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Enhancing Sustainability Benefits through Green Retrofitting of Healthcare Buildings

Aslihan Ergin [1], Isilay Tekce [2]

[1] Istanbul Commerce University, Architecture and Design Faculty, Kucukyali District, Inonu Street. 34840, Kucukyali Campus, Istanbul, Turkey
[2] Özyegin University Architecture and Design Faculty, Nişantepe District, Orman Street, 34794, Cekmekoy Campus, Istanbul, Turkey

aergin@ticaret.edu.tr

Abstract. Green retrofitting practices have critical importance in both the construction industry (CI) and healthcare industry (HI) due to the adverse effects of the existing healthcare buildings on both the environment and public health. Ironically, existing healthcare buildings consume critical amounts of energy, produce wastes, and CO_2 emissions, which have considerable diverse harmful impacts on the health and well-being of the society as well as the environment. Especially, given the main goals of healthcare, green retrofitting is crucial to provide a healthy future for patients and staff of healthcare buildings. There is a sensitive link between providing sustainable healthcare buildings with improving health of the patients. Therefore, green retrofitting of healthcare buildings (GRHB) can be seen as one of the significant contributors that have a critical role in reducing the harmful impacts of the existing healthcare buildings. Nowadays, due to coronavirus pandemic, nations will focus on the physical conditions of their healthcare buildings more than ever for strengthening their infrastructure with appropriate retrofitting approaches. Therefore, the worldwide concerns put the prominence of the importance of patient safety and strong health infrastructure on the agenda of nations. Improvements in the health infrastructure are inevitable for the future, and with regarding this motivation, we looked at the benefits of GRHB in the first place. In the existing literature, there is a lack of comprehensive review associated with the GRHB. This paper focuses on conducting a systematic literature review to investigate the benefits of GRHB with selected academic studies. After the identification of healthcare and green retrofitting specific studies, the benefits of GRHB were determined by frequency analysis and classified under four dimensions, which are environmental, economic, social, and functional. Results demonstrated that reduced energy consumption, reduced costs, and improved energy performance of the building are the three major benefits. In terms of healthcare perspective, the critical outcomes of this study as the main benefits differ from other types of green retrofitting projects, which are improved infection control and improved recovery rate. The results of this systematic review will enhance the understanding of the importance of GRHB and its benefits, which will be useful for academics, green building professionals as well as healthcare building providers.

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1. Introduction

Today, nations are facing a severe health crisis to trying to deliver the necessary care due to the coronavirus pandemic disease which is also known as COVID-19, which has put new pressures on already strained national health systems [1]. Changes in disease patterns, medical intervention opportunities with advanced technology, as well as political and public expectations put healthcare buildings on changing pressures [2]. Under these circumstances, how healthcare service is provided is one critical point since new conditions in healthcare require new configurations of buildings [2]. Ultimately, the coronavirus pandemic is raising questions about the importance of increasing investment in healthcare infrastructure to have better servicecapacity such as flexible rooms and spaces [3]. Therefore, nations will focus on the physical conditions of their healthcare buildings more than ever.

Indeed, enhancing the health and well-being of occupants emerges a critical case, especially for healthcare buildings, since the fundamental aim of their existence is to improve the health of society [4]. For this reason, sustainability and creating green healthcare buildings will become a substantial concern for the HI [5]. Environmental health and human health are sensitively linked, and this link demonstrated that providing environmental-friendly buildings influences on human health enhanced with changing circumstances [6]. Not surprisingly, the number of green healthcare buildings' implementations gained a rapid increase worldwide [4]. As a result of this movement, green healthcare buildings became a significant consideration for this research due to the rapid increase of green hospital implementations.

Ironically, the activities of healthcare itself consume critical pollution to air, water, and soils, consequently, indirect adverse effects on public health [7]. The reality is that creating new environmentally friendly buildings solely does not reduce the environmental effects of the existing building stock since they are not sustainably built [8, 9]. Hospitals or healthcare facilities around the world can be defined as an energy-intensive building type that contributes substantially to environmental impacts while accidentally leading to diseases and adverse health outcomes [10]. Consequently, healthcare buildings have significant scope in the building industry in terms of healthcare-specific requirements. Typical healthcare buildings operate seven days a week and 24 hours a day and support care and treatment for people who are sick and vulnerable [11]. In this context, healthcare buildings require stringent control of IAQ, diseases, medical equipment, and waste management [12] and also require the protection of patients and staff against hospital-acquired contaminations and occupational illnesses [13]. Healthcare buildings cause environmental damage and depletion of natural resources with their current situation [14]. Bilec et al., [6] claim that the facilities and operations of healthcare organizations push healthcare organizations into a complicated position in which they are negating their fundamental role of "first do no harm" by failing to minimize their environmental damage.

