
63.	"living comfort"
64.	"natural ventilation"
65.	"noise"
66.	"SAGRS"
67.	OR 63-66
68.	"sustainable building"
69.	"sustainable buildings"
70.	OR 68-69
71.	"sustainable construction"
72.	"sustainable development"
73.	"thermal comfort"
74.	OR 71-72
75.	"urban green space"
76.	"urban green spaces"
77.	OR 75-76
78.	"visual comfort"
79.	"waste management"
80.	"water conservation"
81.	"water efficiency"
82.	OR 78-81
83.	"delivery rooms"
84.	OR 84-85
85.	"emergency room"
86.	"emergency rooms"
87.	OR 87-88
88.	"health care building"
89.	"health care buildings"
90.	OR 90-91
91.	"health care"
92.	"health department"
93.	"health departments"
94.	OR 94-95
95.	"health facilities"
96.	"health facility"
97.	OR 97-98
98.	"hospital building"
99.	"hospital buildings"
100.	OR 100-101
101.	"hospital care"
102.	"hospital"
103.	"hospitalization"
104.	"hospitalization"
105.	OR 105-106
106.	"inpatient room"
107.	"inpatient rooms"
108.	OR 108-109
109.	"operating room"
110.	"operating rooms"
111.	OR 111-112
112.	"outpatient room"
113.	"outpatient rooms"
114.	OR 114-115
115.	"patient room"
116.	"patient rooms"
117.	OR 117-118
118.	"private hospital
119.	"public hospital"
120.	"kitchen"
121.	"ward"
122.	"emergency department"
123.	"emergency care"
124.	"accident and emergency department"
125.	"laundry"
126.	"casualty department"
127.	OR 117-128
128.	86 or 89 or 92 or 93 or 96 or 99 or 102 or 103 or 104 or 107 or 110 or 113 or 116 or 119 or 129
129.	"patient"
130.	"health"
131.	"recovery time"
132.	"patient recovery"
133.	"risk of infection"
134.	"risk of infections"
135.	"disease"
136.	"length of stay"
137.	"indoor environmental"
138.	"air quality"
139.	"indoor air"

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140.	"psychology"
141.	"psychological"
142.	"quality of life"
143.	"quality of care"
144.	"patient care"
145.	"sick building syndrome"
146.	"surgical management"
147.	"asthma"
148.	"respiration"
149.	"respiratory illness"
150.	"mortality"
151.	"morbidity"
152.	"patient outcome"
153.	"headache"
154.	"unusual fatigue"
155.	"irritated skin"
156.	"sick"
157.	"stress"
158.	"mental health"
159.	OR 131-160
160.	"work performance"
161.	"work performances"
162.	OR 162-163
163.	"doctor performance"
164.	"doctor performances"
165.	OR 165-166
166.	"nurse performance"
167.	"nurse performances"
168.	OR 168-169
169.	"burn out"
170.	"depression"
171.	161 or 164 or 167 or 170 or 171 or 172
172.	83 AND 130 AND 173

An extensive search found peer-reviewed, publicly available, international journals with English as the primary language of publication. Data was collected from the following databases: SCOPUS, PUBMED, EBSCO, and PROQUEST. Using the Boolean operators AND and OR as conjunctions to combine keywords in a search yielded more focused and relevant results across all databases. To avoid inaccurate results, search strategies and limits were used. The search strategy using PUBMED was outlined, whilst in the other three databases the search strategies were adjusted accordingly. In this research, Zotero was used as a reference management software. PI manually searched for references that discussed relevant studies.

C. Inclusion and exclusion criteria

Field experiments, cohort studies, case management studies, case analyses, or health and green hospital case series were included. The papers had to be academic or scientific, and predatory journals or publishers were exempted. Reviews were also excluded from this study. The articles must mention health, green hospital, or green building keywords and after manually reviewing all the papers, only those in hospital or healthcare settings were included.

D. Data extraction and analysis

Each reviewer analyzed the literature using a data extraction template. The template or presentation table was created using keywords and assessment rubrics. The literature presentation table includes green design elements, and patient and staff health aspects.

After using qualitative content analysis and discussing the findings, the reviewer discussed and agreed on the research's green design and health aspects. The health aspects were divided into two: staff and patient health. Staff health includes comfort, satisfaction, performance, motivation, stress, and physical health. Patient health in the hospital consists of comfort, satisfaction, quality of life, care, healthcare-associated infections (HAIs), physical health, mental health, recovery, and safety.

This review did not require ethical approval.

III. RESULT

A. Search Result

The initial data collections from ProQuest were 201 papers, Ebsco were 565 papers, PubMed were 986 papers, and Scopus were 1731. So, the initial search from 4 databases identified 3483 papers. After removing duplicates, 2269 papers remained. 1880 papers were considered irrelevant or unrelated to green issues based on their titles and abstracts. This study manually excluded ten copies, 78 non-English papers, and 116 review papers. After downloading full-text papers to review their content, 28 were excluded because they lacked full-text. Ninety-six of the remaining 155 full-text articles were excluded because they didn't discuss green hospitals and health aspects. The review focused on the remaining 58 papers. The detail stages of systematic review process are shown in Figure 1.

