sustainability

Review

Sustainable Building Standards, Codes and Certification Systems: The Status Quo and Future Directions in Saudi Arabia

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Abstract: Sustainable building practices are a response to environmental issues. Businesses and industries are assessing how their activities affect the environment. The architecture, engineering and construction (AEC) industries have significant impacts on the environment and economy, while the industry is considered one of the largest contributors to greenhouse gas (GHG) emissions and has, therefore, been highlighted by researchers as a key area of intervention with a great potential to reduce environmental impacts. This paper critically reviews and evaluates the current state of sustainable building certification systems with the purpose of having a good understanding of the status quo and possibilities for future directions in Saudi Arabia. It reviews the academic literature on Saudi Arabia's green/sustainable building codes, standards, certification systems, methods and tools. It starts by addressing sustainability in the broadest sense. Then, it investigates sustainability strategies and evaluates the building certification systems in Saudi Arabia, followed by an introduction to the new practice of sustainable healthcare building assessment. Life cycle assessment (LCA) and building information modelling (BIM) techniques have also been investigated. The paper introduces the updated Saudi Building Code (SBC) with further evaluation of the Saudi Green Building Code (SBC 1001-CR). Finally, the paper clearly highlights the key role of sustainable building practices and the need to develop a certification system that considers the new trends and the local context.

Keywords: buildings; sustainability; sustainable building; green building; assessment tools; construction; life cycle assessment

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1. Introduction

As humanity's environmental impact increases [1], businesses and industries are assessing how their activities affect the environment and "'greening" products, processes and services are a response to environmental issues. Meanwhile, the architecture, engineering and construction (AEC) industries have significant impacts on the environment and the economy [2]. Hence, the industry is considered to be one of the largest domains of greenhouse gas (GHG) emissions with an estimated 30–40% of the total global GHG emissions [2].

In 2021, The United Nations' (UN) "Global Buildings Climate Tracker" reported that the AEC industry was on track to achieve complete de-carbonisation by 2050 [3]; however, this was a temporary result reflecting the unprecedented effect of the COVID-19 pandemic. Unfortunately, a negative rebound is expected in the overall progress unless the efforts towards de-carbonisation significantly increase in the industry [3].

Worldwide, organisations have put forth efforts to include sustainability in their management practices [4]. The term 'sustainability' is well-known within the AEC industry, and there is great potential to effect change [5]. The research has highlighted the potential to reduce the environmental impacts resulting from the industry [6] which policymakers have also identified as a key area of intervention [7]. Thus, countries and international bodies have introduced standards, codes and certification systems in order to promote sustainable building practices [8].

The UN agenda for sustainable development has a series of steps that encourage moves towards a sustainable and resilient built environment [9,10] and the AEC industries are at the heart of this transformation plan towards the Sustainable Development Goals (SDGs) [1]; therefore, several proposals quantifying environmental goals have been put forth by the UN, e.g., calculating the GHG emission budgets for countries aiming to harmonise spatial, temporal and sectoral target definitions across scales [1]. Moreover, sustainable building practices perform a significant role in achieving the SDGs and, therefore, countries may incorporate the practice into their strategies with an eye on achieving their SDGs [11]. The UN collaborates with Saudi Arabia and other countries using a common strategic framework to support the SDGs. Saudi Arabia has implemented several policies to achieve such SDGs, under the Saudi Vision 2030, which include a series of initiatives, programmes and projects that are in line with the UN Agenda and are interlinked with the SDGs [12].

Buildings in Saudi Arabia consume about 80% of the generated electricity [13]. The sector is also responsible for large amounts of material usage, with the estimated awarded contracts totalling $52.6 billion in 2019, and this spending is expected to increase with the blooming of new mega projects [13]; therefore, incorporating sustainability strategies may lead to significant improvements in the AEC industry.

In recent decades, Saudi cities have grown significantly and this growth has been accompanied by steady infrastructure development [14]; however, the accelerated development and urban sprawl have caused consequences [15].

Sustainable/green building practices can have advantages in terms of buildings and performance [16] and worldwide, decision makers have developed a wide range of initiatives to promote this practice. For example, the Chinese government recently launched a series of policies that encourage such practices in the AEC field [17]. Moreover, sustainable buildings have become a distinct research area [18]. In addition, the research has suggested that there are gaps in "the development of sustainable building certification systems" [19] and the theme is continuously evolving [20].

Public health and human behaviour are pertinent to the built environment. The recent lockdown and measures aimed at mitigating the effects of the coronavirus have caused decision makers to re-examine our built environment and there have been calls to look at the potential advantages of sustainable buildings in this regard [21].

This paper will review the academic literature on green/sustainable building codes, standards, certification systems, methods and tools, focusing on the context of Saudi Arabia. It will explore the key opportunities and challenges with regard to adopting sustainability in the AEC industries with the goal of having a good grasp of the status quo and possible future directions. For this purpose, we are going to begin with sustainability in the broadest sense. Then, we will investigate sustainability strategies in Saudi Arabia. After that, we will explore the theme of sustainable building standards and codes. The next section contains further evaluation of the building certification systems and assessment methods, followed by introducing the new practice of sustainable healthcare building assessment. Then, the life cycle assessment (LCA) and building information modelling (BIM) are addressed, as both techniques represent the foundation of the digital transformation in the AEC industries. The paper will then introduce the updated Saudi Building Code (SBC) with further evaluation of the Saudi Green Building Code (SBC 1001-CR). After that, the discussion and results section details the implications, gives an interpretation and acknowledges the limitations of the findings. The penultimate section refers to knowledge gaps, future directions and future research recommendations. Finally, the conclusion will synthesise the main ideas and pull all the points together.

In order to examine the potential of sustainable building in Saudi Arabia, the paper discusses the trends and envisions the new directions in this area. The paper attempts to answer the following questions: Q.1 What are the trends of the art in sustainable building certification systems? Q.2 What is the status quo of sustainable building certification systems in Saudi Arabia? Q.3 What are the potential future directions in this area? The study will answer the first question by critically reviewing the literature addressing the trends in sustainable certification systems. The second question will evaluate the status quo of sustainable building within Saudi Arabia. Finally, the third question will try to predict future research dynamics and directions.

2. Sustainability

Sustainability has become a strategic imperative for almost all industries and businesses [22]. It is seen as a multidimensional concept that encompasses environmental, economic and social aspects. The concept has its origins in the Brundtland Report of 1987 [23]; however, the concept has been interpreted by the UN definition of sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs [23]. Worldwide, organisations have put forth efforts to include sustainability in their management practices [4]. In 2015, the UN officially adopted the 2030 agenda for sustainable development that guides global action, consisting of 17 SDGs, see Figure 1 [24].