According to the energy consumption study of healthcare buildings in the USA, healthcare buildings represent 4.8% of the total area in the commercial sector as well as responsible for 10.3% of total energy consumption in this sector [15]. In England, the HI responsible for 18 million tonnes of CO_2 emissions that represent the 30% of total public sector greenhouse gas emissions as well as 3.2% of the total CO2 emissions [16]. The energy consumption and emissions by healthcare buildings cause an increasing burden of illness such as cardiovascular, asthma, and other respiratory diseases [9].

Especially, in terms of the main goals of healthcare green retrofitting is crucial to provide a healthy future for patients and staff of healthcare buildings. Destroying existing healthcare buildings and constructing new ones is not an appropriate way to achieve sustainable healthcare facilities and minimize the harmful outcomes of the HI on the built environment [17]. When energy, water, and materials get taken into consideration, an existing building's retrofit has a considerable positive impact on enhancing the well-being as well as the health of patients, the building's performance, and financial returns [18]. Therefore, GRHB can be seen as one of the significant contributors that have a critical role in not only improving the quality of cure for sick people but also in keeping the health of doctors

and nurses who apply the treatment at the same time. Notably, healthcare facility retrofitting projects are also challenging because of their disturbing nature for patients [19].

The interest associated with the GRHB in the existing literature has been growing. Hence, this paper focuses on conducting a systematic literature review of selected academic studies to the identification of the benefits of GRHB.

2. Research Methodology

This research includes the systematic and structured review process of literature by focusing on related articles on GRHB. Designing the search strategy is the curial part of any study. According to the conducted study by Tober [20], about search engines, the Scopus search engine was identified as the most efficient search engine for the literature review of selected research subjects. Hence, to determine the relevant studies for GRHB, the Scopus search engine was selected to conduct the systematic literature review.

The keywords for searching were identified as "benefit," "green retrofit," and "retrofit," "healthcare building," and "hospital building." These keywords were searched under the title, abstract, and keyword section of the selected search engine with a chosen time limit 2000 to 2020. Searching was done with various combinations of the chosen keywords to identify benefits (Shown in Table 1).

Table 1. Combinations of searching keywords

Combinations of search keywords	
"green retrofit"	"retrofit"
"green retrofit" and "benefit"	"retrofit" and "benefit"
"green retrofit" and "healthcare building"	"retrofit" and "healthcare building"
"green retrofit" and "hospital building"	"retrofit" and "hospital building"
"green retrofit" and "benefit" and "healthcare building"	"retrofit" and "benefit" and "healthcare building"
"green retrofit and benefit and hospital building"	"retrofit" and "benefit" and "hospital building"

Initially, based on conducted structured literature search in the Scopus engine (searched on Feb 2020), firstly, a total of 372 articles were identified. A closer look to the identified articles has revealed that some of the articles involved at least one of the selected keywords for this research in their title or abstract or keywords. Then, 372 papers were arranged in alphabetical order, and the articles with the same name were extracted.

As a result of the elimination process, 100 papers were left. Through the screening of abstracts, titles, and keywords of 100 papers' names, a total of 62 papers were identified relevant for defined keywords. With an in-depth review of the full text of a selected 62 papers, 56 papers were found as relevant for this study in the fourth step. Lastly, investigating the selected relevant papers, only 56 papers were included for the identification of benefits (Shown in Table 2).

