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SUSTAINABLE DESIGN APPROACHES OF LEED-CERTIFIED HEALTHCARE BUILDINGS

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Abstract

Rapidly advancing technology and increasing consumption habits in human needs have increased production and construction. Natural resources and raw materials have been rapidly consumed and the natural environment has been destroyed. The deteriorating ecological balance has caused environmental problems. Realizing that today's humanity and future generations are under threat, the scientific world has turned to environmentalist and sustainable studies in order to prevent environmental problems. For these reasons, in this study, healthcare buildings with LEED (Leadership in Energy and Environmental Design) certificate, which is a sustainability certification system, were examined and compared under the main headings of management, energy and atmosphere, material, indoor environmental quality, water, transportation, land and ecology, innovation, pollution, waste management. As a result of the study, it was seen that LEED certified healthcare buildings prioritize materials and water and indoor quality criteria, while the use of natural resources and transportation criteria remain in the background.

Keywords: Sustainability, sustainable architecture, hospital buildings, environmentally friendly

1. INTRODUCTION

As a result of their unconscious activities, humans threaten living species by causing water, air and soil pollution and cause the destruction of biodiversity. These unconscious activities, which have increased with industrialization, have also affected people's health problems by disrupting the natural balance. As a result of the deterioration of the natural balance and the emergence of health problems, people's sensitivity to the environment has started to increase, and how to create and protect a livable environment has come into question (Soysal, 2014). The World Commission on Environment and Development (WCED), in its Brundlant Report published in 1987, defined sustainability as the ability

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of humanity to continue its development in such a way that the needs of present generations do not harm the needs of future generations (Goodland, 1991).

Sustainable construction refers to the application of sustainable development principles to the wider construction cycle, from the planning, design and construction of buildings and infrastructures, through the extraction and utilization of raw materials from nature to the dismantling of buildings and infrastructures and the management of the resulting waste. Sustainable construction is a holistic process that aims to restore and maintain harmony between the natural and built environment, while creating settlements that are worthy of human dignity and promote economic justice A major cause of the deterioration of the ecological order is harmful wastes in buildings. Architects and engineers should be made aware of this issue and new buildings should be designed and implemented in a way that will not harm nature and prevent global warming (Tavşan, Tavşan and Göksel, 2021). In order for the ecological balance to recover as soon as possible, everyone should approach this issue with the same sensitivity and most importantly, people should be made aware of the fact that we should leave a more comfortable world to our children than the one we inherited from our predecessors (Müftüoğlu, 2011). Today, the fact that the building sector consumes 50% of the raw materials obtained from nature, 40% of global energy and 16% of water, and is responsible for 50% of the waste generated, has brought the concept of sustainability in architecture to the agenda (Çelik, 2009). Intensive water and energy consumption, the chemical content of wastes, the fact that the quality of the interior space affects the treatment process of the patient and the risk of occupational error of the employees have caused the concept of sustainability in hospitals to be questioned. In this study, with the aim of determining the most effective sustainable criteria in hospitals, the concepts of sustainability and sustainable architecture were first mentioned and then the green features of the hospitals that received green certification were examined.

2. SUSTAINABLE ARCHITECTURE

Today, negative developments such as desertification, deforestation, acid rain, global warming, ozone depletion have started to be noticed and environmentalist approaches are developing in different fields against these environmental problems. Along with environmental problems, negative situations such as increasing poverty and inequality in income balance have paved the way for the emergence of the concept of sustainability (Özek Karadeniz, 2010). Sustainability is a concept that envisages that the functions of the social, economic and ecological system continue uninterruptedly without deterioration and consumption (Güney Karadişoğulları, 2013). The concept of sustainability consists of social process, economic prosperity and respect for the environment (Figure 1).