Figure 1. The 17 Sustainable Development Goals (SDGs) [24].

Governments have developed their strategies and policies with an eye on the SDGs with sustainable buildings performing a key function [11]. The SDGs are a major international effort to shift the world towards sustainability and resilience. The Agenda calls for international partnerships at different levels to work cooperatively [25], and the UN has highlighted the AEC industry as one of the most concerning areas for intervention that provides opportunities to limit environmental impacts [10].

The United Nations Environment Programme (UNEP) is the international environmental programme directed by the UN. The programme encourages a global partnership towards protecting the environment by informing, inspiring and enabling [9]. 'Sustainable Buildings and Climate' is an initiative by the UNEP programme, and it aims to promote sustainable building practices and provide a platform for action [9]. The initiative develops strategies, methods and tools to assess and implement sustainable building and pilot studies are used to demonstrate the role of the AEC industries in environmental and climate issues [9]. The pilot studies are an initial implementation approach of a project or idea to prove their viability [26]. The UNEP uses this approach to promote sustainability in different cities in developing countries and to examine the barriers to sustainability. The initiative also provides guidelines and case studies for developers to integrate sustainability into planning, design, construction and operation [27].

However, sustainable building practices remain hampered and are limited in many parts of the world; therefore, it is necessary to create an atmosphere that addresses this and encourages all stakeholders to promote this practice [10].

The World Health Organization (WHO) and the UN have enshrined the right to the highest possible standard of health for everyone [28]. COVID-19 has provided a strong call to reassess our way of living and highlight our built environment's resilience [29], while the lockdowns emphasised deficiencies and limitations in buildings and urban design [21]. Furthermore, healthy, high-performance buildings and their occupants' satisfaction are strongly interlinked and are applicable to the definition of 'health' by the WHO, which is, "A state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity." The definition is particularly pertinent to sustainable buildings [30].

2.1. Sustainability in Saudi Arabia

Saudi Arabia is the world's leading energy producer and the largest country in the Middle East [31], with a total area of two million square km [32], and an estimated population of 34 million [33]. In recent decades the population has dramatically increased [34] and the economy has grown [35].

However, Saudi Arabia has a sensitive ecosystem, limited water resources, and faces frequent incidences of coastal flooding, which have caused the country to be ranked 84th on the 2018 Global Climate Risk Index [36]. The country has an increasing rate of energy consumption and GHG emissions with significant demographic pressures of a 2.3% annual population growth rate [24]. The country has an enormous ecological footprint and a large resource demand [37].

In 2016, Saudi Arabia launched the Vision of 2030, which is an ambitious plan for the future aiming to drive a new wave of investment and accelerate energy transition with sustainability at its heart, focusing on three main areas. See Figure 2 for a brief definition of the three pillars of the Saudi Vision 2030 [14].

Figure 2. A brief definition of each pillar of the Saudi Vision 2030 [14].

The country is intending to draw 50% of its consumed energy from sustainable and renewable resources by 2030; however, the Saudi Vision significantly focuses on the environment, climate issues and other sustainable development goals [14]. The Kingdom endeavours to adopt best practices in all industries and many initiatives, programmes and projects have recently been launched. The Kingdom aims to be one of the world's largest investors in sustainable building [38]. The "Saudi green initiative" is a great example of this effort; the initiative focuses on environmental protection and improving quality of life. Additionally, the initiative oversees all environmental-related efforts within the government, the private sector and through work with foreign governments [39]. Another recent example is the "Riyadh Green Project". The project is one of the most ambitious urban forestation projects in the world. It will increase the per capita share of green space by planting 7.5 million trees across the capital city of Riyadh. The irrigation network system in this project will only use recycled water. This initiative will lead to a reduction in the city's temperature and should improve air quality [40]. Moreover, another great example is the

"Future Saudi Cities", a programme to develop the environmental sustainability of Saudi cities, with improved infrastructure and quality of life. The aim is to achieve sustainable urbanisation in accordance with international sustainability standards. The programme will evaluate the status quo of the selected cities and address challenges in order to develop a strategic solution plan responding to the urban challenges. The programme includes the capital, Riyadh, among the other cities of Makkah, Medina, Jeddah, Dammam, Taif, Al Ahsa, Abha, Tabuk, Jazan, Qatif, Buraydah, AL Baha, Najran, Hail, Araar and Sakaka; however, in sustainable cities there is an underlying consideration to strongly connect to the environment. For instance, with regards to energy, pollution, etc., the programme will consider all the environmental sustainability issues [41]. It is a new approach requiring measurement and evaluation, which promotes development and redirects cities towards an urban future of prosperity.

2.2. Sustainable/Green Building Standards and Codes

As we increasingly recognise the role of buildings in addressing issues beyond the minimum requirement of their occupants' safety, sustainable building codes, standards, certification systems, methods and tools have been developed [42]. They offer help to improve building performance for the 21st century by considering energy efficiency, resilience, health and the occupants' satisfaction.

Sustainable buildings have drawn increasing attention in research and practice [43], see Figure 3 where the coloured lines show the number of published papers per journal each year.

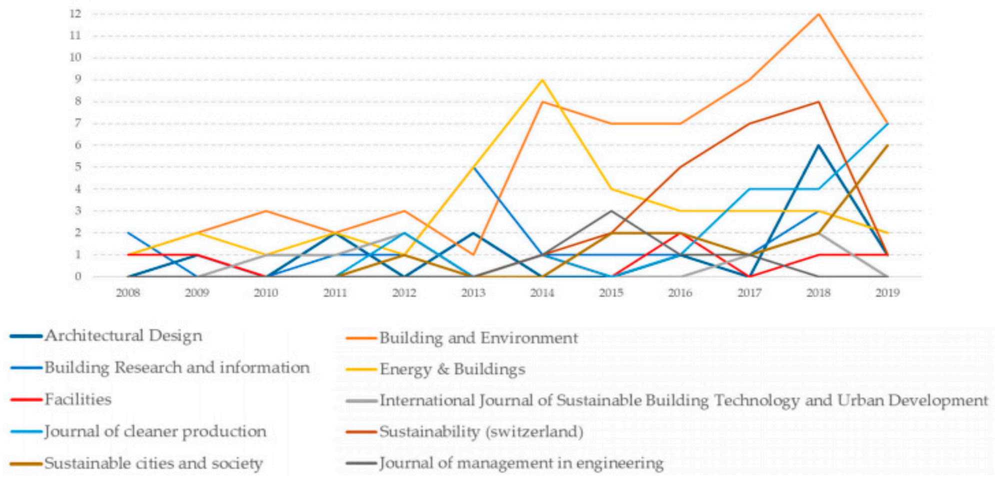

Figure 3. The evolution of published papers [44].