Table 2. The prisma flow diagram for the identification of the relevant papers

Identification	Records identified through Scopus searching (n =372)
Screening	Records after duplicates removed (n=100)
Screening	Records screened abstract-title-keywords (n=62)
Screening	Full-text articles assessed for eligibility (n=56)
Included	Articles included in the analysis (n=56)

After the identification of healthcare and green retrofitting specific studies, the benefits of GRHB were determined and classified under four dimensions, which are environmental, economic, social, and functional. To classify the obtained benefits, frequency analysis was used. The main dimensions were taken from the researchers who made the classification in the literature namely, [1], [4], [20], [26], and [29]. Table 3 represents all dimensions obtained from the existing literature.

Table 3. Main dimensions for the benefits of GRHB in the literature.

Main Dimensions	Resources				
	[22]	[28]	[39]	[67]	[78]
Economic	x	x	x		x
Environmental	x	x	x		x
Social	x				x
Functional				x	
Technical				x	
Organizational				x	
Health and Community	x				

3. Identification of Benefits of GRHB

The main objective of this study is the investigation of the key benefits of GRHB, that are promoted the green retrofitting implementation in healthcare buildings. The review of selected studies in the Scopus search engine includes investigating the benefits of GRHB. According to reviewed literature, twenty-three benefits were determined (Shown in Table 4). The identified benefits in Table 4 were listed by the frequency of availability in the searched literature. Results demonstrated that "reduced energy consumption", "reduced costs", and "improved energy performance of the building" are the three major benefits that most reported in the literature.

3. 1. Classification of Benefits of GRHB

As demonstrated in Table 4, the various benefits, which have a critical role in promoting green retrofitting implementations in healthcare buildings, are identified by a comprehensive review of previous studies. To gain a better understanding of the benefits of GRHB, the classification of identified benefits is essential. To classify the determined benefits, the normative refinement process and frequency analysis was used. As shown in Table 5, identified twenty-three benefits were classified under four main dimensions which are "environmental", "economical", "social" and "structural". Table 5 demonstrates the classification of benefits of GRHB under environmental, economic, social as well as structural dimensions.

3.1.1. Environmental Dimension

The investigation of the benefits of GRHB demonstrated that there are various benefits associated with green retrofitting practices in healthcare buildings. From the environmental perspective, the structured literature review demonstrates that green retrofitting involves thirteen significant impacts of healthcare buildings (Shown in Table 5). GRHB is an effective way of enhancing the environmental performance of existing buildings to achieve energy saving [77]. Especially, improvement of energy efficiency and reduction of CO2 emissions are considerable outcomes of green retrofit design of the existing buildings [67, 69]. Healthcare buildings generate large amounts of wastes thus they are the critical sources of greenhouse emissions [32]. Environmental impacts of healthcare buildings can be turned into significant benefits for both building and human health aspects. According to Eckelman and Sherman [7], reduced waste and greenhouse emissions have considerable advantages that are improved environmental performance and enhanced the quality of healthcare. Another substantial environmental benefit of green retrofitting for the healthcare buildings is the improvement of indoor environmental quality [22, 54, 60, 64, 72]. From the healthcare perspective, providing a healthy indoor

environment to the occupants of healthcare buildings has a direct impact on reducing infections, patient safety as well as recovery rates of patients [4]. As a result, the implementation of GRHB is beneficial from the environmental perspective.

Table 4. Benefits of GRHB

Benefits of GREHB		References	Total
1	Reduced energy consumption	[8], [26], [27], [31], [33], [37], [41], [43], [49], [51], [57], [59], [62], [65], [66], [70], [71], [73], [74], [77]	20
2	Reduced cost	[8], [22], [23], [25], [26], [30], [31], [33], [36], [39], [40], [47], [51], [53], [55], [56], [74], [75], [78]	19
3	Improved energy performance of the building	[21], [25], [38], [41], [42], [44], [47], [54], [56], [61], [64], [74], [77], [78]	14
4	Improved energy efficiency	[21], [26], [29], [30], [36], [40], [45], [50], [63], [66], [69], [74]	12
5	Achieved energy savings	[28], [36], [39], [40], [52], [55], [58], [68]	8
6	Reduced greenhouse gas emissions	[8], [27], [32], [49], [59], [62], [78]	7
7	Reduced CO2 emissions	[25], [32], [50], [55], [69], [74], [77]	7
8	Improved indoor environmental quality	[4], [22], [54], [60], [64], [72], [74]	7
9	Improved health and wellbeing	[4], [6], [22], [60], [66], [74], [76]	7
10	Improved infection control	[4], [6], [14], [19], [29], [79]	6
11	Improved thermal comfort of occupants	[21], [29], [37], [60], [74], [76]	6
12	Improved productivity and satisfaction	[4], [6], [22], [66], [76]	5
13	Improved recovery rate	[4], [5], [6], [19], [76]	5
14	Improved patient safety	[19], [29], [32], [79]	4
15	Improved indoor air quality	[19], [22], [53], [78]	4
16	Rapid payback periods	[8], [24], [74], [75]	4
17	Reduced seismic risk	[34], [35], [46], [48]	4
18	Improved environmental protection	[30], [44], [75]	3
19	Reduced waste	[22], [25], [32]	3
20	Reduced water consumption and quality	[8], [21], [78]	3
21	Improved visual comfort	[22], [76]	2
22	Reduced polluting emissions	[31]	1
23	Reduced the noise level	[21]	1
24	Financial viability	[24]	1
25	Improve hospitals ‘resilience	[29]	1
26	Reduced resource consumption	[72]	1

