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Research Article

Leveraging Green Building Technologies to Understand Sustainability in Bengaluru city

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Abstract

Background: The motivation of this paper is to analyze the growing air pollution level in the city of Bengaluru, as it was once a green city but is now facing problems with the use of private vehicles, such as increasing levels of air pollutants. Green buildings focus on reducing their negative environmental impacts by using less energy and water, and causing less disruption to the environment during construction. Green buildings, which also strive to enhance human health through the design of healthy indoor spaces, are arguably less well-known.

Objective: The main objective is to analyze the most suitable zone in Bangalore for the construction of green buildings. The review of existing green building technologies with the use of natural materials, renewable energy, water conservation, and indoor air quality.

Method: The methodology will include a study of six green building literature reviews with eminent researchers and scientists. The main principles of green building include having indoor air quality of Nitrogen oxides, volatile organic compounds, and particulate matter are the most common air impurities released into the atmosphere by the variability of natural processes and human actions. The advantages of lessened energy and water use are well known, but the potential advantages of green buildings for human health have only lately come into focus. In addition, case study review for Electronic City, Whitefield, and International Airport in Bangalore

Result: To address the comparative study of case study review, Bangalore city data was collected regarding the pollutant levels, then linear regression models were created and reviewed to design green buildings in the future.

Conclusion: The goal of the study is to comprehend how toxins, a rise in urban population density, the usage of novel artificial resources, and traffic contamination all work together to worsen indoor air quality and increase harmful impacts on people.

Introduction

It is estimated that city dwellers spend up to 90% of their time inside and spend a significant portion of their waking hours at work. Thousands of different factors combine to create outdoor air pollution. Most important for health are Particulate Substances (PM) and vaporous pollutants, ozone, Nitrogen Dioxide (NO_2), volatile organic mixtures (including benzene), Carbon Monoxide (CO), and Sulfur Dioxide (SO_2). Burning fossil fuels releases primary impurities such as dust particles, nitrogen oxides, and sulfur into the atmosphere [1]. Motorized road circulation, power generation, industrial bases, and domestic heating are important producers of primary atoms. Ozone (O_3) and PM are the two most important subordinate pollutants formed when primary impurities in the environment interact or react. Evaluating exposure to air pollutants is important because it has been shown that indoor and outdoor air pollutants can have a variety of adverse health effects. To save energy, newly built or retrofitted building infrastructure is becoming more airtight. Thus, while hundreds of different types of pollutants have been found to pose health risks, the release of pollutants from indoor sources, often associated with culinary and space heating, is a significant basis of human air pollution. It is the cause. PM2.5, CO, and SO2 are the pollutants that pose the greatest threat to indoor air quality today. The latter, whether of primary or secondary origin, consist of coarse particles (diameter 10 m; PM10), tiny particles (diameter 2.5 m; PM2.5), or ultrafine particles (diameter 0.1 m; PM0.1) are composed particles can be classified based on their size. Coarse particles also contain

PM2.5, which accounts for about 50% of the mass of PM10 [1,2]. Construction activities, industrial pollutants, and the uplift of soil and road dust from wind and moving vehicles all contribute to coarse particulate matter (PM10). The main sources of particulate matter are direct releases from ignition activities such as gasoline and diesel combustion, wood combustion, coal combustion for power generation, and industrial procedures. Because fine particles can transit long distances (above 100 km), they can spread over large areas with high background concentrations. Improving the energy efficiency of buildings through new laws requiring stricter construction methods will inevitably impact indoor air quality [2,3]. While aeration standards commend high ventilation rates to recover indoor air quality, these structures must also improve their ability to remove pollutants from the air entering the building and from the outside air.

Aim and objectives

To understand the green building technologies in the making of a smart city

1. To analyze green building technologies
2. To develop the linear regression model of Air quality data
3. To understand the statistical data

Research questions.

1. What are green building technologies?
2. Why are smart cities growing around the globe?
3. Is a smart city required to have green buildings?

Methodology

Green buildings of Vancouver, Hyderabad, and across Bangalore have been studied and reviewed regarding how they respond to the air quality levels. Then, the data regarding the air pollutants have been studied, and linear regression models were created to analyze the suitable areas in Bangalore for green buildings.