However, their per capita carbon dioxide emissions and energy consumption clearly highlight this issue and the number of certified sustainable buildings is on a steep rise globally [45].

The assessment of the built environment should consider a broad view incorporating stakeholders and communities as it includes all buildings and living spaces [22]. The built environment is at the core of sustainability issues and is a key element in cities' fabric, and any interventions provide an opportunity for environmental impact reduction.

In the United States, the green buildings movement originated from the need for efficient energy use and environmentally friendly practices [46] and sustainable buildings contribute to creating sustainable communities; however, the philosophy of sustainable design is not only a question of energy efficiency design [47].

Numerous research studies with different approaches towards sustainable building assessment have been published in many countries around the globe [45]. Moreover, research findings in one country may influence industrial change in other countries [48];

however, this should be a systematic research-based process avoiding readymade models and frameworks, which may eventually lead to shortcomings.

The literature of "certification systems and building assessment methods" is multidisciplinary and combines several fields of study and academic interest; however, integrating and classifying the literature for a better understanding of sustainable buildings would help researchers to move forward and influence industrial change [46].

The built environment has an impact on occupants' health, energy consumption, and climate change, all of which foster this research area [49], while the terms, sustainable building, green building, high-performance building, green construction and sustainable construction are used interchangeably in the academic literature [50].

In the design process, the sustainable design approach is different to the conventional methods. Furthermore, sustainable building is defined as "A healthy facility designed, constructed and operated satisfying ecological principles" [51]. Another definition for sustainable building is "A healthy setting based on ecological design" [52]. The major advantages of sustainable building include lowering the environmental impact, increasing the occupants' satisfaction and making efficient use of natural resources [53].

In addition, alternative assessment techniques such as sustainable site development, energy consumption, water consumption, materials selection, indoor air quality and other criteria and sustainable indicators are used for assessment in sustainable design [54]; however, in the design process, the early stages of design are critical as they can affect the whole life cycle of the project [55].

Research has shown that a sustainable building with a 20 year life span saves $50–66 per square foot compared to conventional buildings [56]; therefore, promoting sustainable building practices increases the opportunity for an economic and environmentally friendly built environment.

The AEC industry is responsible for significant social drawbacks as well, e.g., the occupants' satisfaction, job opportunities, noise and air pollution, traffic congestion, public health and many other social aspects, which may directly or indirectly be affected by the industry [57].

Energy saving has become a priority and this is even more important in regions with a hot climate such as Saudi Arabia; therefore, selecting appropriate design features may provide significant opportunities to minimise energy use [58]. At a national level, the AEC industry in Saudi Arabia poses significant energy and environmental challenges [59].

However, sustainable design encompasses environmental, economic and social [22] aspects of sustainability with energy use being only one of the major factors; therefore, engineering systems and techniques such as heating, ventilation, air conditioning (HVAC) modelling, building orientation, isolation, indoor/outdoor lighting, shading, daylight, artificial lighting, glazing, materials, dimensions and many other aspects may be integrated into the design. An example of this is the proposed model by Kurian et al. of a shading technique during daylight which reduces energy consumption, and the simulation shows a reduction in the energy consumption and CO_2 emissions by 19.7% [60].

Sustainable/green buildings have not yet become standard practice and a sustainable assessment methods adaptation would move forward towards this [61]. The increasing demand for energy in the AEC industry also drives the need for change to combat global warming and climate change [62]; however, international bodies and organisations have also clearly highlighted the role of sustainable buildings [63].

Furthermore, there has been a proliferation of green building standards, codes and certification systems in developed countries to guide, demonstrate and document the efforts towards delivering sustainable buildings.

A standard is a set of criteria and guidelines against which a product or service can be judged. Common building practice standards are created by organisations such as ANSI, ASTM, or ASHRAE with the international governance of standards overseen by the International Organization for Standardization (ISO), who hold the worldwide standards that form the basis of industry norms. A standard ISO defined by the ISO is "A document, established by consensus, approved by a recognised body that provides for common and repeated use as rules, guidelines, or characteristics for activities or their results." However, in the last few years, the leading international standardisation bodies have been involved in standardising the core criteria of sustainable buildings [18].

Green building codes have been developed to push the standards in the AEC industries to new levels of sustainability and performance. These codes set the minimum requirements to safeguard the environment, public health and safety and welfare through certain requirements that are intended to reduce the negative impacts and increase the positive impacts of a building on the environment and its occupants [63]. The International Green Construction Code®, IgCC®, sets comprehensive requirements to reduce the impact of buildings on the environment. The document can be used by manufacturers, design professionals and contractors [64].

2.3. Sustainable/Green Building Certification Systems

The green certification system is a comprehensive process of assessment that determines the fulfilment of directly or indirectly relevant requirements, while in the last two decades, building certification systems have been used in many countries [65]. The sustainable design wave has grown with the launch of the Building Research Establishment's Environmental Assessment Method (BREEAM), which is the world's first certification system. See Figure 4 which details the environmental sections and assessment issues in the BREEAM [66].

Management	**Health and wellbeing**
Energy	**Transport**
Water	**Materials**
Waste	**Land use and ecology**
Pollution	**Innovation**

Figure 4. Environmental sections and assessment issues in BREEAM [66].

This was followed by the release of the Leadership in Energy and Environmental Design (LEED) in the United States in 2000 [67]; however, LEED has continued to grow and includes new systems for existing buildings and entire neighbourhoods [67]. The third example is the Comprehensive Assessment System for Built Environment Efficiency (CASBEE), which is a joint governmental, academic and industrial sector approach used in Japan [67]. In addition, there are the Australian Green Star, the French HQE and many more certification systems across the world. See Figure 5 for the list of green building certification systems globally [68].

Large differences exist among these certification systems and the use of such a system outside of their original country is usually limited [69]; however, other countries have also responded to the growing interest in sustainable design and additional international certification systems have been developed that are influenced by these programmes, but are tailored to their own national priorities and requirements.

Worldwide, sustainability initiatives differ in many aspects, for instance in their approach to climate change, resources, policies, regulation and social perception. Hence, the accepted methods/tools of sustainability need to consider each country's context [68].

The AEC industry has direct and indirect impacts on the environment during the built environment's whole life cycle, and it is these impacts which have prompted the creation of green building standards, codes and certification systems that are available in different countries [65]; however, certification systems usually use assessment methods to assess and certify a given building. These building assessment methods assess buildings by satisfying predefined sustainability parameters, which consider the country's context. The environmental and other local conditions differ from one region to another, which may lead to different countries having different priorities and indicators; therefore, each country needs to develop their own sustainability methods considering their own nation's context [69]. In addition, it is challenging to compare all available certification systems [20], as they may have different parameters, structures and weights.