3.1.2. Economical Dimension

From the economical perspective, green retrofitting has resulted in three primary outcomes that are reduced costs of the existing building, rapid payback periods, and financial viability. Jagarajan et al. [78] stated that green retrofitting of existing buildings particularly has a lower cost than demolishing existing ones or constructing new ones. Zuo and Zhao [74] pointed out that the improved energy performance of the buildings contributes to the significant cost savings, notably in terms of the life cycle of the buildings. Also, they [74] added that cost savings provide optimized the costs of operation and maintenance of buildings. Green retrofitting has not only benefits on cost savings from achieved energy savings but also has significant impacts on the economic value of buildings and that has provided the rapid payback period [75].

3.1.3. Social Dimension

Green retrofitting has critical social advantages including health and community benefits for healthcare buildings. It also considers the societal and cultural assets that already exist in the built

environment [78]. Zuo and Zhao [74] stated that the social dimension primarily contains providing quality living conditions, health, and well-being as well as the safety of building occupants. The existing studies demonstrated that green retrofitting not only assists the improvement of building environmental performance but also assists the improved infection control, the recovery rate of patients, thermal comfort of occupants, health and wellbeing of patients, the safety of patients, productivity and satisfaction of building occupants [4, 5, 6, 19, 22, 32, 60, 66, 74, 76 and 79]. Improved indoor environmental quality and provided suitable quality conditions contribute to improving health conditions and productivity of occupants [74]. In addition, reduction of the noise level [21] and improvement of visual comfort [22] are other significant benefits that have a detrimental effect on recovery rates of patients and staff morale [76]. Also, Dalke et al. [84] noted that a well-balanced and attractive environment has considerable impacts on both the health of the patients and the productivity of employees. Further, the satisfaction of patients and employees of healthcare buildings is highly related to the suitable thermal comfort conditions [74]. Therefore, it can be stated that the benefits of green retrofitting interconnected closely with each other.

Table 5. The classification of benefits of GRHB

Main Dimensions	**Benefits of GREHB**
Environmental	Reduced energy consumption
	Improved energy performance of the building
	Improved energy efficiency
	Achieved energy saving
	Reduced greenhouse emissions
	Reduced CO_2 emissions
	Improved indoor environmental quality
	Improved environmental protection
	Reduced water consumption
	Improved indoor air quality
	Reduced waste
	Reduced polluting emissions
	Reduced the noise level
	Reduced the production of solid waste
	Improved visual comfort
	Reduced environmental impacts
	Land preservation
	Forest preservation
	Reduced air quality
	Reduced water quality
	Reduced resource consumption
Economic	Reduced cost
	Rapid payback periods
	Financial viability
Social	Improved health and wellbeing
	Improved infection control
	Improved thermal comfort of occupants
	Improved productivity and satisfaction
	Improved recovery rate
	Improved patient safety
Functional	Reduced seismic risk
	Improve hospitals' resilience

3.1.4. Functional Dimension

The functional dimension of retrofitting considers "the reduction of the seismic risk of healthcare buildings" and "the improvement of hospitals' resilience" to maximize the safety of occupants of healthcare buildings and minimize future structural damages. Due to the critical role of healthcare buildings in the management of emergency response, they have to be designed and built to have high-performance levels under strong ground motions [35]. Ferraioli and Avossa [34]'s study about seismic isolation retrofitting of healthcare buildings demonstrated that healthcare buildings would remain operational after very strong earthquake ground motions. Therefore, the structural benefits have critical outcomes to mitigate the loss of functionality for healthcare buildings during future severe ground motions for understanding the benefits of green retrofitting projects with a specific focus on healthcare buildings and for future research on the subjects.