Literature review

Paper 1: Direction for a Transition toward Smart Sustainable Cities based on the Diagnosis of Smart City Plans [4].

Author: Hee-Sun Choi and Seul-Ki Song [4]

Journal: MDPI

Year Published: 2023

Inference: Define frameworks, metrics, and ideas such as building smart and sustainable cities. The study explores how smart and sustainable cities can drive sustainable growth by integrating smart technology into everyday life and services. These were used in case studies such as the Incheon metropolitan area in South Korea and Goyang City in Gyeonggi Province.

Research gap: However, the formation of three-dimensional units for analytic and assessment indicators should be measured in the forthcoming, as protocols and indicator elements may differ depending on whether the urban spatial area is city-based or project-based. Scoring systems should be enhanced in future studies to allow strategic indicators to be selected about goal-to-goal fit, e.g., through a screening process, optional indicators, weighting, etc.

Paper 2: Investigating Smart City Development Based on Green Buildings, Electrical Vehicles and Feasible Indicators [5]

Author: Armin Razmjoo, Meysam Majidi Nezhad, Lisa Gakenia Kaigutha, Mousa Marzband, Seyedali Mirjalili, Mehdi Pazhoohesh, Saim Memon, Mehdi A. Ehyaei, and Giuseppe Piras [5]

Journal: MDPI

Year Published: 2021

Inference: This study investigates several facets of the growth of smart cities, offers new workable indicators connected to GBs and EVs in developing SCs, and deliberates current obstacles to the growth of smart cities as well as ways to get beyond them.

Research gaps: Governments should therefore implement the necessary legislation, such as increasing EV investment and creating GBs about environmental methods. The barriers include reasons for insufficient government investments in EV and GB development in cities, reasons for improper coordination between national and local governments in achieving the goals, etc.

Paper 3: Buildings Energy Efficiency: Interventions Analysis under a Smart Cities Approach [6]

Author: Gabriele Battista, Luca Evangelisti, Claudia Guattari, Carmine Basilicata and Roberto De Lieto Vollaro [6]

Journal: MDPI

Year Published: 2014

Inference: The examination of the construction's energy demands and the evaluation of demand decrease are the first steps in the methodology commonly used to evaluate building energy efficiency. As a result, a cascade of treatments is used to evaluate the energy savings. They examined the performance of electric movement in six smart cities (Oslo, London, Milan, Hamburg, Bologna, and Florence) [6].

Research gaps: The paper was designed for diverse geometric outlines and boundary circumstances, resulting in different graphic depictions. It consists of designing new diagrams considering scientific information. Window-to-wall ratios and other geographic areas. The goal of this study is to precisely measure the relationships among 'climate-engineering intrusions' and recognize the most effective intrusions to choose based on the accessible monetary budget.

Paper 4: Blockchain and Building Information Management (BIM) for Sustainable Building Development within the Context of Smart Cities [7]

Author: Zhen Liu, Ziyuan Chi, Mohamed Osmani, and Peter Demian [7]

Journal: MDPI

Year Published: 2021

Inference: The purpose of this paper is to discover the possible influence of blockchain and BIM integration in smart city environments on the design of additional sustainable buildings in the CIM/smart city context. This paper examines the relationship among blockchain, BIM, and sustainable construction transversely construction project life sequence phases.

Paper 5: A Review of Energy Modeling Tools for Energy Efficiency in Smart Cities [8]

Author: Fernando Martins, Carlos Patrao, Pedro Moura, and Anibal T. de Almeida [8]

Journal: MDPI

Year Published: 2021

Inference: The current overview analyzes various modeling tools that can be used to evaluate smart city energy systems. It provides an up-to-date summary of the modeling tools currently available, demonstrating their abilities and key latent consequences when seeing energy efficiency goals in the framework of smart cities in Europe.

Research gap: The European Community's legal outline based on the principle of energy efficiency is not sufficient. Cities consequently need to plan for 2030 and 2050 and consider the influence of energy efficiency programs to become smart cities.