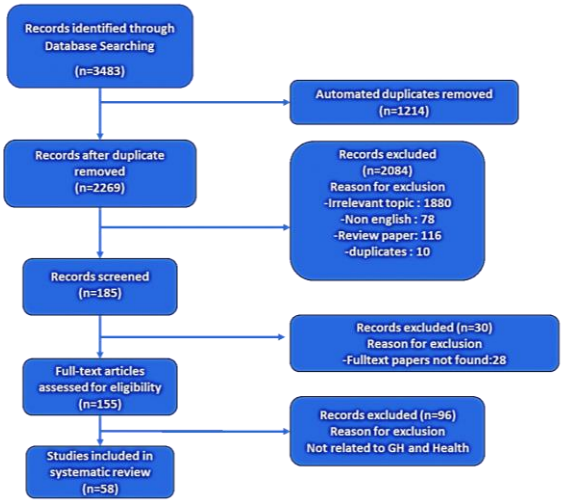

Figure 1: *The Different Stages of Systematic Review*

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B. Content Analysis

The studies included in this review were from 2001-2020 (fifty studies are between 2010-2020, and only eight were between 2001-2010). The country locations of the studies were in nineteen countries from the USA, UK, Canada, Iran, India, Thailand, Greece, Nigeria, Africa, Singapore, Taiwan, Malaysia, Netherland, Japan, Argentina, Portugal, China, Jordan, and Turkey.

The studies reviewed in this paper were held in a healthcare setting. Six studies were conducted in LEED-certified hospitals [6–11], nine studies were conducted in children's hospitals [6,9,12–18], fifteen studies were conducted in general hospitals [19–33], two studies were conducted in a university hospital [34,35], and three other studies were conducted in mental health hospitals [36–38]. Only one study was in a drug rehabilitation centre [39], one study was in a clinic [29], and one study was in a nursing home [40]. Another study was done in several locations, namely in general hospitals and a primary healthcare centre [41]. There are also studies that took place in clinics and acute care settings [36,42]. The remaining studies did not mention the type of the hospital or healthcare setting.

The studies implemented various methods, including case study, descriptive-analytic, cross-sectional, cohort, mix-method, comparative longitudinal assessment, experimental study, and survey study. Since this research examined papers on green and health in hospital or healthcare settings, they discussed components such as LEED/Green Building design, daylight/sunlight, natural environment, natural material, green space, natural ventilation, indoor air quality, energy efficiency, and physical environment with health aspects like quality of care, quality of life, patient recovery/length of stay, patient safety, sleep quality, HAIs, mental health, physical health, etc. According to the full-text review, five studies mentioned green or LEED hospitals [6,9,11,40,43].

Green hospitals or LEED-certified hospitals are linked to patient care, recovery, quality of life, mental and physical health, patient satisfaction, staff satisfaction, and staff performance. Five studies discussed the built environment and health [12,22,37–39]. These studies focused on care quality, stress, hospital-acquired infections, sleep quality, patient satisfaction, staff satisfaction, and performance. Nine studies mentioned a relation between natural light and health [14,15,15,22,36,36,39,42,44,45]. Natural light is linked to health, patient comfort, seasonal depression, fatigue, insomnia, quality of life, physiological health, physical health, patient recovery, eye fatigue, sleep quality, satisfaction, and performance.

Furthermore, eight studies mentioned about natural environment or green space [14,16,18,31,32,35,39,46], nine studies mentioned natural ventilation [20,24,26,28,29,34,39,47,48], and two studies mentioned natural material [10,21] related to health in general, comfort, satisfaction, fatigue or headache, stress, quality of life, physiological health, physical health, patient recovery, and improved clinical outcome. Eight studies mentioned indoor environmental or indoor air quality [20,26,30,44,48–51] with health in general, satisfaction, comfort, performance, airborne bacteria, fungi distribution, allergic or asthma, hospital-associated infection, post-operation problem, physical health, and patient safety. Six studies mentioned thermal comfort and health aspect [11,21,26,36,52,53]. Thermal comfort affects health, satisfaction, performance, stress, physiological health, infection, workplace alertness, eye fatigue, and sleep quality. Seven studies mentioned acoustic comfort [12,31,38,42,44,54,55] with health in general, satisfaction, comfort, performance, stress, quality of life, patient safety, and sleep quality. Three studies mentioned energy efficiency [27,40,54], and three mentioned the relation between waste management [17,54,56] and health in general, performance, fatigue, quality of life, and hospital-associated infection

C. Reviewer Agreement

After reviewing papers on green hospital and health, the reviewer divided "health" into patient and staff health. Patient health includes aspects such as comfort, satisfaction, care quality, life quality, HAIs, physical and physiological health, recovery, and safety. Meanwhile, staff health includes aspects such as comfort, satisfaction, productivity, performance, motivation, stress, and physical health.

IV. DISCUSSION

Green design with hospital occupants' health and wellbeing

Green building is now widely used. Green buildings reduce energy and water use, site pollution, and waste and aim to improve human health by designing healthy indoor environments. The health benefits of green buildings have only recently been studied, but the benefits of reduced energy and water consumption are well-known. [2] In this study, seventeen studies mentioned green design (i.e., environmental sustainability, natural light, natural environment, green spaces, natural ventilation, indoor air quality, thermal

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comfort, acoustic comfort, waste management) and health in general. Other studies mention patient or staff health, such as physical or mental health, recovery time, comfort, satisfaction, safety, quality of life, etc.

A. Patient Health and Wellbeing

Hospitals prioritize patient health in order to improve health, that is why hospital design must be able to promote patient health. 28 studies were reviewed that discussed green hospital patient health. Green aspects include built environment, Green Building design, LEED design, environmental sustainability, daylight, natural environment, green space, indoor air quality, natural ventilation, thermal comfort, acoustic comfort, and water efficiency.