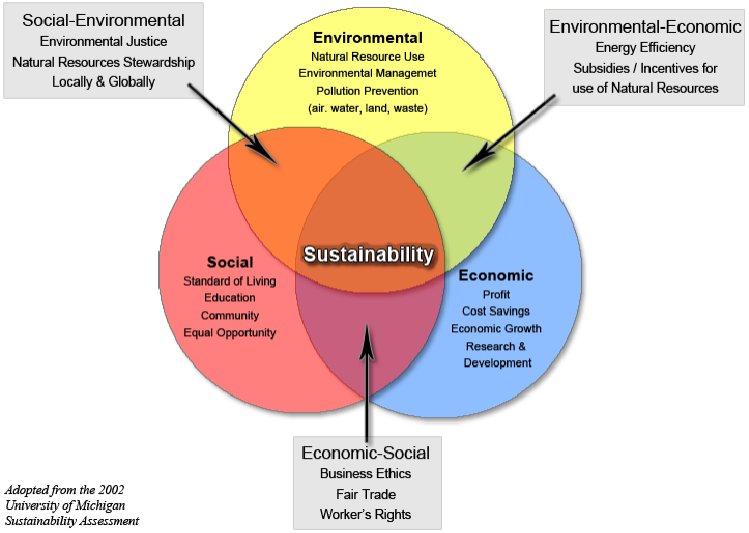

Figure 1. The tree spheres of sustainability (Morris, 2010)

Sustainable buildings protect and improve the health and productivity of users with their indoor quality, are sensitive to the consumption of natural resources during construction and use, minimize carbon emissions by using renewable energy sources, do not cause environmental pollution, save money by using energy, water and materials effectively, and create resources for other buildings after demolition or return to their place in nature without harming the environment (Tavşan, Tavşan and Bahar, 2021). Although the initial investment costs of sustainable buildings are usually expensive, they provide economic benefits when considered in the long term. For example, orientation and design according to the sun, detailing of the building envelope to provide heat conservation and natural lighting bring additional costs, while on the other hand, savings in electrical energy are achieved by downsizing the heating-cooling-ventilation system and reducing lighting costs (Tavşan and Bal, 2021). The aim of sustainable architecture is to reduce material, energy and water consumption, to select environmentally sensitive materials, not to engage in activities that will increase the emission of harmful gases, to use renewable energy resources, to provide healthy interiors for users. to provide environments and comfort conditions at optimum level, to reduce the environmental damage of waste (Demirel Etli, 2013). Design criteria for sustainable and ecological buildings can be classified under the following headings.

Designing buildings with simple plan types, small scales and compact forms ensures that they provide minimum heat gain on hot days and maximum heat gain on cold days in terms of energy conservation. Volume organizations should be made in order to minimize energy losses. For example, while positioning the spaces in the plan, placing the spaces that need heating on the south façade and considering the volumes with low heating requirements on the north façade. Building envelope design

with high thermal performance; elements such as walls, floors, windows and doors are the elements that separate the building from external factors and provide the passage of heat energy.

Optimal orientation of the building; It is possible to utilize the sun for heating, the prevailing wind for cooling and ventilation by positioning the buildings in the most appropriate way (Müftüoğlu, 2011). Energy efficient land use; It provides great benefits from resources and energies by using natural materials on the land where the building will be built and pre-existing structures in the environment. Choosing energy-efficient materials; choosing low-energy materials without compromising durability and other performances in buildings is an environmental approach (Miller and Ip, 2013). Use of Renewable Energy Sources; Energy sources that are used by all living things in the world and are accepted to be inexhaustible thanks to their renewable feature are called renewable energy sources. These energy sources both pollute the environment less and reduce the need for limited resources. Use of Recyclable Materials; Although new processes such as dismantling, collecting, grouping and obtaining a new product are required for the materials and elements used in the building to be recycled after their use for various reasons, their reuse will provide a lot of environmental benefits (Gao, Ariyama, Ojiyama and Meier, 2001). Water efficient building design; The fact that the water problem has reached serious values in some regions has caused some measures to be taken. Thus, the building has been given an ecological characteristic. For example, the use of low-consumption installations and tools in the building, collecting and using rainwater, recycling and reusing wastewater, water-efficient landscape design and keeping the amount of water to be spent for the maintenance of plants to a sufficient extent providing comfort conditions inside the building; Ecological buildings are buildings with suitable environment and comfort conditions for human health. The comfort conditions sought within the building are thermal, visual and auditory comfort conditions and indoor air quality. Protection of plants and animals; The formation of the landscape around the building is caused by the prevailing wind direction and the climate of the region. If we interfere with the slope of the land, we disturb the natural balance. Over time, this will lead to landslides, climatic deterioration, and damage to the generations of plants and animals. For this reason, it is an environmental practice to preserve the existing vegetation in the design area as much as possible and to utilize them for indoor air conditioning (Müftüoğlu, 2011).