Paper 6: Investigating Smart City Development Based on Green Buildings, Electrical Vehicles and Feasible Indicators [5]

Author: Armin Razmjoo, Meysam Majidi Nezhad, Lisa Gakenia Kaigutha, Mousa Marzband, Seyedali Mirjalili, Mehdi Pazhoohesh, Saim Memon, Mehdi [8]

Journal: MDPI

Year Published: 2021

Inference: This paper reviews various characteristics of smart city growth, familiarizes new viable metrics related to GB and EV in SC design, and presents existing obstacles to smart city growth and solutions to overcome them.

Research gap: Findings show that improving liveliness and source efficiency will be particularly significant to reduce industrial releases in the 2020s, paving the way for large-scale emissions reductions and an alternative to decarbonization. Infrastructure is built for the means. The introduction of new ideas and advancements in GB and EV, as well as economic and financial benefits to consumers, will be the major motivations for accelerating the realization of SC (Figure 1).

Theoretical framework for green building

To qualify as a "green building", buildings must be constructed and resource-efficient at all phases of the building life cycle, including planning, design, structure, progression, maintenance, reconstruction and decommissioning.

Energy Efficiency in Building

Energy efficacy in a building can be achieved through:

Reducing building energy consumption (by using energy-efficient devices)

Local production of energy from renewable resources and buildings that can generate excess energy and feed it into and feed it into intelligent grid infrastructure to share energy, as well as from other resources that waste energy. Form-dependent energy utilization. Martin and March [8] classified building clusters into three types:

- Pavilions – standalone buildings

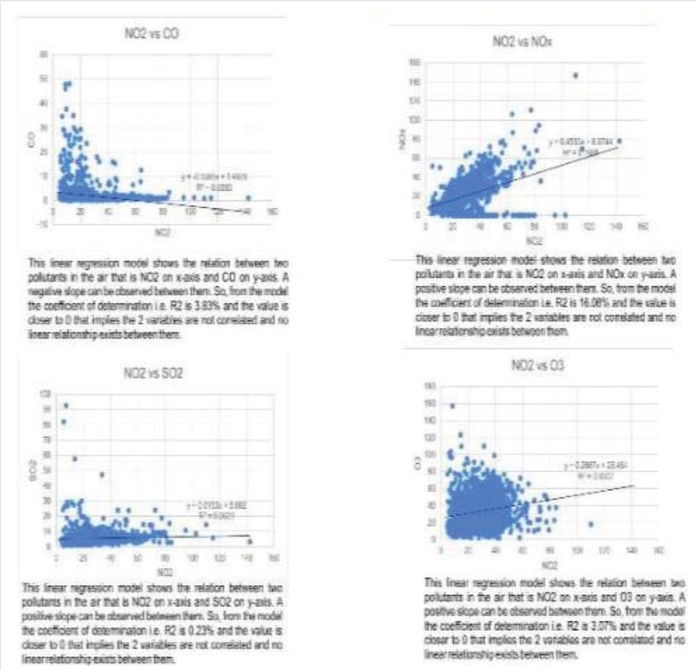

Figure 1: Linear Regression Model for Air Pollutants.

- Streets – rows of buildings
- Courts – Open spaces enclosed by buildings

Ways to achieve energy efficiency:

- Use of rooftop
- Solar photovoltaic units
- Solar thermal amassers and possibly storage mechanisms
- Skylight or screens for daylighting
- Foliage for green roofs
- Heat recovery vents

Daylighting

A good daylighting strategy necessitates:

1. Fenestration
2. plan shape
3. internal finishing
4. Partition layout for optimum daylight entry and distribution

Avoidance of unwanted solar gains

Relationship between volume and cooling – It is possible to reduce temperatures in the occupied zone by increasing the number of rooms that are more likely to overheat. If this strategy is carried out in a planned manner, it would also reduce the amount of energy needed to cool that space.

Airflow around a building

Airflow around a single building (Figure 2):

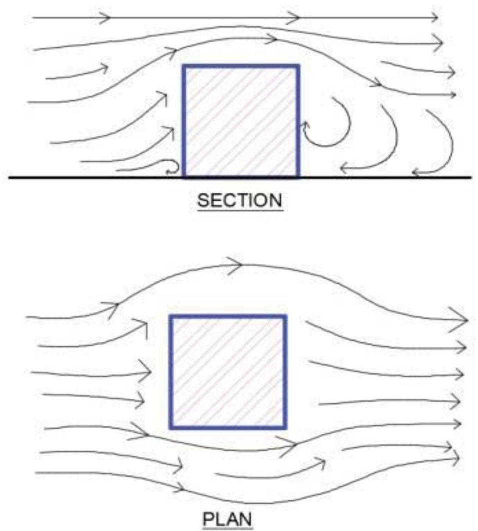

Figure 2: Building Sections indicating the airflow movement.

