Life Cycle Assessment (LCA) Based Environmental Impact Assessment of G+20 Storied Apartment Building using Building InformationModeling(BIM): A Case Study

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Abstract

Life Cycle Assessment (LCA) is an effective method for evaluating the environmental implications of building construction. However, it is mostly used for post-design reviews and rarely utilized to support or optimize design decisions during early design stages due to its complexity and professional expertise requirements. This study aims to assess and reduce the environmental impact of a 20-story apartment building through appropriate design and material selection. Multi-story buildings are commonly preferred in larger towns and cities, but their development can have significant environmental impacts on the surrounding region. The "cradle-to-grave" LCA approach is used to determine the adverse hazards associated with the 20-story building model, including carbon dioxide (CO_2), sulphur dioxide (SO_2), phosphate ($(PO_4)_3$), trichlorofluoromethane (CFC-11), and energy consumption. Environmental effect categories, such as the potential for global warming, ozone depletion, acid rain, and others, are described using these corresponding amounts. LCA analysis is conducted using computer software. This research work estimates the environmental impact of multi-story building construction using the LCA tool, which can help identify upcoming challenges in constructing environmentally friendly buildings without affecting society for builders, entrepreneurs, and financiers.

Keywords: Sustainable building, building information modeling, life cycle assessment, environmental impact assessment

1. Introduction

Construction activity is a critical indicator of a country's growth. However, the increase in building footprint is having a significant impact on the environment. This is due to the construction industry consuming scarce natural resources and emitting gases that harm the environment. Most of these effects are typically associated with a project's use and construction stages. Due to the growing awareness of the detrimental effects of construction, construction sector stakeholders are pressuring each other to conduct LCA analyses before work begins. Life cycle assessment (LCA) is a practical method for assessing the long-term environmental effects of a building. LCA techniques can quantify the adverse environmental effects due to different materials and reduce them. LCA provides several options for the same activity, making it easier to compare impacts.

Life cycle assessment (LCA) and building information modeling (BIM) are the foundations for analyzing a building's environmental performance over its life cycle [1]. LCA is an essential component of building project sustainability, and using BIM may result in a better LCA procedure [2]. BIM and sustainability are critical topics in the Architecture, Engineering, and Construction (AEC) industry as they update and enhance traditional practices. Due to the increasing relevance of sustainability concerns in building projects and the continuous developments brought about by BIM technology in the AEC sector, there is increased interest in the link between sustainability and BIM [3]. Making informed and well-structured design decisions at the start of a task may improve the effectiveness and efficiency of the sustainable design process [4]. It is critical to use BIM technologies to integrate project disciplines because design changes made early in the project's development have a tremendous impact on sustainability [5]. According to GulzhanatAkhanova et al.[6]combining the design models will allow the multidisciplinary data to be combined into a single model. With integrated sustainability analysis within BIM technologies, examining the many design options may move more quickly. The designer may discover more environmentally friendly design options to assist them in making better choices early in the design process. As a result, designers can anticipate how the building will affect the environment in the future[7].

Ignacio ZabalzaBribián et al. [8] investigated life cycle assessment, energy, environmental impacts, and eco-efficiency of building materials. In this study, the authors looked at several construction materials' life cycles and environmental impact features, such as primary energy consumption, global warming potential, and water demand. The authors stated that the information supplied might aid in selecting materials with a focus on minimizing environmental consequences. Salman Azhar et al.[9] investigated the use of BIM for ecological sustainability and the Leed rating process using the case study of Salisbury University's Perdue School of Business building,.ToveMalmqvist et al. [10] attempted to quantify the life cycle assessment for a building using the ENSLIC approach. The author inferred that to get beyond some of the current hurdles to increasing LCA adoption; it is preferable to begin with more straightforward, simplified LCA tools. Ahmad Jrade et al. [11] developed a technique for modeling the methods for executing an ecological style for building projects at the theoretical stage using a usable model that integrates BIM, LCA, and relational databases. The limitations of the proposed technique also have been addressed by the author. The author has also addressed the limits of the suggested approach. Because it does not include all current green aspects, it cannot be employed during the detailed design stage of a construction project.