1) Patient Comfort and Satisfaction

Five studies [13,39,43,45,55] mentioned green aspects related to patient comfort and satisfaction. These aspects were comprised of LEED design, built environment, daylight, natural environment, green space, thermal comfort, and acoustic comfort.

A study by Campion et. al. found LEED design improved patient comfort and satisfaction in an oncology unit. Patients were asked 16 questions to compare hospital designs with and without LEED standards. Satisfaction increased when the hospital is cleaner and quieter. Patient satisfaction increased by 7.1% due to the hospital's quietness. P 0.001. [43] This is in line with a study by Kotzer et al. (2011) and Wu et al. (2019), wherein acoustic comfort affects patient comfort and satisfaction.

Table 2: *Details papers included in the systematic review*

NO	Author	Country, year	Method, Hospital	Green design aspect	Health aspect
1	Bilec et al.	US,2010	Case study-Children's Hospital of Pittsburgh (CHP)	LEED design, Green building design	Quality of life, staff satisfaction and productivity
2	Easy&Naseri	Iran,2015	Descriptive analytic-Drug Rehabilitation Center	The use of Light, Spatial form and structure, natural environment, and green space	Patient satisfaction, quality of life
3	Chaivisit et al.	Thailand, 2018	Thailand University Hospital	Indoor Air Quality (humidity, thermal comfort)	Airborne bacteria and fungi distribution -> allergic, asthma, sick building syndrome
4	Sagah Zadeh et al.	US, 2018	Mixed-method, 136 healthcare professionals at a primary care clinic, an acute care hospital, and a mental health clinic in texas	environmental features, daylight, thermal comfort	improving workplace alertness, optimizing workplace safety
5	Muthuri, Senkubuge and Hongoro	Africa,2020	Cross-sectional-public hospital and mission hospital, 553 healthcare professional	Source of water	Overall motivation
6	Kembel, et al	US,2012	Providence Milwaukie Hospital, Milwaukie, OR, USA, on 27–28 February 2010	Indoor air quality, natural ventilation, thermal comfort	Hospital-associated infection
7	Sookchaiya, Monyakul, and Thepa,	Thailand, 2010	Thailand hospital building- Assess relative humidity and temperature	temperature, humidity -> thermal environment	human comfort and health
8	Nyrud, Bringslimark and Bysheim, 2014	UK,2014	In the preference study, Norwegian hospital Respondents (n = 93) included nurses, auxiliary nurses, physicians, and other hospital staff.	Natural environment	Patient preference
9	Thiel et al.,	US,2014	Comparative longitudinal assessment (pre-post-move)-Children's Hospital of Pittsburgh	LEED design	Productivity, quality of care, staff satisfaction
10	Sattayakorn, Ichinose and Sasaki	Japan, 2017	General Hospital in Bangkok-928 occupants, including 451 patients, 331 visitors, and 146 medical staff	Indoor air environment, thermal comfort	Physiological health,
11	Karthikeyan and Samuel	India, 2008	In ten different hospital operation theatres in India, 200 respondents	Indoor air quality, Natural ventilation	Physical health, post-operative problems
12	van Oel, Mlihi and Freeke	Netherland,2020	Mix method-Two hundred four respondents, 60% patients, and 40% medical professionals, engaged in discrete choice experiments visualizing a single patient room. Hospital in the Netherlands	daylight access, windows matter, panoramic view, open door (connected to 'outside world')	Patient preference, satisfaction
13	Short and Al-Maiyah	UK,2009	UK National Health Service	low energy ventilation, energy consumption, comfort cooling, natural ventilation	Healthcare-acquired infection, patient experience, and offset the effects of heatwaves
14	Cheong and Chong	Singapore, 2001	IAQ Audit and 51 questionnaires were distributed to the hospital staff and were completed and returned.	Indoor air quality, thermal comfort	physiological symptoms during working hours and physical parameter complaints from staff
15	Shepley et al.	US, 2009	by surveying administrators who serve in "best practice" facilities that teach these concepts. Phase 1: Practitioner Focus	Daylight, water efficiency	Health in general
16	**Schreuder et al.**	**Netherland, 2015**	**In the pre-occupancy evaluation, 2,598 (Dutch and international) employees from the various diagnostic and research laboratories, pharmacy, central sterilization, rehabilitation medicine, rheumatology, and health science departments, received the survey.**	**Daylight, ventilation and temperature, noise reduction, view, air quality, sustainability**	**Perceived wellbeing, overall satisfaction, work performance**
17	Megumi Maruyama et al.	Japan, 2008	Shimane University Hospital	Natural materials, thermal comfort	stress level, physiological health
18	Fay, Carll-White, and Real	UK,2018	observational techniques, physical measurements of walking, and staff questionnaires. The final sample (N= 87) was composed of 34 emergency nurses, 15 nurse care technicians, 20 physicians, and 18 other staff members, including paramedics, managers, and physician assistants	lighting, visibility, patient room layout, storage	Efficiency and staff satisfaction
19	Alzubaidi and Soori	Japan, 2011	Case study- A Hospital Diagnostic and Treatment room in Qatar	Physical environment: Efficient lighting design, visual comfort, energy efficiency	patient satisfaction, patient safety, staff performance
20	McCunn and Gifford	Canada, 2013	Based on photographs, a site tour, interviews with the NRU manager and with the son of a patient of 5 months, comparisons were made between the NRU and the acute care setting design considerations reviewed by Chaudhury et al	noise reduction; lighting; ergonomics, furniture, and equipment; and patient room design and unit layout	nursing error--staff performance
21	Huffling and Schenk	US, 2014	Case Study- evaluates the ICU on four areas of environmental sustainability	Environmental sustainability, Acoustic comfort, energy efficiency	stress, patient safety