As the titles suggest, sustainability in architecture is a comprehensive field that needs to be addressed from multiple perspectives, extending to architecture, interior architecture, landscape architecture and urban design. For a building to be sustainable, it will not be enough to have one of these titles. If the

structural features cover many of the above-mentioned topics, we can talk about sustainable architecture.

3. LEED CERTIFICATED HEALTHCARE BUILDING DESIGN

LEED has emerged as an environmental movement originating in the United States of America (USA); it is the world's most comprehensive responsibility project that works for individuals to achieve a healthy quality of life by producing market-compatible and environmentally friendly buildings; and offers buildings that aim to reverse the changes in the climate as a result of the damages caused by the construction industry. LEED certification is a system developed by the United States Green Building Council (USGBC) in 1998 and stands for Leadership Energy Environmental Design. The system aims to protect nature and natural resources to minimize the negative impacts of buildings and neighborhoods on the environment (USGBC, 2009). Worldwide, projects certified as health care facilities total 1,668. 1,376 health care facilities certified under LEED for Building Design and Construction (LEED BD+C), 259 health care facilities certified under LEED for Interior Design and Construction (LEED ID+C) and 36 health care facilities certified under LEED for Operations and Maintenance (LEED O+M). The majority of health space certifications fall under LEED BD+C, where the U.S. leads in gross square footage with a share of almost 68%, followed by Canada, with about 17% (Jhunjhunwala, 2023). Here are the top five:

- United States: 1,088 projects; nearly 147 million square feet
- Canada: 150 projects; over 36 million square feet
- United Arab Emirates: 7 projects; over 5 million square feet
- China: 11 projects; over 5 million square feet
- Turkey: 13 projects; over 3 million square feet

Since hospitals operate 24/7 and use many energy-consuming equipment, hospital buildings consume more energy compared to offices and residences of the same size. In hospitals, energy consumption is reduced by using renewable energy sources, energy-saving lighting elements, and natural ventilation in addition to mechanical ventilation. Since hospital wastes are infectious and toxic, they pose a danger to employees, patients and society. Recycling or reuse activities should be implemented to reduce the environmental impact of these hazardous wastes. If these cannot be done, less hazardous products should be selected instead of hazardous products or hazardous wastes should be disposed of in accordance with the regulations (Özkan, Bayın and Terekli, 2014). Hospital wastewater can be classified in two groups: domestic wastewater from units such as kitchens and laundries and hospital-

specific wastewater generated as a result of diagnosis, treatment and research activities. Since hospital-specific wastewater contains hazardous pollutants, it must be treated on-site before being directed to the sewage system of the region where it is located (Top and Bilgili, 2012). Along with the control of wastewater, water use is made efficient with activities such as reducing unnecessary water consumption, ensuring the use of rainwater by treating rainwater, landscaping with plants and trees that consume less water (Özkan et al., 2014). Sustainable hospitals are not only environmentally sensitive but also ensure that patients and staff are physically and psychologically comfortable. Factors such as optimum daylight utilization, indoor air quality, landscape, ergonomics, acoustics are effective in the duration of the patient's stay in the hospital, stress conditions of patients and their relatives, and increased productivity of the staff. In addition, indoor air quality prevents infections in the hospital (Özkan et al., 2014).

4. METHODOLOGY

In this study, the most effective sustainable criteria in hospitals are examined. As a method, the concepts of sustainability, sustainable architecture and sustainable hospitals defined in the literature were investigated. The green features of the hospitals certified through the sustainable criteria of Leed and Bream, which are the most common and richest certificates, are examined. As a source, books, articles, theses, dissertations, scientific publications and databases published on the subject were utilized.

The density ranking of LEED certified hospital buildings by country is as follows: USA, Canada, United Arab Emirates, China and Turkey. Therefore, hospital buildings located in the United States of America, which has the highest number of LEED certificates, were selected for the study. Another selection criterion was the LEED certification of Gold, Platinum and above. The construction years of the buildings were taken as 2000 and later.