Country	GBRS Name	Organization	Starting	Version
Austria	TQB 2010	OGNB	2010	National
	BREEAM AT	DIFNI		National
Czech Republic	SBToolCZ	IISBE Czech/CIDEAS	2010	National
France	HQE	HQE	1997	International
Germany	DGNB	German Sustainable Building Council	2008	International
	BREEAM DE	TÜV SÜD DIFNI	2011	National
Italy	LEED Italia	Italy GBC	2006	National
	ITACA	IISBE Italia	2004	National
The Netherlands	BREEAM NL	Dutch GBC	2011	National
Norway	BREEAM NW	Norwegian GBC	2011	National
Portugal	SBToolPT	iiSBE PT	2009	National
Spain	VERDE	Spanish GBC	2011	National
	BREEAM ES	ITG	2010	National
Sweden	BREEAM SE	Swedish GBC	2011	National
	Miljöbyggnad		2011	National
Switzerland	BREEAM CH	DIFNI	2011	National
	Minergie ECO	MINERGIE	1998	National
United Kingdom	BREEAM	BRE	1990	International
	HQM		2015	National
	CEEQUAL		2011	International

Figure 5. List of green building certification systems globally [44].

Building assessment methods are a discipline that assists with predicting, identifying and evaluating the potential effect of an alternative [70]. They are used to examine the particular building's performance and they drive results from predefined processes following a comprehensive assessment [71]. They assess the building's performance by means of specific criteria and indicators [72]. Moreover, a holistic approach is needed to examine and verify a building's performance [73].

The use of assessment methods is voluntary; however, some countries enforce the use of these methods for publicly funded projects [73]. The methods have created a paradigm shift in environmental design that encourages creative problem solving and innovation [74], and they are globally promoted due to their significant advantages [75].

These methods have evolved reflecting new research findings and updates [76] which have driven intensive research in this area across the globe [77].

The primary advantage of using such sustainable methods is to provide comprehensive characteristics of the proposed design with the goal of reducing any negative environmental impacts [73]; however, other secondary advantages may include cutting costs, design validation, the occupants' satisfaction and an increasing awareness of sustainability issues.

Building assessment methods use different approaches towards assessment including LCA, life cycle cost analysis, productivity analysis, operation and maintenance optimisation, indoor air quality and other approaches [20]; however, the existing methods are in a transition phase and the next generation will encompass all aspects of sustainability. This will be more of a quantitatively-oriented approach instead [78], which may provide a means of transparency and improve comparisons [79].

2.4. Healthcare Building Assessment

The healthcare sector accounts for a number of negative environmental impacts, including GHG emissions, pollution and waste and evidence of these impacts is mounting [80]. Countries and governments should commit to embracing the sustainability of healthcare services to protect and improve people's health, and that of the community [81].

According to the WHO, of the waste generated by the healthcare sector, 10–25% is regarded as hazardous and contains chemical, biological or radiological waste [82]. There is a growing need to understand the health consequences associated with healthcare and its environmental footprint as investment increases in the sector around the world [83]. The sector accounts for 1 to 5% of the total global environmental impacts of GHG emissions, particulates, nitric oxides, sulphur dioxide, nitrogen rich runoff waters, malaria risk and water scarcity [83].

Worldwide, healthcare climate footprint studies have been undertaken in a number of countries: in the US, research has found that the country's healthcare emissions have reached 9.8% of the national total, with an estimated 655 million metric tonnes of carbon dioxide equivalent; in the UK, it has been estimated that the footprint in 2017 was 27.1 million metric tonnes of carbon dioxide equivalent, which represents approximately 6.3% of the country's climate footprint; in Australia, the findings were 7% and in Canada, 5% [84].

In addition, the buildings and facilities where healthcare is provided cause an environmental burden, e.g., the hospitals in Europe along with their supply chains are responsible for 5% of the annual CO_2 emissions [85].

Worldwide, many countries are moving towards fulfilling their commitments towards the climate change agreement, e.g., the UK has announced its commitment for the National Health Service (NHS) to become carbon "net zero" by 2040 [86].

At the national level in 2022, the government of Saudi Arabia officially launched the Healthcare National Comprehensive Transformation Programme, with the main purpose of totally restructuring the sector. The programme also focuses on public health, disease prevention and improving the accessibility to services [14].

Hospitals have more than one function and are continuously changing where different systems and medical equipment are used. In these types of buildings, the potential for hazardous material is high, and water/energy consumption is also high [87].

The healthcare system is seen as critical for sustainable development [88]. For example, the WHO defines sustainable healthcare as the balance of environmental, social and economic design, to meet people's healthcare needs and aiming to optimise healthcare outcomes without compromising future generations' healthcare needs [89].

Healthcare sustainability reporting aims to build a better healthcare system using effective metrics; therefore, interest is increasing in how healthcare systems may report sustainability and environmental performance [90].

There has been a growing interest in sustainability measures reporting and clinical service quality in healthcare, and reporting in this context may cover different aspects of the services, e.g., accessibility, costs and efficiency [91]. One of the most globally comprehensive approaches to healthcare sustainability reporting is taken by the National Health Service (NHS) in England, which is referred to as the Sustainable Health Dashboard [91]. This dashboard gives performance data on a range of indicators in the domains of governance, resources, carbon, water, waste, pollution and plastics. Australia has also put forth efforts towards public health service reporting requirements [91].

In addition, sustainable healthcare assessment methods have been proposed and developed to promote sustainable goals using different algorithms, machine learning and other emerging technologies [92]. An example of this is a research study to assess the sustainability of the Iranian healthcare system by an exponentially distributed stochastic model, which has resulted in a sustainability index for environmental, social and economic measures as 54.40%, 66.80% and 48.80%, respectively, which indicates that the social sustainability aspect is higher than previously and, therefore, some improvements are necessary [93].

Usually in given certification systems, each building's type has a different purpose and function; therefore, the assessment criteria, credits and weights differ accordingly, for instance, for residential, commercial, education, healthcare, retail, etc. [94]. The healthcare building and physical premises have an impact on the occupants' health and wellbeing and, therefore, green healthcare design, which integrates all stakeholders' expertise in the design process, may help.

In addition, evidence-based design guidance and tools for environmental reporting have developed in different countries, e.g., the Green Guide for Healthcare by LEED [95]. An increasing concern about the sustainability of healthcare buildings and facilities has accelerated the development of such guidance and certification schemes [85].

Healthcare buildings and facilities designs are complex and sometimes contradictory with a great number of occupants, systems, equipment and supplies in one place. Additionally, it is necessary to consider different variables and parameters [96]. The best practice for sustainable healthcare buildings and facilities designs consider the building's entire life cycle [8].

