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Analysing the Current State of Knowledge on Green Buildings

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Research Article
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Abstract The growing environmental impact prompted the development of green building methods as a means to enhance the construction process while also reducing that impact. Here, we provide a comprehensive bibliographic study. This led to the discovery of 124 publications about green buildings in 40 prestigious scientific journals. In order to learn about the most prolific writers and nations, as well as how the articles have changed from 1980 to 2011, a quantitative analysis is performed on them. After that, we provide suggestions for each part of Green Building based on our qualitative analysis, which tries to identify the most important factors and challenges. Our hope is that this article will help those working in the field of building science and practice make more informed choices that will have a positive impact on green building sustainability and energy efficiency.

Keywords Green Buildings, State of Knowledge, Bibliometric Analysis

1. Introduction

During the whole building life cycle (design, construction, operation, maintenance, and demo lit ion), green building aims to improve the building's efficiency by using energy, water, and materials that are available on site. The main goal is to reduce the impact on the environment and human health [1]. Enhancing current conventional design, construction techniques, and standards; reducing operational costs; boosting productivity; creating better living and working environments for occupants; and e xtending the life of buildings via increased durability and efficiency [2]. More and more people are relocating to urban areas, which has led to a dramatic uptick in the construction of buildings and skyscrapers. This has been good for the city's economy, but it has had devastating effects on the natural world. This process accounts for 30% of global warming gases, 65% of trash production, 70% of power use, and 12% of water usage[3, 4]. It also demands a large amount of materials. Hence, design principles to reduce these consequences should be implemented[5-6]. This is why the goal of green building design is to lessen the financial burden of building development and upkeep. Cutting down on energy use and the negative effects on the environment caused by the building and its placement. Creating a welcoming space to boost productivity is another perk, as is improving the health, safety, and comfort of building occupants.

This research aims to analyse the current level of knowledge in accordance with this notion. In addition, a decision-making tool for green building construction was offered via a qualitative analysis. As a Master's Thesis, this study was conducted[7].

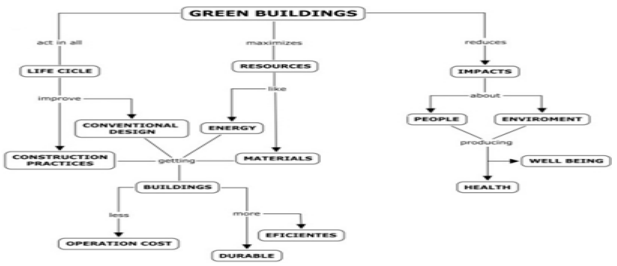


Figure 1. The meaning of Green Building

2. Research Method

The study was carried out by first doing literature research, and then processing and analysing the articles identified. The research was organised into the following five stages:

1) Initial strategy and diagnostics.
2) Searching bibliometric databases and reviewing citations.
3) statistical evaluation.
4) Making use of and analysing the outcomes.
5) Evaluation of quality.

In the first stage, known as "in itial approach," we learned the fundamentals of the subject, which included getting to know Green Buildings, finding relevant keywords, and developing search techniques. Green Building, LEED, materials, prices, and the Green Building Council were some of the terms used in a cursory search on Google and other popular search engines. One had a better grasp of the subject after perusing the material found on several websites. This initial study has shown that the topic of green buildings is gaining traction in many nations and is of great interest to many individuals, groups, and businesses.

In Phase 2, we will begin our study in Scopus and Science Direct, two online bibliographic databases that include abstracts and citations for academic journal articles, book series, and handbooks. We will restrict our search to the years 1980 to 2011 using the search technique outlined in Table 1. Scientific, international, and topic-related criteria led to the selection of these databases. Year, country, database, paper type (article or handbook), author, and nine categories identified as common aspects in the literature were used to classify the results of a thorough review of all articles (some of which were only abstracts and were not considered). The first six—sites; water conservation; energy efficiency; interior quality; materials; design; and innovation—are based on evaluation criteria currently employed in prestigious Green Building certification programmes like LEED. The last two groups, trends and costs, are critical considerations for any Green Building project's viability. The "other" category is for things that don't fit neatly into the others but are nonetheless important to highlight. In this phase, the papers found were filtered, removing duplicate articles, and eliminating papers which were not strongly related with the topic of the study.