Selected buildings analyzed, management, energy and atmosphere, material, indoor environmental quality, water, transportation, land and ecology, innovation, pollution, waste management as main items; land management and procedures, use of existing buildings within the site, use of renewable energy, use of low energy, basic climate management, energy sub-metering, energy efficiency in building systems, recycled materials, environmentally sound and healthy materials, local materials, durable materials, indoor air quality, smoke control, lighting design, daylight management, natural ventilation, thermal comfort, acoustics, health and comfort, water consumption reduction and equipment, efficient use of water, water recycling, pedestrian and cyclist facilities, transportation facilities, public transportation facilities, electric vehicle charging station, use of building area,

ecological conservation, plant selection, regional importance, innovative system, additional function, outdoor light pollution, reducing harmful gas emissions, indoor pollution source control, waste material, waste water management, prevention of construction-related pollution as subheadings.

5. FINDINGS

Today, buildings are defined and categorized by various green building certification systems to assess their environmental performance. These systems provide a measurable reference to objectively demonstrate the impact of building projects on the environment and to determine their sensitivity in protecting natural resources. Since the criteria that make a building green are defined with certification systems, it is possible to know in which respect and to what extent a certified building is green. However, it should be kept in mind that the selection of the green building valuation system should be made correctly, otherwise negative results may be obtained in terms of applicability and cost. For this reason, regional differences such as climatic conditions, materials and techniques should not be ignored when selecting and implementing international certification systems (Karaca, Atılgan and Zekioğlu, 2018).

LEED certificates are basically awarded under 5 main categories. These are sustainable landscapes, water efficiency, energy and atmosphere, indoor quality and use of materials and resources (Tavşan and Yanılmaz, 2019). Sustainable landscapes include land management and procedures and the use of existing buildings within the site. Pedestrian and bicycle paths, accessibility for all types of pedestrians and vehicles, parking facilities and proximity to public transportation, easy accessibility can also be addressed within the scope of sustainable landscapes. In addition, charging stations for electric vehicles, one of the recently widespread sustainable vehicle systems, are also included in some LEED-certified healthcare buildings.

In the water efficiency category, both the recycling of wastewater and the reduction of water consumption are addressed. The use of equipment that reduces water consumption in building design and the efficient use of water is an important element both in terms of sustainability and during LEED certification processes. Energy and atmosphere, which are both among the LEED certification criteria and an indispensable part of sustainable building and interior design with the rapid depletion of natural resources, is an issue that needs to be addressed in a wide scope. For this reason, the use of renewable energy sources, the use of low-energy equipment and systems in energy-consuming structural functions are very important in the buildings considered within the scope of the study. In addition to these, the use of advanced air conditioning systems and energy measurements at certain intervals are also necessary. Indoor quality is divided into many sub-categories. Daylight

management and lighting design in relation to daylight, natural ventilation, thermal comfort and acoustics also play a role in ensuring indoor quality. Similarly, light pollution caused by daylight and the control of pollution sources in the context of reducing the emission of harmful gases are also related to indoor quality. Finally, it is important for sustainable buildings that the materials selected in both building design and interior spaces are environmentally friendly and healthy. Obtaining materials from the environment depending on the building location contributes to sustainability as well as reducing the cost. Another factor in material selection is the use of recycled materials.

The names, construction years, locations, areas, designer architectural offices and LEED certificates of the 11 healthcare buildings determined by applying the selection criteria within the scope of the study are given in Table 1. The health buildings were built between 2006 and 2019 and their areas vary from 8.008 m² to 129.228 m².