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22	Alvaro et al.	Canada, 2016	In a pre-test–post-test quasi-experiment, three buildings were investigated in this study: the former hospital (Bridgepoint Hospital; occupied until April 2013), the new hospital (Bridgepoint Hospital; occupied as of April 2013), and a comparison hospital, West Park Healthcare Centre—	Hospital facility design, natural environment, green space	Patient and staff well-being--overall satisfaction, overall health, depressive symptom, burnout
23	Sheehan et al.	UK, 2013	collected data from 98 wards within 19 participating mental health provider National Health Service (NHS) Trusts in urban and rural areas of England	built environment features: views, link to outdoor, colors, flooring, observability of patients, and characteristics of the nursing station	Staff satisfaction
24	Varni et al.	US, 2003	Children's Convalescent Hospital- survey questioners, focus group discussion	Built environment: views of natural environments, natural scenes,	health outcome and satisfaction—patient-perceived stress during hospitalization, staff satisfaction
25	Kotzer et al	US, 2011	Children's hospital. Using a pre/post descriptive survey design.	Built environment: natural light, noise, temperature, quiet a space	staff and family satisfaction, effective healing environment
26	Pyrke et al.,	Canada, 2016	A pre-post cross-sectional survey in a mental health facility	Built environment: design features, maximized natural light, complete patient control over noise, light exposure	Sleep quality
27	Lenfestey et al	US, 2013	Semi-structured individual interviews and triads were conducted with 26 experts in the hospital. A grounded theory approach was used for interview coding and interpretation.	hospital design, water, and air quality	Healthcare-associated Infection (HAIs)
28	Henderson-Wilson and Weerasuriya	Australia, 2017	Thematic paper, hospitals	Green spaces, natural environment	Mental health
29	**Chenven and Copeland**	**US, 2013**	**discusses a national project of the Healthcare Career Advancement Program, funded by the U.S. Department of Labor, to support green job development. Implementation was accomplished through a labor/ management collaboration between union locals and 11 employers in four regions throughout the United States.**	**Greening healthcare: reduction of medical waste, increased recycling, conversion to use of green chemicals**	**Healthcare-associated Infection, health and safety of workers, asthma and respiratory problems**
30	Ghersin et al.	US, 2020	The PICU at Massachusetts General Hospital for Children/Harvard Medical School in Boston, Massachusetts. Not to mention the methodology and sample	Reducing medical waste/medical waste management	delivery of health care--reducing morbidity (HAIs and transmitted infections), improving patient care
31	Piccoli et al	Italy, 2020	The Italian Society of Nephrology is presenting this position statement	Water conservation, energy conservation, waste management	Health in general
32	Kulariyasup, Horpibulsuk and Horpibulsuk	Thailand, 2018	Nursing Home. 1st phase procedure: collect anthropometry data on the elderly in the existing nursing home to determine facility dimensions. 2nd: the researchers attended training courses and visited various buildings certified, 3rd: 3-D modeling of the nursing home using the SketchUp software. To determine the overall thermal transfer values (OTTV) and the roof thermal transfer values (RTTV), the effect of sunlight on the building model was assessed.	building utilization, water management, waste management, environmentally friendly materials selection, natural light	quality of life, physical and mental health of elderly
33	Cáceres Guido et al	Argentina, 2018	A taxonomic survey in children's hospital	green space in the hospital	improve the well-being and health of patients, caregivers, and healthcare staff
34	Nourmusavi Nasab, Karimi Azeri and Mirbazel	Iran, 2020	children's desired atmosphere during treatment was examined via 16 drawings and 24 interviews with children at a children's hospital in Iran.	Natural light, green space, and water features	stress/mental well-being, quality of patient experience, patient well-being
35	Escombe et al.	UK, 2019	Two general hospitals with high TB prevalence. Room ventilation was measured pre-and post-modification using a carbon dioxide tracer-gas technique in four waiting rooms and two consulting rooms.	Natural ventilation	TB transmission
36	Fonseca et al	Portugal, 2018	collecting and analyzing experimental data of selected parameters in three healthcare units in Portugal: Two general hospitals and one primary healthcare center	sustainability, Indoor Air Quality: indoor air temperature, relative humidity, natural ventilation	reduced airborne infection, reducing fungi concentration, patient safety, occupational health and safety
37	Daniel Lawrence, Jayabal and Thirumal	India, 2018	The hospital building in Madurai, India. Measurement of indoor air quality. The selected occupied hospital patient room has an indoor volume of 122.64 m3, and it contains two windows and one door with one fan	Indoor air quality: naturally ventilated, fresh air supply, temperature flow, relative humidity	thermal comfort, improvement of the reduction of oxides and particulates, benefit patient, occupant health
38	Karanikola et al	Greece, 2020	General University Hospital of Alexandroupolis, Greece. Two-step cluster analysis and the hierarchical cluster analysis. Respondents: 370 medical staff, 563 nursing staff, 80 administration staff, 187 other department staff	hospital indoor and outdoor spaces	Occupants' satisfaction --promote healing, well-being, and productivity.
39	Nimlyat	Nigeria, 2018	The Case Study Method. Three different hospital categories were chosen based on the structure of the Healthcare Delivery System in Nigeria.	Indoor environmental quality: Thermal quality, Acoustic quality, Visual quality, and IAQ.	Occupants' satisfaction --promote healing, well-being, and productivity.
40	**Thibaudeau**	**Not mentioned, 2008**	**experience from a selection of more than twenty projects totaling over six million square feet, including projects that are LEED® registered and certified, including projects pursuing gold certification, following Minnesota's Sustainable Building Guide (B3), and following Green Guide for Health Care™ (GGHC)**	**design with LEED criteria, natural environment**	**Staff performance, patient health, visitor well-being, and improved clinical outcomes**
41	Wu et al	China, 2019	a series of field measurements and subjective evaluations that investigate the thermal comfort and acoustic performance of eighteen hospitals in China.	acoustic and thermal environment	Patient comfort, patient satisfaction
42	Khalid et al.	Malaysia, 2018	field survey assessments of thermal comfort were conducted in three Malaysian hospitals with air conditioning capabilities for patient rooms. A total of 389 responses were collected in hot and humid conditions.	Thermal comfort	health conditions of the patient, patient comfort
43	Manika et al.	UK, 2016	two Barts Health Trust hospitals (part of the NHS). The data used in this paper is drawn from a rich secondary dataset containing actual workplace behaviour measures (collected via observations) and self-reported data from employee interviews and patient questionnaires.	Energy-saving, environmental sustainability	Quality of sleep, patient satisfaction with the hospital, ability to concentrate, and less discomfort/headache, provided beneficial rest for patients.
44	Kaplan and Forst	USA, 2017	Pilot study. Five are based in the Midwest, three in the West, two in the Northeast, and two in the Mid-Atlantic. All are health-care organizations that include hospitals and an array of outpatient facilities.	Environmental sustainability	worker and patient health and safety
45	Lo Verso, Caffaro and Aghemo	UK, 2016	A field study: objective and a subjective approach, reporting results from field activities in four hospitals in Turin and Asti (region of Piedmont, Italy)	Daylight/lighting, visual comfort	nursing staff's job satisfaction and reduced stress
46	Gilkeson et al.	Uk, 2013	The study was carried out in a former Nightingale ward (A-Block) at St. Lukes Hospital, Bradford, United Kingdom. Experiments were conducted over fifty randomly selected days over five months between April and September 2010.	Natural ventilation	Airborne infection risk
47	Qian et al	China, 2010	A field measurement. Hong Kong Island is a TB hospital GH and an outpatient SYP clinic with naturally ventilated wards.	Natural ventilation	Airborne infection
48	Escombe et al	The UK, 2007	Ventilation was measured in 368 experiments in 70 naturally ventilated rooms in eight hospitals in Lima, Peru.	Natural ventilation	Airborne infection