Corner effect – Corner acceleration occurs when wind reaches a tall building's vertical edge. The sharp building shapes that cause acceleration around the corners are the primary source of this effect. In a built environment, the areas that can cause the most discomfort are those in the corners of tall buildings. Channel Effect – A layout of tightly grouped buildings along the streets or in an open space map can be installed to reduce the wind commitment by initiating the channeling effect

Case studies

Design TERI campus, Bengaluru

(Figure 3)

Design BCIL TZED homes, Bengaluru

(Figure 4)

Electronic City/ ITES/Airport, Bengaluru, India

In this study, we compare the case studies in Bangalore with eminent corporate organizations that have used the Green Building application and technology (Figure 5).

The air pollutants with Standard deviations and variance for CO and NO have been outliers in the study. Further, in Tables 1,2, a detailed interpretation of the regression model and descriptive statistics is tabulated. Also, after calculating the arithmetic mean, mode, median, standard deviation, and variance, PM10 had the highest value, which implies that it has a higher concentration as an air pollutant in the air.

Discussion

This study focused on finding the highest R2 by using

Table 1: Interpretation of Regression Model for Air Pollutants.

Combinations		R^2	y = mx + c
X	Y		
PM2.5	PM10	0.2054	y = 0.7741x + 55.564
NO	NO^2	0.2532	y = 0.8949x + 19.575
NOx	NH_3	0.0147	y = 0.1003x + 23.952
CO	SO_2	0.0108	y = 0.1079x + 5.3174
O_3	Benzene	2.00E-05	y = 0.0045x + 3.4242
NO	NOx	0.2841	y = 1.0765x + 9.5925

Table 2: Descriptive Statistics for Air Pollutants for Bengaluru.

Formulas	Mean	Median	Mode	Standard Deviation	Variance
PM2.5	35.82	30.92	31.78	22.07	487.23
PM10	83.24	77.36	48.92	38.11	1452.06
NO	9.41	7.52	5.74	7.47	55.81
NO_2	28.00	26.92	26.31	13.29	176.53
NOx	19.72	19.14	0	15.08	227.49
NH_3	21.98	19.635	24.05	12.74	162.30
CO	1.84	0.92	0.85	3.97	15.76
SO_2	5.52	5.03	5.81	4.19	17.52
O_3	32.87	30.6	25.3	18.40	338.72
Benzene	3.22	0.81	0	16.32	266.47
Toluene	4.75	1.79	0	16.02	256.74