4. Discussion and Conclusions

This paper provides critical outcomes of a structured review of the benefits of GRHB in CI and HI. To highlight the findings of this study, similar green retrofit studies that are focused on other types of buildings such as offices, homes, etc. were discussed regarding the results of this study.

The findings showed that the benefits of GRHB can be divided into four different main dimensions respectively environmental, economic, social as well as functional. As a result, it was found that the most reported benefits of GRHB are reduced energy consumption, reduced cost, improved energy performance of the building, improved energy efficiency, achieved energy saving, reduced greenhouse gas emissions, reduced CO_2 emissions, improved indoor environmental quality, improved health and wellbeing, improved infection control.

A closer look to the identified benefits demonstrated that the most mentioned benefits by researchers are mainly based on environmental dimension such as reduced energy consumption, improved energy performance of the building, improved energy efficiency, achieved energy saving, reduced greenhouse gas emissions, reduced CO_2 emissions, improved indoor environmental quality.
In terms of the economic benefits, reduced cost, rapid payback periods, and financial viability have become the forefront. The social aspect of GRHB covers mainly maintaining the infection control, the thermal and visual comfort of healthcare building' occupants, the recovery rates of patients, the productivity of healthcare staff, and patient safety. Indeed, it can be stated that the determined social benefits of GRHB are also supportive drivers for the fundamental aims of healthcare buildings. Additionally, as a functionality issue, the seismic strength of the building is essential for the health and well-being of all the patients and staff.

In terms of office buildings, green retrofitting is also a critical issue for business strategy of companies. Tobias [80] noted that companies will need to keep their position in competitive in a marketplace to achieve that objective; they need to consider green retrofits as part of their plans. Improved energy efficiency, the high environmental performance of buildings, reduced usage of water are the main similar considerations of green retrofitting of commercial buildings [67]. Furthermore, it is significant that from an economic perspective, to mitigate the operation costs from lighting, cooling, and heating of buildings, green retrofitting is a critical approach [81]. Ilter et al. [82] stated that green retrofitting is not only provides considerable energy savings and operation cost benefits but also improve the health and comfort of building' occupants that lead to increased occupants' productivity and satisfaction**.** Similarly, Paradis [81] specified that improved indoor environmental quality contributes to enhanced productivity as well as the health of occupants, and also occupant safety and accessibility are critical outcomes for green retrofit projects. Aforementioned studies regarding the other types of buildings show that green retrofitting studies have similar outcomes with healthcare buildings' green retrofit.

However, green retrofitting actions in healthcare buildings are more critical than other types of buildings since healthcare buildings require special consideration. The ironic truth is that with their non-stop 7/24 operations that consume a high amount of energy, they try to provide the health of society. [19] states that poor environmental design of healthcare buildings is a greater risk for patients

and staff since it can be resulted in acquiring hospital-associated infections (HAIs) and increasing patient' staying days in hospitals. During green retrofitting providing health and safety standards for patients is significant due to the potential of disturbing for patients such as dissatisfaction and discomfort [19]. With the application of GRHB, healthcare buildings improve their environmental performance that also contributes critical outcomes, especially for the healthcare environment. The structured literature review demonstrated that the main differentiated benefits of GRHB than other types of buildings are; a. Improved infection control, b. Improved recovery rate of patients (hospital stays)

It can be stated that differences exist between the green retrofit studies in healthcare buildings and other types of buildings are mainly related to the main consideration of healthcare buildings is sensitive to health and well-being. Results of this study highlighted the significance and differences of investigation of the benefits of GRHB specifically for the healthcare environment. Consequently, this structured literature review will be constructive for understanding the benefits of green retrofitting projects, specifically focus on healthcare buildings and for future research on the subject.

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