Table 1. Keyword combinations per search strategy

SEARCH STRATEGIES		
SS-1	TITLE	"Green Building"
SS-2		"LEED Certified Building"
SS-3		"Green Building" AND "LEED Certified Building"
SS-4		"Green Building" AND "Cost"
SS-5		"Green Building" AND "LEED"
SS-6		"Green Building" AND "Water"
SS-7		"Green Building" AND "Sustainable Building"
SS-8	TITLE-ABTRACT-KEYWORD	"Green Building Council"
SS-9		"Green -Building" AND "Material"

Phase 3, a quantitative study was done using some aspects of the article such as the number of articles published per journal and the indexes given by the Journal Citation Report (JCR), most recognized authors (taking into account authors with two or more publications), publications countries, the articles evolution throughout time, publication by category and the articles evolution over time and per category

On phase 4, the data gather on the preview phases was analysed using the categories on phase 2 as reference. The articles with the highest references number and their keywords are the main focus on this phase.

Finally on phase 5 a qualitative analyses was done by an exhaustive study of the articles and summarizing all the main contributions of the most relevant ones.

3. Results

3.1. Quantitative Analysis

A total of 218 papers were found and reviewed, 21 of these papers were duplicated and 73 papers were not strongly related with the topic of the study. Therefore 94 papers were eliminated, leaving 124 articles to be used in the study.

3.1.1. Relevant Journals

To assure the veracity of the research, the Journal Citation Reports (JCR) index was used as a resource to know the impact of these articles in the scientific community. More than a half of the articles (69.4%) were published in journals with Q1 ranking.

Table 2. Journals with the highest scientific production

JOURNAL	JCR	#PAPERS	%PAPERS
Building and Environment	Q1	36	29.0%
Energy and Building	Q1	17	13.7%
Building Research and Information	Q1	12	9.7%
Landscape and Urban Planning	Q2	5	4.0%
Others	--	54	43.5%

3.1.2. Relevant Authors

The authors with more publications are: Dai, Y.J.; Ma, Q.; Wang, R.Z.; Zhai, X.Q. from Shangai Jiao, with 4 publications each one.

3.1.3. Countries

The countries with most publications are U.S.A, China and Canada, with 27.7%, 16.7% and 8.6% respectively.

3.1.4. Evolution throughout Time

The evolution of Green Buildings research from 1980 until 2011 is shown on Figure 3. The first article appeared in 1997. Before 2007, the number of art icles was very fe w and intermittent. After that year, an increase on interest was evident: 70% of the papers were published.

3.1.5. Research Categories

The most researched categories, based on phase 2 are: Energy Efficiency (25.8%), Tendencies (15.3%), and Design and Innovation (14.5%).

3.2. Qualitative Analysis

3.2.1. Research Approach

As a result of the first approach (phase 1), LEED was the rating system most mentioned. The country with the highest number of publications is United States with 27.7%. This could be attributed to the fact that LEED Rating System is the rating more internationally recognized, developed by US Green Building Council.

3.2.2. Green Buildings Aspects

The first step to contribute with the sustainability is the design of the structure. As a prelude to the construction phase, which has a great in fluence on many other aspects, a good design takes into account: costs, energy efficiency, water saving, materials, etc.