Patrick Bynum et al. [12] investigated the viewpoints of designers and builders on the use of BIM for sustainable design and construction. The authors have conducted surveys among various owners, architects, and builders and concluded that most of the professionals believed that the major use of BIM was project organization and visualization rather than sustainability. Laura Alvarez Anton et al. [13] emphasized the importance of integrating LCA and BIM to obtain better sustainable and environmental decision-making methods in the early design phase. ElkeMeex et al. [14] accentuated LCA is the best possible way to quantify the environmental impact assessment of a building. The authors have also mentioned the several voids that must be filled to fulfill the user needs of architects for the EIA tool application in early design. Building information modeling was used by Xining Yang et al. [15] to conduct a situational analysis on environmental footprint accounting for a housing estate in China. The author attempted to integrate the BIM and LCA with the available local software tools in China and the Chinese and European life cycle database employed for the integration. Finally, it was reported that the estimated carbon footprint is 2993 kg CO2eq/m2. FarzanehRezaei [16] researched integrating LCA and BIM in the early and detailed design stage for a residential building in Canada. Revit and openLCA have been used for the integration with the Ecoinvent database. It concluded with remarks that the integration may help building designers conduct environmental studies of their designs and subsequently choose more sustainable materials to reduce environmental consequences.

2. Materials and Methods

2.1. Building Information Models (BIM)

Building Information Models (BIM) have become increasingly popular in the construction companies over the past few decades as a result of the multiple benefits and resource savings they give throughout the design, planning, and construction of new structures.Earlier computer-aided design (CAD) initiatives in a range of sectors fueled the development of 3D modelling during 1970s [17].While many construction industry companies developed integrated analytical tools and object-based parametric design modeling (the fundamental notion of BIM), the construction industry remained firmly entrenched in traditional 2D design for a long time.BIM modelling was originally utilised in pilot projects to assist architects and engineers in the design of buildings in the early 1990s [18].Because of this, significant research trends have been concentrated on improved prior planning and designing, simulation, modelling, measurement, pricing, and information management.BIM is used for preplanning, design, construction, and integrated project delivery of buildings and infrastructure, but research has recently shifted from earlier life cycle (LC) stages to maintenance, refurbishment, deconstruction, and end-of-life considerations, particularly for complex structures.Building Information Models (BIM) have increased in popularity over the last few decades as a means of designing, planning, and developing new structures due to their numerous benefits and resource savings. 3D representation was developed in the 1970s as a result of early computer-aided design (CAD) efforts in several projects.BIM modelling was first used in experimental projects in the early 2000s to aid architects and engineers in building design [19]. As a result, primary research directions concentrated on improving strategy and design, clash detection, visualisation, measurement, costing, and data management.Recent advancements in the design, architectural, and engineering fields have included specialised tools including energy analysis, structural analysis, scheduling, progress tracking, and project site safety.

Building information modeling (BIM) is a computerized depiction of a building's technical features. It is a three-dimensional digital model with all the physical and functional characteristics. BIM software has been developed, including Revit, Navisworks, Tekla, and ArchiCAD. The process of BIM will vary based on the nature and stages of the project. [20]. The Architecture, Engineering, and Construction (AEC) sector has evolved and advanced to the point where technological advancements are more dependable and widely applied. Building information modeling is one of the most significant advancements in the AEC industry recently. BIM is a method that involves building an intelligent model that links AEC specialists and allows for more efficiency in the planning, building, and maintenance of structures and infrastructure [21]. The development of BIM has made it possible to manage and integrate information more effectively throughout the life cycle of a building, making the best use of the design data that is currently available for performance analysis and sustainable design [22]. BIM delivers several benefits and resources savings during a structure's design, planning, and construction phases. The Industry Foundation Classes (IFC) open data standard for BIM facilitates interoperability in the Architecture, Engineering, and Construction (AEC) industry [23].