From an architectural point of view, there are two significant trends currently shaping healthcare building and facilities design: Evidence Based Design (EBD) and Eco Effective Design (EED). Firstly, EBD focuses on the support of positive health outcomes through a growing number of solutions informed by research and practical knowledge. In this concept, the wellbeing of the occupants is the core concern with occupants-oriented design decisions being made. Conversely, EED supports the improvement of ecological health and the quality of the indoor environment. These two trends have an impact on healthcare design and research has highlighted that it is important to consider the dialogue between them and promote the benefits of each [97]. To illustrate this, when designing a clinic, there is a conflict between the occupants' interests and protecting the environment, as a larger clinic provides comfort for occupants while resulting in greater environmental impacts [97]. Moreover, there is no simple answer to the question of "How to make a healthcare building and facility sustainable?" This is because sustainability encompasses different aspects and has more than one dimension [8]; however, understanding the actual requirements and assessing available alternatives using a healthcare building assessment may facilitate the process.

2.5. Life Cycle Assessment

2.5.1. Overview

The Life Cycle Assessment (LCA) approach has been receiving increasing attention in the AEC industries [98]. Research has shown that this methodology gives a better understanding of environmental impacts [13] as it considers the entire life cycle of a product, process or service.

It is a cradle-to-grave approach, which includes all phases from extracting the materials to designing, constructing, operating and finally demolishing a building. It estimates the embodied environmental impacts and provides a comprehensive view of environmental trade-offs [99]. It is, therefore, an integrated way of treating the assessment of environmental impacts [100].

The LCA has been defined as "A technique to assess the environmental impacts associated with a product or system by compiling an inventory of relevant inputs and outputs of a product or system; evaluating the potential environmental impacts; and interpreting the results of the inventory analysis and impact assessment of all phases" [101]; however, the methodology is often employed as an analytical decision support tool [101].

2.5.2. The Historical Background of the LCA

The United States Department of Defence were the first to use the LCA technique [102]. The current modern environmental understanding of the LCA appeared first in a research study by Coca Cola in 1969 to study the environmental impact of the packaging process [103]. In the United Kingdom, the first experience of life cycle thinking was published as a handbook by Boustead and Hancock [104]. The integration of the LCA and a life cycle cost analysis sustainability approach in the AEC industries is predominantly driven by building certification systems [98] and the need to assess environmental impacts and performance.

In 2017, the UN published the Life-cycle Assessment initiative strategy, which is a public private partnership to enable the global use of processing methodology in decision-making [105], the most recognised LCA standards published by the ISO; however, the basic requirements of the LCA in different industries has mostly built upon the ISO14040 and ISO14044 standards [106]. In regards to the AEC industry, the main requirements can be found in the CEN standard of Construction and the LCA standard [107]. Meanwhile, the European Commission recently published a framework for building sustainability performance into improving sustainability in buildings [108].

The LCA in Buildings

The LCA is gaining increased attention as an important tool to assess buildings' environmental impacts and has gradually become a distinct working area within the practice [109]. The LCA draws a full science-based picture of environmental impacts by using standardised metrics for global warming and carbon footprints [110]. It assesses all phases in the entire life cycle of a building [111]; however, the traditional way of improving a building's environmental performance was only through the setting and targeting measurements of energy and water consumption and other measures, e.g., waste production. In other words, the focus was on tangible measures; therefore, the traditional approach did not consider the environmental impacts in all phases. However, the LCA provides the full picture which can help lead to a reduction in the environmental impact of a building.

The Implementation of the LCA in the AEC Industries

The ISO has defined four distinct steps of the LCA, including its goal and scope, an inventory analysis, impact assessment and the interpretation of results. Figure 6 shows the framework of the LCA followed by a brief description for each step [112].

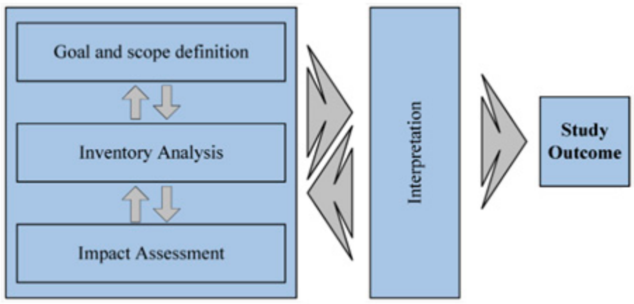

Figure 6. The Life Cycle Assessment Framework [112].

Goal and Scope

This is the first step of the LCA, which identifies the purpose of the study and determines the precise questions. These need to be set carefully, otherwise the entire results of the LCA can be affected [98]. According to the ISO, this step states the study purpose, application, audience, detailed systems' function, system boundaries, the allocation procedure, functional units, selected impact categories, assumptions, impact assessment methodology, required data, limitations and reporting type [112].

Inventory Analysis

This is the second step of the LCA and covers data collection and calculation procedures [112]. The step is also associated with the scoping process, since data collection may lead to redefining the boundaries. The ISO refers to different levels of this step as quality data collection: processing the data and allocation procedures [98]. The inventory analysis or life cycle inventory step should export data from a predefined database, usually a building materials and components database, which has already been detailed in the previous step and includes scenarios, components, materials, and assumptions [101].

Insufficient data may hinder this step; however, recently an international database has emerged and grown gradually, and it includes all the database categories: public, academic, commercial, and industrial [98]. The inventory analysis refines the system boundaries and verifies the collected data using benchmarks. Additionally, a sensitivity analysis may result in the exclusion of phases with negligible impact [98].

Impact Assessment

The third step of the LCA is defined by the ISO as "Examining the system from an environmental point of view using category indicators and impact categories with the results from the previous step." The life cycle impact assessment provides information for the next step of the life cycle interpretation [113]. The framework starts by defining the impact categories such as global warming, acidification, toxicity, etc. There is then a classification process, which assigns the results of the life cycle inventory to the impact categories, e.g., classifying carbon dioxide emissions as causing global warming. The impacts are then modelled within the impact categories, e.g., modelling the potential impact of carbon dioxide on global warming using their respective GHG potential [112].

Interpretation

The final step of the LCA analyses the results, conclusions and limitations and provides recommendations. It also reports the results used for the interpretation in an understandable format [112].

2.6. Building Information Modelling

Building Information Modelling (BIM) is a term used to describe a variety of activities in object-oriented Computer Aided Design, which supports the representation of project elements in terms of their 3D geometric and functional attributes and relationships [114].