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49	Kim et al.	Us, 2015	A survey study of LEED-certified Hospital (Michigan Health Hospital and cancer center) and conventional hospitals (main hospital campus)	LEED-certified hospital	Occupant comfort and satisfaction
50	Alfa and Öztürk	Turkey,2019	A field study of the indoor environmental quality (IEQ) of 4 wards in the General hospital at Minna, Niger State, Nigeria, was conducted, and responses from 271 patients were obtained	thermal comfort, lighting, acoustic, indoor air quality	health satisfaction, health recovery
51	Xuan	China, 2018	A multiple-methods approach combining a questionnaire survey and semi-structured interview was tested for practical post-occupancy evaluation. The study compared one non-LEED healthcare facility with five LEED-certified healthcare buildings	LEED Hospital	staff comfort and productivity/performance
52	Alzoubi and Al-Rqaibat	Jordan, 2015	Pediatrics Ward in King Abdullah University Hospital (KAUH). A multi-method approach using building simulation software (RADIANCE)	daylight	visual comfort, human performance, and psychological and physical well-being of patients. Enhancing patient health
53	Waroonkun	Thailand, 2018	Sara Phii Community Hospital in Thailand. The analysis utilized the Analytic Hierarchy Process (AHP) method. The AHP method is used as a tool for logical decision-making and questionnaire surveys, in-depth inter. view	Lighting, temperature, noise level, air quality, greenery, parking area	Users satisfaction
54	Chang and Chien	Taiwan,2017	Chiayi Chang Gung Memorial Hospital, Chiayi County, Taiwan. Discrete choice modeling (DCM) [27–29] is utilized as the experiment design in this study	Outdoor space, natural environment	psychological and physical well-being and healing benefits
55	Azmoon et al	Iran, 2013	Isfahan Al-Zahra Hospital, Iran. cross-sectional research was conducted on 82 shift-work personnel of 18 nursing workstations	Thermal comfort, Light	Sleep quality, eye tiredness
56	Allah Yar and Kazemi	Iran, 2020	Akbar Children's Super Specialty Hospital in Mashhad, Iran. In experimental research, a researcher-constructed structured questionnaire was used to collect the data	green space--dish garden	physical and psychological health
58	Campion et al	US, 2016	Magee-Women's Hospital (Magee) of the University of Pittsburgh Medical Center (UPMC). analyzing different metrics across three years for the same unit (oncology) spanning the traditional hospital (Unit 2800) space and the new green addition (Unit 5800)	Green building design	Quality of care, productivity, patient outcome, patient and employee satisfaction
59	Derks et al.,	Netherland, 2018	In the Netherlands, objective and subjective data were obtained to determine the thermal comfort perception of the nursing staff.	Thermal comfort	Work performance

The built environment, patient comfort, and satisfaction were also studied by Kotzer et al. (2011) and Easy&Naseri (2011). (2015). The natural environment, daylight, acoustic, and thermal comfort improves patient comfort. Natural light improves patients' hospital experience. [39] This is coherent with Lo Verso et al. (2016), that found access to daylight and the ability to see the outside world effects patient satisfaction. [45]