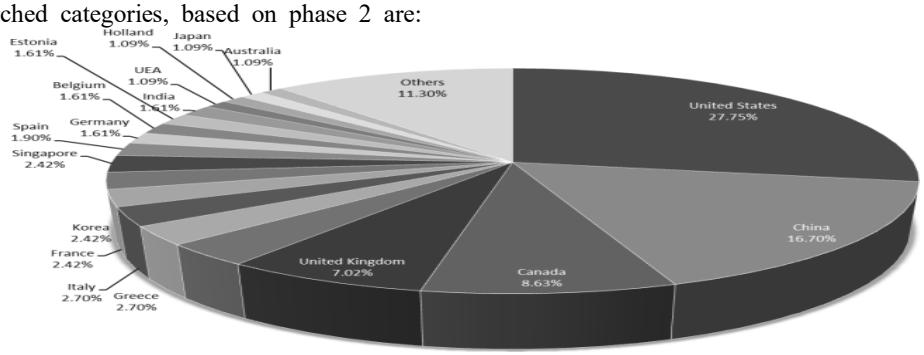


Figure 2. Publications by country

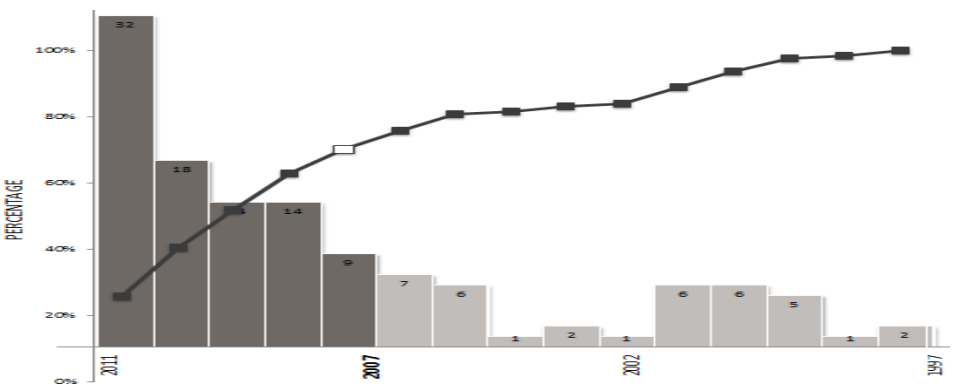


Figure 3. Paper published per year and its evolution throughout time

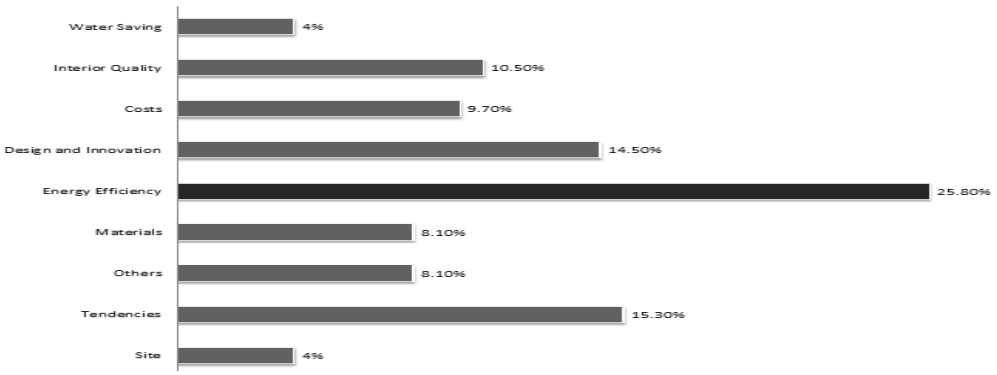


Figure 4. Papers related with Green Buildings aspects

This stage makes use of building information modelling (BIM), a 3D modelling design process that produces results much more quickly than conventional methods. Autodesk Revit is a building information modelling (BIM) technology that enables users to superimpose many sorts of designs, including structural, architectural, plumbing, and more. During the building process, the user may easily observe and prevent errors. In addition, using Autodesk Revit may result in the indirect or direct acquisition of up to 38 LEED points. However, 70% of the software purchase cost goes into training and adaptation for this tool, and initial productivity is 50% lower. The investment is recouped with a 25% improvement in production after the training period (around three months) [8].

According to many experts, buildings account for 30–40% of total energy consumption[9, 10]. Even if a forty percent reduction in energy use is possible with design-phase energy efficiency techniques. There was no correlation between the degree of LEED certification and any efficiency metric that was considered statistically significant. Basically, the energy performance of a LEED-Silver building was not better than that of a LEED-Certified structure. This could be because a lot of work has gone into making buildings as energy efficient as possible; to be LEED certified, a building needs a minimum score of 40 and a maximum score of 33–37 (category dependent), so it's easy to meet the few extra requirements for LEED certification if that's what the stakeholder is after, but it's not so easy to get LEED-Go ld/Platinum certification [7].

An important part of the Leadership in Energy and Environmental Design (LEED) rating system is water conservation, which is associated with energy efficiency [11]. One tactic that is often associated with better water use is the green roof. However, there are instances when buildings are marketed as "green" just because they have what are called "skin vegetable or green roofs." Environmentally friendly roofs have the ability to reduce pollution via shading the air, which decreases the likelihood of flooding and acts as a thermal insulator[12], however these components alone will not render the structure environmentally friendly.

On the other hand, the worker may have a common illness that hinders their performance, such as asthma, rhinitis, or dermatitis. Some people experience symptoms of Sick Building Syndrome while at work, such as dryness and itching of the eyes, nose, throat, and skin; congestion of the nasal passages; lethargy; headache; and these symptoms go away as they leave the building [13].

Concrete is the most widely used material in building construction, yet its production has a significant effect on the environment. There have been recent initiatives to develop a greener clinker, with the goal of lowering CO2 emissions by 25-30% during manufacture [14].

According to LEED, one of the most important factors in creating a green building is the use of glass. Building facades often make extensive use of glass, accounting for 25–40% of the total. Intense indoor heat and eye strain, known as the "cave effect," may result from being in direct sunlight for too long [15]. It is also suggested to use eco-friendly materials like linoleum, natural stone, native wood, clay brick, lime or silica paint, etc.[16].

Without mandating a certification system, the World Green Building Council advocates for a grading system for green building certification. Certification rating systems vary from one nation to another in response to local construction codes, climate, and other factors; nonetheless, these variations have no bearing on the final score.

One of the primary drivers of green building is countries with environmentally friendly laws. Developed nations' regulations and benchmarks facilitate prominently displayed Green Building tax credits to encourage their construction. In underdeveloped nations, however, green building certification is totally optional and paid for by the owner; the government offers no financial incentive to hasten the process.