2.2. LCA Standards and Terminology Referred to in the Present Study

Life cycle assessment (LCA), sometimes known as environmental LCA, is a method for analysing the important environmental consequences of a product or process from raw material extraction through end-of-life.There were numerous attempts to standardize the life-cycle estimation approach. The Global Standards Organization established the standards that were the most widely acknowledged. In order to provide thorough information on LCA technique, the Canadian Standards

Association released Z-760 Environmental Life Cycle Assessment, the world's first national LCA guideline, in 1994.

- Environmental management, life cycle assessment, principles and framework- ISO 14040 (1997)[24].
- Environmental management, life cycle assessment, goal definition and inventory analysis-ISO 14041(1998) [25].
- Environmental management, Life-cycle impact assessment-ISO 14042 (2000) [26].
- Environmental management, Life-cycle interpretation-ISO 14043 (2000) [27].

We are all aware that the globe faces serious environmental problems like global warming, ozone layer loss, trash buildup, etc. Recent studies have shown that the world's climate is changing quickly and will last for some time. As a result, there is an urgent need to reduce the harmful effects of our contemporary way of life to rescue our environment and the globe. [28]. In high-density areas like Delhi, buildings are responsible for 90% of the carbon emissions from electricity usage during operation. Life-cycle assessment (LCA) is used more frequently to realize the building industry's low-carbon transition to attain a green global economy [29]. Measuring and evaluating an item's environmental impact across its complete life cycle is called "life cycle assessment." It is seen as a promising technique for understanding possible energy consumption, carbon emissions, and environmental effects by setting a scope of analysis for a specific product during its entire life cycle. It is also referred to as the "Cradle-to-Grave" approach [30]. The LCA approach used in this study emphasises a thorough understanding of the environmental consequences of material conversion, including not just waste disposal, material and energy consumption, and environmental effects.

The system boundary of a design and construction process is schematically shown in Figure 1. This study defines the system boundary as "Cradle to Grave" or "from a starting point of procurement to end-of-life." The total effects of material extraction and manufacturing processes, transportation, building construction, upkeep, repair, and material replacement throughout a building's life cycle, energy, and water use, and knocking down and end-of-life processing of building materials make up a building's life cycle carbon footprint. HVAC, lighting, office equipment, elevators, and water supply are the key sources of carbon emissions during the operating stage. Consideration might also be given to seclusion from the surrounding vegetation. A flowchart of carbon emissions at various stages is shown in Figure 2.