2) Quality of Care during Hospitalization

Quality hospital care is essential for patient healing. Four of the studies that were reviewed [6,9,39,43] mentioned the green aspect of the quality of care during hospitalization. Bilec et al. (2010) studied the relocation of the Children's Hospital of Pittsburgh into a new, green facility (LEED v.2.1 certified). They found that prescribing errors affected hospital care quality. The doctor's medication error was due to factors such as distraction or the environment, not the doctor's incompetence. The new facility reduces stress, improves comfort through temperature and humidity management, and eliminates noise, which reduces prescription errors. [9] This is in line with the results of studies by Thiel et al. (2014) and Easy&Naseri (2015) that Green building design, such as LEED-certified daylight, acoustic comfort, natural environment, and green space, can improve hospital care.

Moreover, according to the Mortality Index, the new LEED v2.1 children's facility has improved health care. According to P 14 0.005, Children's Hospital's mortality rate dropped by nearly 20%, and the Mortality Index (P 0.001) fell by almost 30%. [6]

Campion et al. (2016), also compared the LEED-Silver-certified woman's oncology new unit with the old team (non-LEED certified) and found that pharmaceutical metrics can also measure the quality of care. However, the study found no significant differences in medical error metrics. [43]

3) Quality of Life during Hospitalization

Four studies [12,14,39,40] mentioned green design related to the quality of life during hospitalization. According to Kulariyasup et al. (2018), the new Thammapakon Pho Klang Nursing Home was green and energy-efficient. The new nursing home's practical aspects include building use, water management, waste management, environmentally friendly material selection, and the impact of buildings on building users and the environment's health. Daytime floor plans take advantage of breeze and sunlight, which shields the building's exterior wall from sunlight. This allows users to be able to sleep well. Energy-saving landscaping includes shading the building with trees and this study was found to have improved life quality.

Moreover, Design strategies improved children's hospital quality of life.[14] Playing, having a hobby, a family presence, a colorful environment, and a cheerful environmental design (such as proper decoration and furniture for children), along with adequate light and green space, can create an environment conducive to children's development. The natural environment, natural ventilation, and acoustic comfort can improve hospitalization quality of life. [12,39]

4) Hospital Associated-Infection (HAIs)

Hospital-associated infections (HAIs) are a significant hospital management concern. Healthcare-associated infections threaten public health. The built environment, including building design, affects the spread of pathogens in healthcare facilities. [25] In this review, eight papers discuss hospital-associated infections

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(HAIs) and green aspects like built environment, natural ventilation, natural environment, indoor air quality, and thermal comfort. According to Lenfestey et al. (2013), HAIs are partially transmitted and acquired due to the built environment. As hospitals consolidate cleaning agents and products that can clean and disinfect multiple surfaces, interest in these products grows. Environmental Protection Agency (EPA) and LEED are two sources of information on low-emitting disinfection products and materials.

In addition, a study by Kembel et al. (2012) found that architectural design influences the built environment's microbiome, specifically the building's air ventilation. The study found that increased airflow and natural ventilation reduce airborne pathogen risk. This finding is consistent with Escombe et al. (2007), Qian et al. (2010), and Chaivisit et al. (2018) that found natural ventilation reduces airborne disease cross-contamination. Thus, natural ventilation should be used in hospitals to control infections. By modifying existing infrastructure to increase natural ventilation, risk of tuberculosis can be reduced with minimal or no financial costs.

Furthermore, according to Sookchaiya, Monyakul, and Thepa (2010) and Fonseca et al. (2018), indoor air quality and thermal comfort in hospitals affect patient health. In the tropics, there are two factors that are hard to control that affect thermal comfort and health: high humidity and temperature. Microorganisms thrive in high relative humidity, especially in air-conditioned rooms with closed covers or poor ventilation. [49] Natural ventilation improves indoor air quality. If outdoor air quality is good, using natural ventilation as a supplement to mechanical ventilation can reduce energy consumption and improve environmental and economic sustainability. According to the study, reducing indoor humidity reduces fungi concentration and airborne infection risk. [41]

5) Patient Physical Health

Physical health is the focus of hospital care. People go to the hospital for medical attention, therefore the hospital should be pleasant and clean. A well-designed hospital may speed recovery. [3] Based on Alzoubi &Al-(2015) Rqaibat's study of indoor daylight quality in the Pediatrics Ward at King Abdullah University Hospital (KAUH), lighting in hospitals affects patient health. Access to natural light improves patients' physical health. The hospital's interior and exterior should be designed to improve patients' health.

Meanwhile, according to Alvaro et al. (2016), Chang&Chien (2017), Kulariyasup et al. (2018), and Allah Yar&Kazemi (2018), the natural environments and green spaces contribute to hospitalized patients' physical health (2020). Allah Yar and Kazemi (2020) studied the effect of a typical Dish Garden as a surrogate for green spaces on physical health. The group exposed to the Dish Garden was physically healthier than the control group. Blood pressure, heart rate, and respiration rate normalized in the Dish Garden group. According to another study, hospitalized patients benefit from green spaces. This research suggests that hospital management and designers should incorporate more natural elements, such as plants, to increase patient contact with nature. Studies show that natural elements are therapeutic. [23,32,40]