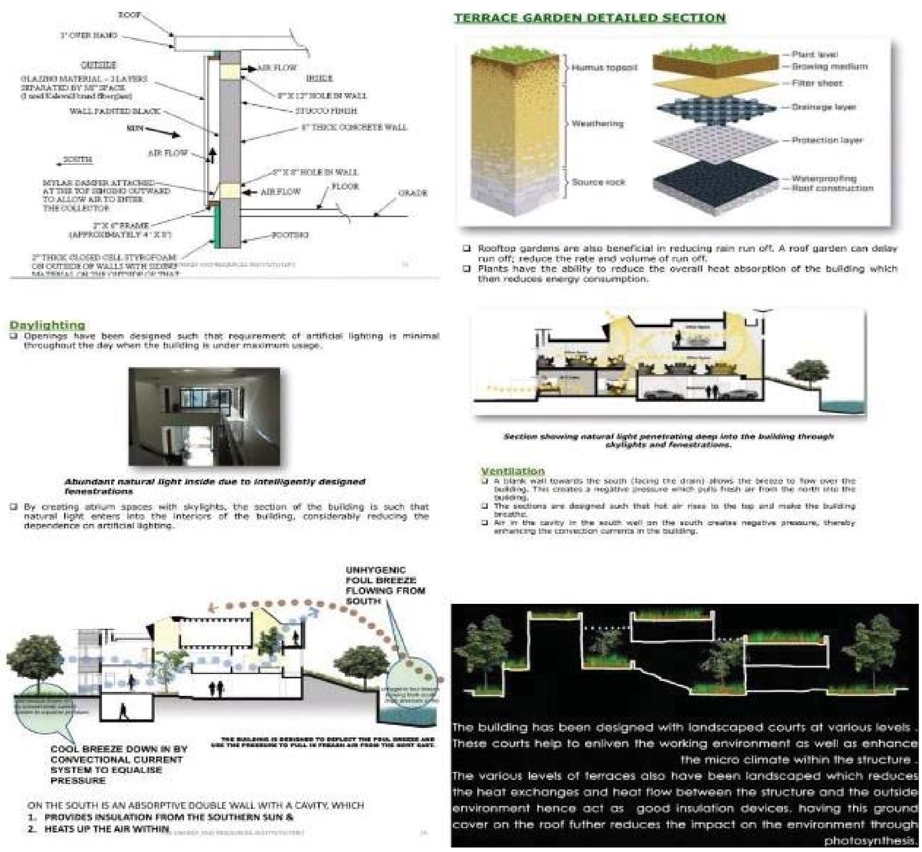

Figure 3: A Detailed Case Study for Green Building TERI Campus, Bengaluru.

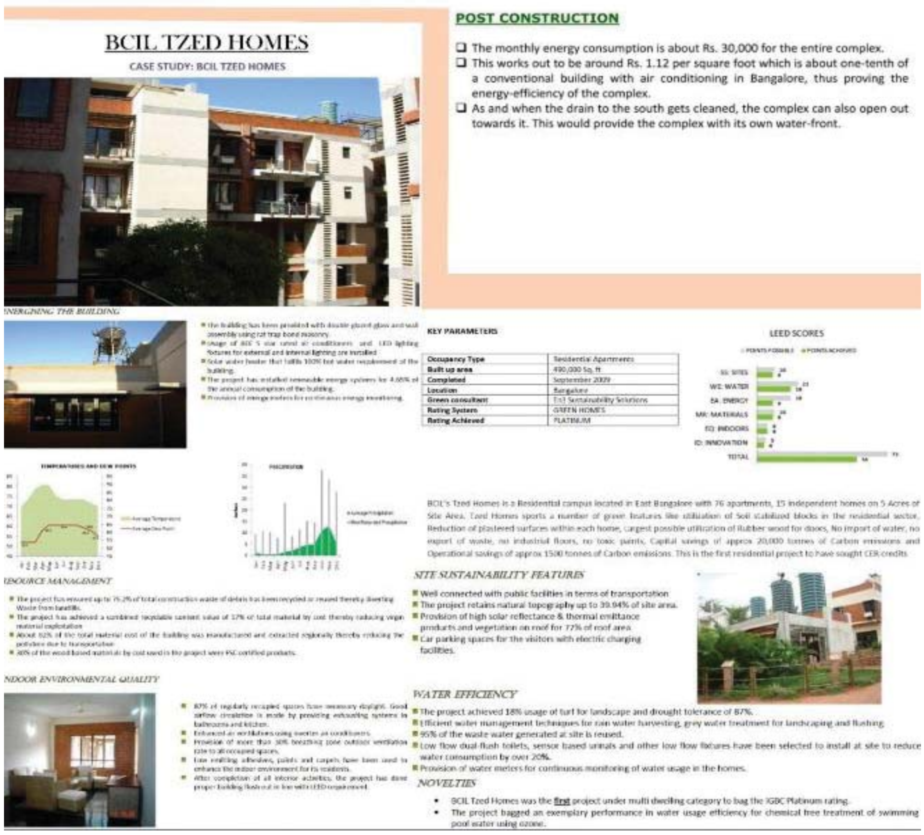

Figure 4: A Detailed Case study for BCIL TZED with Architectural designs.