While green construction projects sometimes have higher initial costs, the increased savings during the structure's lifespan more than make up for it. In fact, green buildings may fast recoup their initial investment and even add to their profitability. That is why it is financially feasible to construct

Green Buildings.
Among the most important considerations for all parties involved are the financial advantages, which include: reduced respiratory illness, cost savings, increased profitability, increased market share through marketing, and low operating costs [17].
While there have been some attempts to implement policies, there have been some technical issues with the construction, and there has been a general lack of knowledge and awareness of green technologies, the biggest obstacle to their application has been the initial additional cost.

(4) Suggestions

To avoid mistakes in the LEED paperwork, use building information modelling (BIM) and other technologies like Autodesk Revit and IES Virtual Environment, among others, to undertake 3D modelling simulations of building operating behaviour and energy need calculations.
Improve water conservation and energy efficiency by using a green roof and building automation. In addition, a green roof and automated building systems may enhance the interior quality, making it more comfortable and efficient for users. Incorporating ergonomic features, providing occupants with more control over lighting, and using finishes with minimal toxicity may all contribute to enhanced indoor quality. In addition, a Post Occupancy Evaluation (POE) is suggested. Double or triple glazing in the façade, together with eco-friendly materials like natural stone, native wood, clay brick, linoleum, lime, or silica paste, might help lessen the cave impression.
Legislation that is both voluntary and obligatory promotes and supports green building practices. Put another way, it is the flagship project for eco-friendly construction.

Table 3. Green Building aspects

	MAIN ASPECT	RECOMENDATION	OBSTACLES
DESIGN	The shape and orientation can significantly influence the design and then affect costs, energy efficiency, water savings, materials, etc.	BIM is a 3D modelling design method. It generates results very fast compared with traditional methods. Also with this method it can be obtained a gain, directly or indirectly, LEED points.	Initial training and adaptation are required, which costs about 70% of the acquisition cost of the software, additionally the initial productivity falls 50%
ENERY EFFICIENCY	Buildings consume 30-40% of energy.	Implement the use of green roof, solar collectors, building automation, triple glazing	A huge number of proposals with lack of data, lack of time, low budget, low technical experience. Furthermore, the uncertainty about what concepts or elements need to be improved and/or can be improved.
WATER SAVING	Water saving is necessary to conserve water and its closely linked with reduce energy consumption (contributing to energy efficiency)	Implement the use of green roof to water reuse and energy performance, and building automation as infrared sensors in bathrooms to improve the performance water.	Initial cost of water reuse systems, the design of one strategy varies and depends of building characteristics, and aesthetics.
QUALITY INDOOR	Related directly to health, comfort and productivity.	Use low toxicity finishes, allowing occupants more control over lighting, including ergonomics aspects. Furthermore, it recommends a POE (Post Occupancy Evaluation).	There are many diseases such as asthma, rhinitis, and dermatitis, among others that could propagate causing poor performance in the worker. Also, the Sick Building Syndrome could appear. .
MATERIALS	Concrete and glass are the most used materials.	Ecological materials as natural stone, native wood, clay brick, linoleum, lime or silica paint, etc. The use of double or triple window glazing.	"Green" is not clearly defined, making it difficult to find green materials and in most of the occasions green materials are more expensive than conventional.
LEGISLATION	As mandatory encourages, promotes and contributes to the green building construction. In other words is the main starter of green buildings.	Encouraging the use of evaluation systems in state agencies or public building projects.	Poor or non-existent in development countries. There is no single plan.
COSTS	Determine the profitability of the project	Perform of a cost-benefit assessment and plan projects, taking into account the additional investment cost.	Some of the benefits are hard to measure such as health and, productivity, performance

4. Conclusions

A large body of literature exists on the topic of Green Buildings, as shown by the number of publications retrieved from the literature review. More and more individuals, organisations, and nations are showing interest in becoming part of the "Green Movement" due to the positive impact it can have on the environment, the financial rewards, and, of course, the admiration and renown that come with it.
The United States has the most papers published worldwide, which may be explained by the fact that the US Green Building Council's LEED grading System is the most renowned certification grading system in the world.
All the components of a green building are interdependent, and a structure is considered environmentally friendly if it satisfies all the requirements for certification. Energy efficiency measures are put in place as a result of good design, which could or might not affect water savings. Several components, including materials, gadgets, and green technology, are required to carry out these efforts. The most typical obstacle is the initial cost increase associated with green development.

Because it affects other green building features (design, materials, water conservation, cost), energy efficiency is the most researched issue. Thus, cost-effective energy efficiency might be a promising area for future study.

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