In BIM, the information from all engineering disciplines, including drawings, locations, orientation, quantities and specifications, is processed and assessed. This enables designers to visualise and optimise the performance of a building [56]. BIM is defined as a "Shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decisions" [115]. BIM is a digitalised technology platform that has received notable attention in research and practice in recent years. BIM also delivers an integrated and innovative approach to enhance the sustainability of a design [116] and optimises the use of information between designers, contractors, manufacturers and other stakeholders.

Research has established that the use of BIM has also increased in building renovation as it offers a wide range of advantages in rendering, facility management, documentation control, maintenance, information management, quality control, quality assurance, energy management, retrofit and other applications [114]. The notion of life cycle thinking is quite new in the AEC industries [117], and the integration of the BIM life cycle may add great value [118]. The integration of it affects the energy efficiency for designers and planners in the early stages of design and decision-making.

An increasing use of digital models has been supported by the sustainable building design movement [119]. Digital tools play an important role in sustainable building by providing a data integration platform that examines alternatives in the design process [120]. Meanwhile, BIM standards and guidelines consider the categories of design, planning, construction, operation and maintenance [116].

Lu et al. have established a relationship of synthesis between BIM and green buildings in a comprehensive study which reviewed publications from 1999 to 2016 and presented a critical reflection on BIM and sustainable buildings [119]. The study also showed that BIM supports green building assessments in design, construction, operation and retrofitting [119].

Furthermore, designers can take advantage of BIM at different stages of the design process, including schematic design, detailed design and construction shop drawing [121]. The information and data management in BIM may be utilised for a building performance analysis which extends the life span of a building [56]. Volk et al. declared that BIM integrates information and promotes the collaborative design process [115]. This integrated approach provides convenient access to building information that facilitates sustainable building assessment [122].

BIM provides information that supports credit calculations to define the levels of sustainability associated with building certification systems [123]. BIM is a great energy modelling management tool which may help in achieving sustainable building standards in the early design phase [124] and is an energy simulation tool in the operational stage [125], which allows end-users and facility managers to control and optimise energy consumption [126].

Tools such as Autodesk Revit make the conversion of GBS files easy and use energy modelling software such as eQuest and EnergyPlus, which provide an integrated approach to reduce consumption, stabilise system performance and analyse alternatives [127]. The BIM models can be easily modified providing opportunities for cost effective design [128]. The social advantages of BIM include aiming to improve the occupants' comfort levels and safety, schedule management, geometric information, and materials and other features which may increase occupants' satisfaction and safety [129]. Moreover, BIM may be used in waste management by developing an efficient materials recycling plan [130]. The BIM-LCA refers to an early design approach that helps in the selection of sustainable materials and products [131], while integrating the BIM model into the internet of things provides complete geometric descriptions and allows a visualisation approach for energy consumption [132]. Additionally, all layers of information may be integrated into the BIM model in the construction phase and applied in facilities management during the operation phase [133]. The BIM model also adjusts a HVAC system's design parameters and improves indoor air quality using airflow that analyses and calculates energy consumption accordingly [134], e.g., through ventilation calculation and analysis to reduce consumption and increase the occupants' comfort. The BIM tool can also estimate the potential cooling load for a HVAC and effective interior/exterior lighting using lighting system simulations [119].

2.7. The Saudi Building Code

Generally, building codes are mandatory national or international document requirements used in the AEC industry. Governments and authorities enforce stakeholders to comply with certain building codes and requirements [135]. The application and enforcement of building codes is a potential solution for incorporating environmental, safety and other measures [10].

The Saudi Council of Engineers (SCE) has defined building codes as the set of document requirements, rules, regulations, standards and best practice recommendations that work together as the main reference in building and construction [136]; however, building codes and regulations have become less prescriptive and more functional or performance oriented [137].

Furthermore, building code amendments offer opportunities that encourage flexibility [135] and there has been an increase in performance-based design concepts using innovative methods and materials [137].

Codes detail how buildings should be constructed, with what type of materials and how much energy/water is consumed, etc. Usually, building codes use historical data to predict issues that may occur during the life cycle of buildings. Unfortunately, current scarcities in climate data or poor-quality data in many parts of the world make it challenging to update building codes [10]. Worldwide, some countries are trying, for example, the UK has incorporated aspects of climate change adaptation into their building codes and standards [10]; however, in developing countries there is an increasing effort towards introducing mandatory and voluntary building codes, but the adaptations to incorporate climate regulations are still inadequate in many developing countries [10].

Building code compliance is a critical issue that still gains much attention [135]. In 2018, the Saudi Building Code National Committee (SBCNC) published the new Saudi Building Code (SBC) and announced a five year implantation plan [138]. The plan started on 20 June 2018. Since then, the code must be applied to all building types including governmental buildings, high rise buildings, hospitals, hotels, mosques, sports arenas, educational buildings, malls, communication towers, industrial buildings, high hazard buildings, wedding halls, cinema auditoriums, theatres, healthcare centres, motels, residential buildings, entertainment buildings, business buildings, airports, banks, TV stations and post offices [136]. Building codes aim at setting the bare minimum requirements that guarantee safety and public health [64,136]. In the SBC, the main engineering discipline codes are mandatory, such as the general building code SBC-201-CR, the structural building code SBC-301-CR, the electrical building code SBC-401-CR and the mechanical building code SBC-501-CR [136].

The Saudi Green Building Code, SBC 1001-CR, is an incorporated part of SBC 2018 [139]; however, this part is voluntary [138] and draws attention to the environment, public health, safety and general welfare [139]. The Saudi Green Building code is also considered to be a tool to promote green practice.

The SBC-1001-CR established regulations and the minimum requirements for green buildings and site considerations using prescriptive and performance related provisions [138]. The International Green Construction Code, IgCC®, is the foundation in SBC-1001-CR development [139]. Approved methodology by the Saudi Building Code National Committee (SBCNC) was used to meet the local context including regulatory requirements, weather and materials [139]. The code is fully compatible with the International Construction Code, namely, the ICC family of codes [64].

The SBC-1001-CR addresses site development and land use, material resource conservation and efficiency, energy and CO_2 emissions reduction, water resource quality and efficiency, indoor environmental quality and comfort, commissioning, inspection, operation and maintenance, and existing buildings and existing building site development [139]; however, any effort towards developing local sustainable building assessment methods should consider the baseline requirement of the Saudi Green Building Code.

3. Discussion and Results

The development of the sustainable building assessment methods research area is fragmented by the diversity of the involved disciplines and, therefore, having a broader prospective of its evolution with a critical comprehensive review is crucial [140]. Most of the common methods have been analysed using different approaches in the academic literature [141]. These methods are currently in the transition phase and the second generation will encompass all aspects of sustainability [20]. This new generation may use different approaches such as the life cycle and building information modelling [142].