Besides, research by Cheong&Chong (2001), Karthikeyan&Samuel (2008), Sookchaiya et al. (2010), and Chaivisit et al. (2018) found good indoor air quality improves occupants' health. Sookchaiya et al. (2010) found that air temperature and humidity affect indoor quality, thermal comfort, and health. The temperature and humidity inside a building can affect a patient's symptoms and can lead to rhinitis, allergies, asthma, tuberculosis, influenza, and sinusitis. Chaivisit et al. (2018) found that airborne fungal exposure causes allergic rhinitis, sick building syndrome, and the growth and spread of bacteria, viruses, and dust mites. Poor air quality and thermal comfort in hospital operating rooms increase the risk of post-operative wound infection. [49]

6) Patient Physiological Health

Physiological health is as important as physical health in-hospital patient care. Negatively perceived built environment elements may cause stress. [12] According to a study by Kulariyasup et al. (2018) about a green nursing-home model in Thailand, the green design improved the elderly's physiological health. [40] Recent studies have shown that exposure to natural light or daylight has been associated with decreased depression and improved mental health, as mentioned in the studies by McCunn &Gifford (2013); Alzoubi&Al-Rqaibat (2015); and Lo Verso et al. (2016) that hospital lighting has a direct impact on patient well-being, daylight has a positive effect on patient's mood and patients' psychological wellbeing.

Moreover, the natural environment and green space improve patient health in hospitals. A 2015 study by Easy&Naseri found that patients are often dissatisfied with the background of drug rehabilitation centers. This stress can lead to cognitive dysfunction, depression, irritability, and high blood pressure. Green space and nature can reduce stress and bring mental peace. This is in line with the study by Alvaro et al., 2016; Henderson

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Wilson&Weerasuriya (2017); Chang&Chien, (2017); Karanikola et al. (2020); Allah Yar and Kazemi (2020); and Nourmusavi Nasab et al. (2020) that natural environment and green spaces in healthcare settings can improve patient mental health. People who visit green spaces can improve their mental health through improving a person's ability to self-manage mental illness, recognize limitations, and seek social support. [57]

7) Patient Recovery and Patient Safety

Studies mentioned that environmental sustainability, natural light, green space, and indoor air quality affect patient recovery and safety in hospital buildings. Alzubaidi &Soori (2012) conducted a study in a hospital's Diagnostic and Treatment Room and found lighting plays an important role. It aids hospital staff and patients in their recovery. Visual comfort and energy use must be considered when designing hospital lighting. The sensitivity to daylighting in healthcare facilities has been shown to affect patients' recovery time, as mentioned by Lo Verso et al. (2016). Easy and Naseri (2015) also found that a natural environment or green space helps patient recovery. Another study on the physiological effects of trees and green space on hospitalized patients' recovery found that green space can shorten patients' stays.

In addition, environmental sustainability and air quality can improve hospital patient safety. Kaplan&Forst (2017) found that environmental sustainability initiatives can improve worker and patient health and safety. Currently, more healthcare leaders are reducing their environmental and patient health impacts. Some of the country's largest and most influential health systems have joined Healthier Hospitals, a national program with 1300 hospitals to implement sustainability activities such as less waste, safer chemicals, more intelligent purchasing, healthier food, and engaged leadership. Six types of data could reflect the impact of environmental sustainability initiatives on worker or patient health and safety: worker illnesses and injuries, sick leave and disability, patient HAIs, slips, and falls, and patient satisfaction survey responses. [58]

Due to its effects on patient safety, occupational health and safety, and energy consumption, good indoor air quality (IAQ) management in healthcare facilities affects sustainability performance. The findings suggest that natural ventilation should supplement mechanical ventilation systems in healthcare facilities through reducing energy consumption and enhancing environmental and economic sustainability. Proper control of relative humidity and CO2 concentration in healthcare facilities can reduce the risk of airborne infections, improving patient safety. [41]

B. Staff's Health

Since its mission is to improve health and well-being, the hospital is seen as a place of "help, care, and service." [9]. Staff health and well-being are as crucial as patient health, and hospital patient health and well-being eight papers on green aspects of staff health and wellness.

1) Staff Comfort and Satisfaction

Twelve papers discussed employees' comfort and satisfaction in green hospitals and healthcare facilities. Xiadong Xuan compared one non-LEED healthcare facility to five LEED-certified healthcare buildings in 2018. He interviewed 249 occupants and six facility managers in six healthcare settings to determine which variables correlated with comfort and productivity. Improved building design, higher temperature satisfaction, more efficient space, excellent noise controllability, and a better ability to satisfy occupant demands in a LEED-certified healthcare facility would improve staff comfort. [7]

Furthermore, Bilec et al. and Thiel et al. found that Children's Hospital's new green facility (LEED v.2.1 certified) improves staff comfort and satisfaction by regulating temperature and humidity. [6,9] In another study by Kim et al., LEED-certified hospitals were rated more comfortable by staff than conventional non-LEED-certified hospitals. The green hospital's indoor environment and design was able to improve staff comfort. [8] Campion et al. also mentioned that the post-move oncology unit with a green hospital design (LEED-certified) improved staff satisfaction better than the pre-move (traditional hospital space). Based on the staff survey, the green hospital design showed better satisfaction in the workspace, layout, aesthetic, acoustic, and lighting. Thermal comfort trended negatively in the staff survey. [43]

An additional four studies were able to link hospital-built environments to staff satisfaction. Sheehan et al. studied staff satisfaction and the building environment. Over 1,500 psychiatric inpatient staff responded, finding that wards offered various services and architectural design elements. Noncorridor design and patient bathrooms led to high staff satisfaction. There were no statistically significant effects on forwarding views, color schemes, flooring patterns, patient observation, or nursing station characteristics. [37]

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According to Fay et al., the built environment can influence healthcare processes, which improves care delivery and staff satisfaction. The workplace environment affects employee productivity, morale, and happiness. [59] Moreover, Kotzer et al. used a demographic form and surveys of family and staff satisfaction before and after occupancy of the new facility design. Pre/post mean scores for staff satisfaction improved on all survey subscales with statistically significant improvement (p.05) in most areas for all nursing, social work, therapy staff, and families on selected inpatient units. Layout, natural lighting, storage capacity, writing surfaces, and overall aesthetics and comfort improved. [13].