Table 1
LEED Certificated Healthcare Buildings

No	Name	Year	Location	Area	Architect	Leed Certification
1	OHSU: Center for Health and Healing	2006	Portland, USA	47.438 m²	ZGF Architects	LEED 2009 Healthcare Gold
2	Providence Newberg Medical Center	2006	Oregon, USA	16.350 m²	Mahlum	LEED-NC 2.1 Gold
3	Dell Children's Medical Center	2007	Texas, USA	8.008 m²	Karlsberger	LEED 2009 Healthcare Platinum
4	El Camino Hospital	2009	California, USA	5.188 m²	KMD	LEED 2009 Healthcare Gold
5	West Kendall Baptist Hospital	2010	Florida, USA	32.244 m²	Wilmot Sanz	LEED-NC 2.2 Gold
6	Johnston Memorial Hospital	2011	Abingdon, USA	21.367 m²		LEED-NC 2.2 Gold
7	Katz Women's Hospital	2011	New York, USA	27.406 m²	Skidmore, Owings & Merrill	LEED ID+C, LEED BD+C
8	Nemours Children's Hospital	2012	Florida, USA	55.236 m²	Perkins&Will	LEED-NC 2.2 Gold
9	Eskenazi Health Downtown Campus	2013	Indiana, USA	129.228 m²		LEED-NC 2.2 Gold
10	Methodist Olive Branch Hospital	2013	Mississippi, USA	18.420 m²	GSP	LEED 2009 Healthcare Gold
11	Washington Adventist Hospital	2019	Maryland, USA	39.019 m²	CallisonRTKL	LEED 2009 Healthcare Gold

Health structures are analyzed in Table 2 within the framework of 10 main categories and 38 sub-categories. According to Table 2, OHSU: Center for Health and Healing provided the subheadings of converted material, environmentally friendly and healthy material, local material and durable material in the material category. Together with Methodist Olive Branch Hospital, it is the only health structure that met all the headings in the materials category. OHSU did not do well in the transportation and innovation categories. Providence Newberg Medical Center meets most items in the energy and

atmosphere and material categories but does not do as well in the remaining categories. It does not meet any of the items in the transportation category. Dell Children's Medical Center conducts important studies on the efficient use of materials and water, and water recycling. Dell Children's Medical Center, which is also weak in transportation, has an effective design in external light pollution, reducing the emission of harmful gases and indoor pollution source control. This shows that it is capable of improving indoor quality. El Camino Hospital is not successful in the areas of energy and daylighting, but it is successful in the areas of transportation and efficient use of water. West Kendall Baptist Hospital provides the highest number of categories out of 10 main categories and 38 subcategories in sustainability. It meets all subcategories in the transportation area, as well as many of the headings in the areas of interior quality and efficient use of materials. Katz Women's Hospital, on the other hand, is quite deficient in the areas of efficient use of water, transportation and innovation. However, it has studies on the effective use of materials and the inclusion of recycled materials in the design. Nemours Children's Hospital, while giving importance to interior quality, also includes the effective use of materials. Water recycling, low water consumption, ecological conservation and plant selection are also important. In addition to using the land efficiently, it also draws attention with the abundance of green areas. Eskenazi Health Downtown Campus is a large-scale project that emphasizes the efficient use and recycling of materials and water. However, despite its large area, it has weaknesses in the areas of use of renewable energy and low energy use. Like Katz Women's Hospital, Methodist Olive Branch is another hospital that is far behind in the areas of water and waste management, transportation, land and ecology, and innovation. In addition to the categories in which it falls short, it also has efforts in the areas of efficient use of materials, indoor quality, and energy. Washington Adventist Hospital, on the other hand, has a very balanced design with at least one sub-category in each main category (Table 2).

Table 2
Sustainability Criteria for LEED Certificated Healthcare Buildings

BUILDING NO		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Management	A1	■	■	■	■	■		■	■	■	■	■
	A2											
Energy and Atmosphere	B1	■	■		■	■		■			■	■
	B2	■	■	■	■		■	■	■		■	■
	B3		■									
	B4											■
	B5		■			■	■	■	■		■	■
Material	C1	■	■	■			■	■	■	■	■	
	C2	■	■	■	■	■	■	■	■		■	■
	C3	■		■	■	■	■			■	■	■
	C4	■	■	■		■	■	■	■	■	■	
	D1	■	■	■	■	■	■	■	■		■	■