A methodical review by Lazar and Chithra studied the published literature on "the development of building assessment methods" using a bibliometric approach which revealed that the most dominant keywords include rating systems, sustainability, environment, assessment, sustainable development, green building, AHP, and MCDM with the major productive countries in this area being Australia, China and Hong Kong [143]. The research concluded that studies in developing countries are limited [143]. In addition, assessment systems need to be developed for other types of building as well [143].

Kamaruzzama et al. compared the most commonly used assessment methods in their manuals [144]. The study examined 10 assessment methods from different countries: LEED, BREEAM, CASBEE, Green Star, HQE, BEAM Plus, Green Mark, GBI, MyCrest and GBLS [144]. The study findings revealed that fourteen themes were considered for assessment including a sustainable site, indoor environment quality, management, energy, water, waste, transportation, material, pollution, innovation, economic, social needs, culture and the quality of service. Energy and indoor environmental quality were the dominant themes [144]; however, most of the methods are considered weak in evaluating economic and social elements with respect to the environmental element. In addition, the quality of service is overlooked in most of the methods [144].

Darko et al. used the Scopus database to categorise the main agents involved in green construction [50]. This research examined the research trend through analysing published papers on the subject of green building in 10 selected journals from 1990 to 2015 in terms of the annual green building publications numbers, countries' contributions, institutions, authors and the covered topics [50]. The study analysis revealed an increasing green building research interest and indicated that researchers from developed countries have contributed to the majority of the research in this area [50]. In addition, the green building research tends to focus on project delivery and developments, certifications, energy performance and advanced technologies [50].

Aarseth et al. carried out a systematic review and highlighted some sustainability strategies [145]. They stated that the sustainability research in a project context is still nascent and fragmented [145]. In addition, they also concluded that sustainability is a salient issue that needs to be thoroughly considered [145].

Olawumi et al. reviewed global research on sustainability and sustainable development [146]. This study conducted a scientometric review analysing 2094 bibliographic records from the Web of Science database. The study findings revealed an evolution of this research area from the definition of the Brundtland Commission to the recent development models and sustainability indicators [146]. The study also indicated that the existing research in sustainability is mainly focused on the environmental sciences, green/sustainable science and technology, building technology, civil engineering and construction [146]. In addition, the study finally concluded that the emerging trends in sustainability research include sustainability indicators, sustainable urban development, environmental assessment, water management and public policy [146].

The analysis of several certification systems shows that there exist certain tendencies such as an expansion from predominantly environmental to a more comprehensive sustainability assessment [147]. In addition, some certification systems have deepened the assessments of resilience, and BREEAM is an example of this [147]; however, a more profound consideration of building resilience aspects is necessary and more resilience related items may be embodied either by the modification of criteria or by introducing new defined criteria according to territorial characteristics. The study also suggested that top certification systems such as LEED and BREEAM have transformed into more unified platforms [147] by including guidance for different building types, methods, tools and schemes.

A critical review by Mattoni et al. used a methodological approach to evaluate well-established and selected international certification systems which revealed that CASBEE was considered to have the highest sustainability issues [148]. The study also highlighted the following elements that need to be considered in all the certification systems to improve sustainability assessment: environmental hazards, seismic risks, the LCA, recycling, indoor air quality, the heat island effect, noise and pollution, which are currently not considered in any selected certification systems [148].

Moreover, a study by Liang et al. reviewed and analysed the evolution in the literature on sustainable building and sustainable assessment tools from 1990 to 2021 and critically concluded that there are deficiencies in the used research methods of studying the building sustainable assessment tools, as most of the reviewed studies had not developed a unified assessment framework for different tools resulting in insufficient accuracy [149].

Ameen et al.'s study reviewed the characteristics of six international assessment tools and stated that the weights that represent the indicators against sustainability parameters should reflect the local characteristics [150].

Cordero et al. comprehensively reviewed the most common certification systems in European counties and indicated that the trends in this area seem to lead to encompassing the three macro-categories of environmental, economic and social with a similar weight [44].

Roh et al. developed a framework of green building index certification systems that effectively reduce carbon emissions associated with building construction in South Korea [151]. An overall index based on the three pillars of sustainability was developed incorporating a carbon emission index, a habitability index, and a carbon economic index [151]. Then, the framework combined with the concept of eco-efficiency developed into a life cycle based certification system [151]. This system was more of a quantitative approach that promotes the carbon emissions reduction in building construction [151]. A case study was also employed to confirm its applicability; however, the limitations were identified as detailed weights with the method of selecting a reference building not being clearly defined. This study represents practical oriented research in the form of case studies reflecting the characteristics of buildings with existing certification systems [151].

Assaf et al. critically emphasised that building assessment methods have been designed for a specified region and several factors may hinder the direct use of any existing environmental assessment methods in any different region [152]. These factors include the geographic location, climate, the technology and materials used, policies and populations [152].

In the Middle East and North Africa (MENA) region, Ferwati et al. developed a Qatari sustainable neighbourhood assessment model aiming to promote sustainability in urban areas [153]. The study stated that it is crucial for urban planning and building design to have strong strategies that consider green requirements in the early stages [153]. In addition, Qatar has also introduced a domestic building assessment tool called the Qatar Sustainability Assessment System, QSAS [154].

Abu Dhabi is another example in the region which has developed the Pearle Building Rating System (PBRS), which is a sustainable building appraisal aiming to promote sustainability in the city [155].

In Saudi Arabia, the Mostadam Certification System was developed a few years ago. Furthermore, research by Al-Surf et al. discussed the level of AEC stakeholders' awareness in Saudi Arabia with regard to green certification systems and the results have shown that the level of awareness has improved with respect to previous studies [156]. In addition, 57.5% of the respondents elected to use LEED, while the remaining 42.5% chose to use local recognised systems in Mostadam. Moreover, the study concluded that the determination to use LEED was due to the fact that this system has evolved over more than 25 years and with LEED accredited experts in the market, while the new Mostadam system is still in its infancy [156]. Moreover, the country recently initiated sustainable urban planning strategies as climate change mitigation efforts [157]; however, the implementation of these strategies is in its infancy in urban greening with green buildings just starting to gain prominence. In addition, few studies have assessed the extent of the implementation of these urban planning strategies [157]. As such, there is a need to double the efforts in promoting green practice in the AEC industries [157].

However, Al-Homoud et al. stated that there are limited studies in the MENA region that have reviewed the status quo and the potential energy efficiency of buildings [158].

A study by Sabbagh et al. investigated the limitations of green buildings in the Arab world by analysing dedicated initiatives, academic activities and feedback aimed at supporting the green movement. The study emphasised that an applicable assessment method should satisfy local requirements [159] as the international certification systems do not address climate difference, local materials, energy resources or water scarcity [160].