Thus, natural light for at least three hours a day has been linked to lower, higher job satisfaction, good indicators of burnout, and lower staff turnover. [45] Studies by Waroonkun, Fay, et al., and Lo Verso et al. found that daylight or natural light significantly impacts efficiency and employee satisfaction. [31,45,59]

2) Staff Productivity and Performances

The quality of hospital services also depends on staff productivity and performance, although staff comfort and satisfaction are related to productivity and performance. Several studies found LEED-certified hospitals had higher staff productivity than non-LEED hospitals [6,43,43]. In a study of a new emergency department, Fay et al. confirmed that structure and process are interrelated factors influencing efficiency and satisfaction. The built environment affects performance and productivity. [59]

Alzubaidi and Soori; McCunn and Gifford; Alzoubi and Al Rqaibat; Easy and Naseri; and Fay et al. found that lighting is vital for hospital workers to perform their duties. The visual environment, including natural light quality, affects staff performance and productivity. Natural light can improve human performance. [15,22,39,42,59] Furthermore, based on the studies by Derks et al. and Nimlyat mentioned that indoor environmental quality and thermal comfort have an impact on staff performance and productivity. [51,53]

Hospital noise and energy efficiency also has an affect on staff productivity and performance. McCunn and Gifford found that noise in a neurorehabilitation unit decreased staff productivity. [27,42] However, Schreuder et al. found that hospital buildings with better noise or acoustic comfort did not improve staff commitment, working environment, or work performance. [44]

3) Professional's overall motivation

Staff motivation is key to high-quality hospital care. Cross-sectional research by Muthuri et al. in Meru County, Kenya, found that household size, water unavailability, safe drinking water, the acceptable primary source of water, handwashing station 5m from toilets, and overall hospital safety were all associated with the level and types of motivation among healthcare professionals in the public and mission hospitals of Meru County. In the study, the motivation of healthcare professionals was lower when water wasn't readily available but increased when water was acceptable in color, smell, and taste. When located near restrooms, healthcare workers were more enthusiastic about hand washing. [19]

4) Staff's Stress

Stress among hospital staff is well-documented worldwide, and it's been linked to negative effects on patients' physical and mental health. [60] Staff stress is important in hospital management because it can lead to employee burnout and affect hospital services. Varini et al. (2004) found that negative perceptions of the built environment can exacerbate stress. Natural views reduce psychophysiological arousal and stress, including those from hospital windows. Easy and Naseri (2015), Karanikola et al. (2020), and Nourmusavi Nasab et al. (2020) mention the effect of green space on stress (2020). Hospitals have unique workplaces. Even though training and daily exposure to stressful incidents strengthen employees, psychological stress during the workday exhaust their mental resources, and they sometimes need a break from work stress. Health care workers often work in gardens and communicate with plants to treat patients. Green space promotes safety and reduces stress and pressure. [14,35,39]

In addition, a study by Megumi Maruyama et al. (2008) on the evaluation of stress levels with physiological parameters, i.e., HR, BP, arterial vascular compliance, core temperature, and plasma levels of cortisol, ADH, oxytocin, adrenaline, noradrenaline, and dopamine, revealed that redecorating the isolation room with natural materials may reduce stress levels. [21]

McCunn&Gifford (2013) and Huffling&Schenk (2014) found a link between hospital noise and staff stress. Noise can affect hospital staff's ability to communicate and concentrate, leading to stress and burnout. A study on environmental sustainability found that noise may also affect ICU nurses. Due to delayed alarm response, noisy ICUs can cause stress, irritability, and decreased patient safety. [42,54]

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5) Staff's Physical Health

For good hospital services, it's just as important for hospital staff to be physically healthy at work as it is for them to be mentally healthy. A survey by Karanikola et al. (2020) with hospital staff in General University Hospital of Alexandroupolis, Greece, about indoor and outdoor design in healthcare and a choice experiment approach study by Chang&Chien (2017) on the influences of landscape features of green space revealed that green space could reduce physical symptoms such as fatigue during work. Looking out a window or at a picture of a tree can provide an indirect connection to nature. It is good for doctors' physical health. [32,35]

Green space and daylight affect staff's physical health, including fatigue and eye tiredness (Azmoon et al. (2013), Alzoubi&Al-Rqaibat (2015), and Easy&Naseri (2016). (2015)). The human internal clock needs light to function. Humans have developed rhythms, such as body temperature, that aid communication and indicate the time of day. Isolation can cause fatigue and insomnia. As the light intensity increased, night shift nurses' eye fatigue decreased.

V. CONCLUSSION

Based on the results of the review, it can be seen that green building design nowadays has been widely adapted. Several green design aspects affect patient and staff health. LEED design, green building design, environmental sustainability, natural environment, green space, indoor air quality, thermal comfort, acoustic comfort, waste management, and water conservation is known to have positive effects on patient and staff health. Implementing green design concepts in hospitals can enhance human health and the quality of care in hospitals.

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