S.NO.	PROJECT NAME		DESCIPTION
1.	Wipro office, Electronic City, Location: Bangalore, India.		1. The campus and its buildings will accommodate 17,000 employees on a 48-acre campus with a software development block (SDB), cafeteria, learning center, customer care center and guest block, allowing employees to be self-sufficient. 2. The total construction area is more than 1.8 million SFT. The entire site slopes gently from northeast to southwest. 3. A small courtyard is enclosed by a low SDB. 4. Vehicle traffic is restricted to the arrivals vestibule and around campus.
2.	Cisco SystemsIndustry: Networking Location: Bangalore, India		Background 1. Give employees a co-office experience 2. Developing scalable and sustainable solutions that can be replicated in other Cisco locations around the world Smart parking: 1. Intelligent parking systems show how IoE technology can be used in cities of the future, where sensors in parking lots can help monitor the number of parked vehicles and display available parking spaces.
3.	Kempegowda International Airport	 	1. The first stage of construction of the project is expected to be accomplished by March 2021 and will serve 25 million travelers annually. 2. All corridors throughout Terminal 2, covering approximately 255,000 square meters after the conclusion of the construction phase of the first plan, connect explorers with fauna.

Figure 5: Comparative Table for Green Projects in Bangalore.

the linear regression model of major air pollutants found in the city of Bangalore. From the studies, it was found that the coefficient of determination (R2) is the highest in the comparison chart of NO and NOx, that is 0.2841. Short- and long-term acquaintance with PM has been linked to increased mortality in both developed and developing nations, according to several meta-analyses and studies. Short-term PM exposure has been estimated to have a comparative risk (RR) increase for all-source death of 0.4% to 1.5% for coarser PM10 and 0.6% to 1.2% for finer PM2.5.

Additionally, it may be helpful to mandate emissions challenges of all construction resources, furniture, and equipment both before and during their usage in green buildings to effectively manage and characterize IAQ in those structures. To do this, green buildings might need continuous or even routine IAQ measurements. Such monitoring would enable the correction of unacceptable pollution levels and sources and would offer information for the re-certification of buildings. To ensure that favorable IAQ values are obtained and maintained, IAQ recertification of green buildings may be included in certification programs.

Conclusion

The building industry is thought to be moving towards environmental protection through sustainable building. Sustainable building practices are encouraged to achieve construction projects that balance economic, social and environmental performance. Accepting this, the relationship between sustainable development and construction is clear. Construction is of great economic importance and has a large impact on the environment and society. Construction professionals all over the world are paying more attention to this issue as environmental protection becomes increasingly important [8-10]. The usage of sustainable building construction methods has been promoted as a strategy to promote economic development in the construction sector while reducing environmental effects. To mitigate the negative environmental impacts of this construction and achieve sector sustainability, three principles will be used: resource efficiency, economy, and design for human adaptation. They serve as a foundation for incorporating sustainability ideas into construction projects from the start.

Recommendations

The framework has the potential to significantly speed up the comprehension and use of sustainability in building design [11,12]. It emphasizes the necessity of an integrated and holistic strategy for adopting sustainability in building projects and gives a succinct review of sustainability principles, strategies, and approaches. It aims to deliver a comprehensive outline for refining standards and similar methods for assessing the environmental performance of buildings [13,14]. Identify and describe the difficulties to consider in the design, construction, operation, renovation and demolition of new or existing buildings. It identifies and describes the difficulties to consider during the planning, construction, operation, renovation, and demolition stages of new or existing buildings. It is not meant to replace existing assessment systems like BREEAM, BEES, LEED, etc.; rather, it is meant to be used in conjunction with and as a supplement to them. Filthy air can be injurious to both human well-being and the health of the environment, it is crucial to regularly monitor air quality [15]. Low- and middle-income nations, in contrast to most industrialized nations that have completed industrialization programs over the course of several years, have undergone a rapid urbanization and industrial development process, making them the nations with the greatest burdens related to air pollution in recent years. This peculiarity maliciously affects the strength of individual occupants in these non-industrial nations, as they are presented to the joint harmful impacts of family and encompassing air contamination. Before the impact on public health is obvious, it is necessary to translate an extra risk of mortality of "05% per 10 g/m3 PM10". In the Netherlands (population 16 million, approximately 140,000 deaths per year, average PM10 concentration >30 g/m3), the daily variation in PM10 deaths translates to at least 2,100 deaths from air pollution each year. —nearly twice as many deaths as those caused by traffic accidents.

This study would be further carried out in finding suitable parameters for green buildings. This might include indoor air pollution levels that influence housing characteristics.

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