A research study by Jamil et al. analysed the challenges in the AEC industry using the analytic hierarchy process and stated that there is a lack of regulation within the sector [161]; however, the climatic variation in Saudi Arabia may challenge the use of unified assessment certification systems within the country. The study by Al-Rashed et al. suggested an approach to classify the climate of the country into in five zones as follows: Riyadh, Jeddah, Dhahran, Khamis Mushait and Guriat as they represent the variation of climatic features in the country [59].

4. Future Directions

As buildings' impacts on the environment increase, the global debate on this issue will grow [20] and, therefore, so will the creation of green building standards, codes and certification systems [20]. This review has provided an insight into the evolution and trends in building certification systems development by reviewing recent published research papers considering the Saudi context. The main purpose of this review is to have a good understanding of the status quo and future directions in Saudi Arabia.

Previous discussions have shown that sustainable certification systems are a broad and multidisciplinary research area with a growing number of global published studies; however, the increase in new keywords is an indication of their constant evolution.

Furthermore, in the 1980s the concern was about the environmental impacts of a building and since 2000, the certification systems and their methods of assessment have started to become the focus. In recent years, sustainable assessment methods in urbanisation have increasingly grown with global interest in research and practice; however, research has suggested that the evaluation of the current certification systems and methods is going to continue and the next generation of assessment methods will be more of a life cycle quantitatively-oriented approach rather than qualitative.

Furthermore, discussion has also shown that developed countries have put forth tremendous efforts to promote sustainable building assessment research and there are four main themes of this research area including project delivery and development, certification, performance and technology.

Moreover, the discussion has highlighted some limitations in current certification systems. There are weaknesses and differences in common systems such as BREEAM, LEED, GreenStar or CASBEE, and almost all the current certification systems are criticized for regional and language barriers, and for not considering the economic and social aspects or the risk of green washing [162].

Most certification systems have been designed for use in a specific region or country and some have then become more resilient and internationally spread, by including equivalent international codes and regulations for single credits calculation or even an entire evaluation category, e.g., the LEED Regional Priority; however, each certification system has continued to adopt their own procedures, metrics, terms and levels, i.e., language. The consequences of this are that, for example, both the top ranks in LEED and BREEAM are hardly comparable. This may cause a misinterpretation especially for non-technical stakeholders [162].

Furthermore, certification systems are increasingly required to address the three pillars of sustainability by encompassing the environmental, economic and social aspects [163]; however, most current certification systems are still not considering the economic and social aspects.

Moreover, the success that certification systems have had increases the risk for green washing which may lead to a certification system becoming a marketing tool for the elite instead of being a powerful tool for spreading the concept of sustainable buildings. In addition, there is a risk of undesired phenomenon such as of point chasing [164] or LEED brain [165] increasing, which means focusing on earning credits and points without developing effective case-by-case solutions.

Recently, the European Union has released a framework for assessing and reporting the sustainability performance of buildings [44] together with the call to create uniform certification systems languages. The EU proposes a common set of core criteria that relates the building energy performance according to EU priorities. As a result, many international certification systems are aligning to ensure common EU policy, which allows for integration within certification systems [162].

Furthermore, a major limitation of many certification systems is the inclusion of the LCA; therefore, future work should focus on an overall life cycle sustainability assessment. Although previous research studies have recommended including different aspects of the LCA, a major revamp is still needed to prioritise and incorporate the LCA in certification systems [68].

In addition, future research may study the barriers towards sustainable building adoption in developing countries and examine the green building market. BIM–Green integration may also be considered in future due to the proven advantages in design and the decision-making process. Future research studies may also adopt new approaches to explore the dynamic and interdependent behaviour of this area as an emerging practice in developing countries; however, the review has highlighted knowledge gaps for further investigation.

Previous discussions have also shown that developing such a framework for assessment should consider the stakeholders' perspective and consider the local context. Learned lessons from other countries are also available, as some countries have successfully rekindled the trajectory of green building; however, this is not the case in many developing countries.

Furthermore, the current international certification systems are not applicable to Saudi Arabia in particular and the country has recently initiated sustainable urban planning strategies as a climate change mitigation effort; however, the implementation of these strategies is in its infancy in urban greening, with sustainable buildings just starting to gain prominence. In addition, few studies have assessed the extent of the implementation of these urban planning strategies; therefore, there is a need to increase the efforts in promoting green practice.

Moreover, an emerging direction is the WELL certifications systems, supported by the International WELL Building Institute, IWBI or fitwel by the Centers for Disease Control, CDC. The approach focuses on measures that certify and monitor aspects of buildings that impact occupants' health, satisfaction and well-being, e.g., air, water, light, comfort, etc. [162].

5. Conclusions

This paper has critically reviewed and evaluated the current state of sustainable building certification systems in a Saudi context, and sustainable certification trends with the purpose of having a good understanding of the status quo and possibilities for future directions in Saudi Arabia. It is clear that this research area is broad and fragmented due to the great diversity of the involved disciplines. It has been observed that the theme has drawn significant attention in the last few years with an increasing number of published studies and research in international journals, derived from national and international efforts in promoting sustainability. Furthermore, sustainable/green building assessment methods are currently in a transition phase and the second generation will encompass all aspects of sustainability. This new generation may use different approaches such as the life cycle assessment (LCA) and building information modelling (BIM).

Building assessment methods have been designed for specified regions and several factors may hinder the direct use of an assessment method in a different region. These factors include geographic location, climate, the technology and materials used, policies and populations size.

Recently, the country of Saudi Arabia has initiated sustainable urban planning strategies as climate change mitigation efforts; however, the implementation of these strategies is in the early stages in urban greening with green buildings just starting to gain prominence. In addition, few studies have assessed the extent of the implementation of these urban planning strategies; therefore, there is a need to increase efforts in promoting green practice in the AEC industries.

The climatic variation in Saudi Arabia may challenge the use of unified assessment certification systems within the country and the certification systems should consider such variation of climatic features in the country. Globally, there are clear concerns regarding the environmental impacts of buildings and there is growing interest towards adopting sustainable building practices. This paper reviewed the academic literature on green/sustainable buildings considered in the context of Saudi Arabia, and introduced the concept of sustainability within the AEC industries. It also explored the state-of-the-art trends in building certification systems. Life cycle assessments (LCAs) and building information modelling (BIMs) techniques were both investigated as they represent the foundation of the digital transformation in the AEC industries. The updated Saudi Building Code (SBC) was introduced and the paper further evaluated the Saudi Green Building Code (SBC 1001-CR). Finally, the paper identified knowledge gaps, potential future directions and future research recommendations, and clearly highlights the need for developing a certification system that takes into consideration the new trends and the local context.

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