Indoor Environment Quality	D2					■						
	D3	■	■	■		■	■			■	■	
	D4	■	■					■	■	■	■	
	D5				■							■
	D6	■			■	■	■	■	■		■	■
	D7							■				
	D8	■	■	■	■	■	■	■	■	■	■	
Water	E1		■	■	■	■	■	■	■	■		■
	E2	■	■	■	■	■			■	■		■
	E3	■	■	■						■		
Transportation	F1	■			■	■			■			
	F2				■	■						
	F3				■	■						■
	F4					■			■	■		■
Land and Ecology	G1				■							
	G2	■		■		■	■		■	■		■
	G3		■	■	■	■	■		■			
Innovation	H1											
	H2		■		■	■			■	■		■
	H3									■		
Pollution	J1		■									
	J2	■	■	■		■	■	■	■		■	
	J3	■	■	■	■	■	■	■	■		■	
Waste Management	K1	■										■
	K2											
	K3	■		■	■	■	■	■	■	■		■

A1: Land management and procedures
A2: Utilization of existing buildings within the area
B1: Use of renewable energy
B2: Low energy use
B3: Basic air conditioning management
B4: Energy sub-metrics
B5: Energy efficiency in building systems
C1: Converted material
C2: Environmentally friendly and healthy material
C3: Local material
C4: Durable material
D1: Indoor air quality
D2: Cigarette smoke control
D3: Lighting design
D4: Daylight management
D5: Natural ventilation
D6: Thermal comfort
D7: Acoustic
D8: Health and comfort

E1: Water consumption reduction and equipment
E2: Efficient use of water
E3: Recycling water
F1: Pedestrian and cyclist facilities
F2: Transportation facilities
F3: Benefiting from public transportation facilities
F4: Electric vehicle charging station
G1: Use of building space
G2: Ecological conservation
G3: Plant selection
H1: Regional importance
H2: Innovative system
H3: Additional function
J1: External light pollution
J2: Reducing the emission of harmful gases
J3: Indoor pollution source control
K1: Waste material
K2: Waste water management
K3: Prevention of pollution from construction

6. RESULTS

The use of eco-friendly green buildings not only in offices, shopping malls, residences, factories and hotels, but also in hospitals, which are in use 24/7 and consume large amounts of energy, food and medical supplies to provide high quality care, are a major source of pollution worldwide, have a large and costly carbon footprint, reduce pollution, waste and inefficiency in the health sector, and provide financial and ecological benefits, enabling the creation of sustainable health infrastructure.

When the LEED certified buildings in healthcare buildings are examined, we see that the recycling of materials, the use of environmentally sensitive and local materials are at the forefront. Although

more than half of the 11 health buildings examined have studies on the efficient use of water, no studies on water recycling were found. In healthcare buildings, which are one of the buildings where energy is consumed every day and every hour of the week, it should be aimed to reduce energy consumption and increase renewable energy consumption, but in healthcare buildings with LEED certification, the energy required for artificial lighting and equipment where electrical energy is consumed intensively is not obtained from sustainable sources.

Another factor to be considered in health buildings is ease of transportation. The relationship between ambulances and vehicles and roads is an indispensable element in sustainable healthcare buildings. In the analyzed buildings, it was observed that this situation was not taken into consideration in health buildings except El Camino and West Kendall Baptist hospitals. In addition, healthcare buildings are the primary building type where many chemical wastes are generated. Only OHSU and Washington Adventist hospitals have practices on waste recycling in the health buildings analyzed.

Healthcare buildings serve many different patients with inpatient or outpatient intervention. Indoor quality is very important especially in healthcare buildings with hundreds of rooms for inpatients. As a result of the study, it was seen that LEED certified healthcare buildings meet the sub-headings of indoor air quality, thermal comfort, acoustics, reducing the emission of harmful gases and indoor pollution source control.

As a result, healthcare buildings with LEED certification give importance to the efficient use of materials and water and indoor quality, but not to the use of natural resources and transportation. In order for a building to be sustainable, the use of natural resources for energy production and recycling of waste are issues that cannot be ignored, especially in healthcare buildings.

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The article complies with national and international research and publication ethics. Ethics Committee permission was not required for the study.

Conflict of Interest Declaration

The authors declare no conflict of interest.

Contribution Rate Declaration Summary of Researchers

The authors declare that they have contributed equally to the research.

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