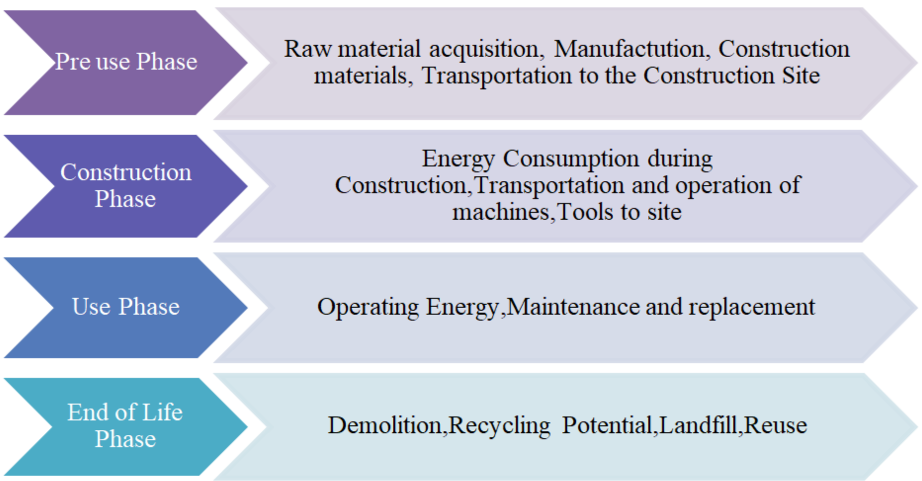

Fig.1. Cradle to Grave system in building’s LCA

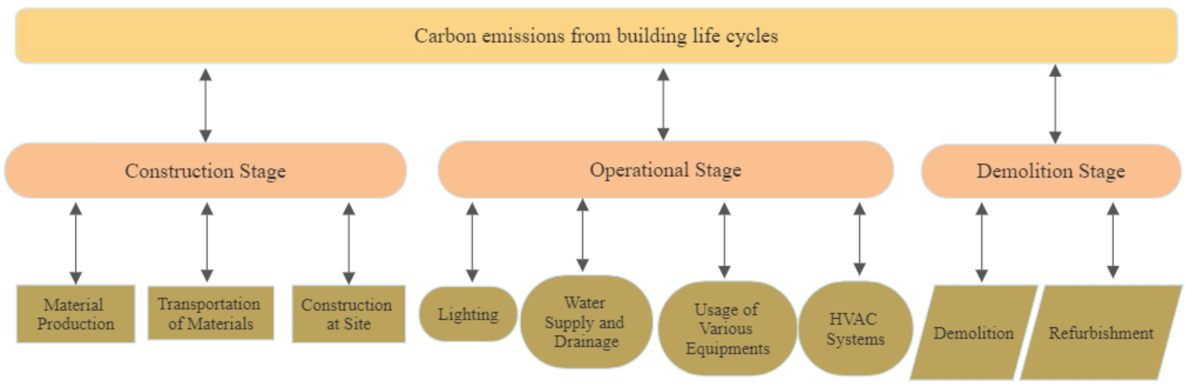

Fig. 2. Composition of a building's life cycle carbon emissions

The distribution of various building performance techniques is illustrated in Figure 3. The application of life cycle assessment (LCA) in the building sector has emerged as a distinct area of focus within LCA practice. This is due to the complexities of buildings, which differ from other intricate products in several ways. First, buildings have extended lifespans that can exceed 60 years, making it challenging to estimate their entire life cycle from inception to final decay. Second, the structure can undergo significant modifications throughout its lifetime, which can be much more substantial than those made during the initial construction phase. The ease with which changes can be implemented and the ability to reduce the environmental impacts of such changes are both characteristics of the original design. Third, many of the environmental impacts of a building occur during its use. Therefore, proper design and material selection are critical in reducing in-use environmental burdens. Fourth, the building industry has numerous stakeholders, and the designer's role is to make decisions regarding the final structure or its required performance rather than constructing it. Since each building is unique, with inconsistent overall design, new decisions must be made for each situation.

Product / Manufacture Stage [A1-A3]			Construction Process Stage [A4-A5]		Use [B1-B7]							End-of-Life Stage [C1-C4]				Benefits & Loads Beyond [D]
					Building Fabric					Operation of the Building						
Raw Material Extract / Process / Supply	Transport	Manufacture	Transport to the Site	Assembly / Install in the building	Use / Application of Installed Products	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Deconstruction / Demolition	Transport to Waste Process	Reuse-Recovery-Recycle	Disposal	Reuse-Recovery-Recycle Potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Cradle-to-Gate			Gate-to-Grave													
Cradle-to-Grave																
Cradle-to-Cradle																
System Boundaries																

Fig. 3. Composition of different life cycle approaches of a building

3. BIM Modelling

The BIM model is built in Autodesk Revit 2022 for its parametric modeling feature. BIM modeling was developed with the requisite LOD. Hence, the model could be mapped with One Click LCA tools for life cycle assessment, which would be helpful for timely and accurate information retrieval. The developed G+20 storied apartment building has a floor area of 405 m^2, contributing to a total floor area of 8100 m^2. The BIM model was constructed using Revit Architecture and rendered using Lumion 12 rendering software. The developed BIM model can be exported and imported to the life cycle analysis tool One Click LCA, and it was observed that One Click LCA is ideally suited to the Revit model. This collaboration protocol is known as interoperability.

Figure 4 illustrates the floor plan of the case study apartment building created using Revit Architecture. Figure 5 depicts a 3D view of the same apartment building, rendered using Lumion 12 software.

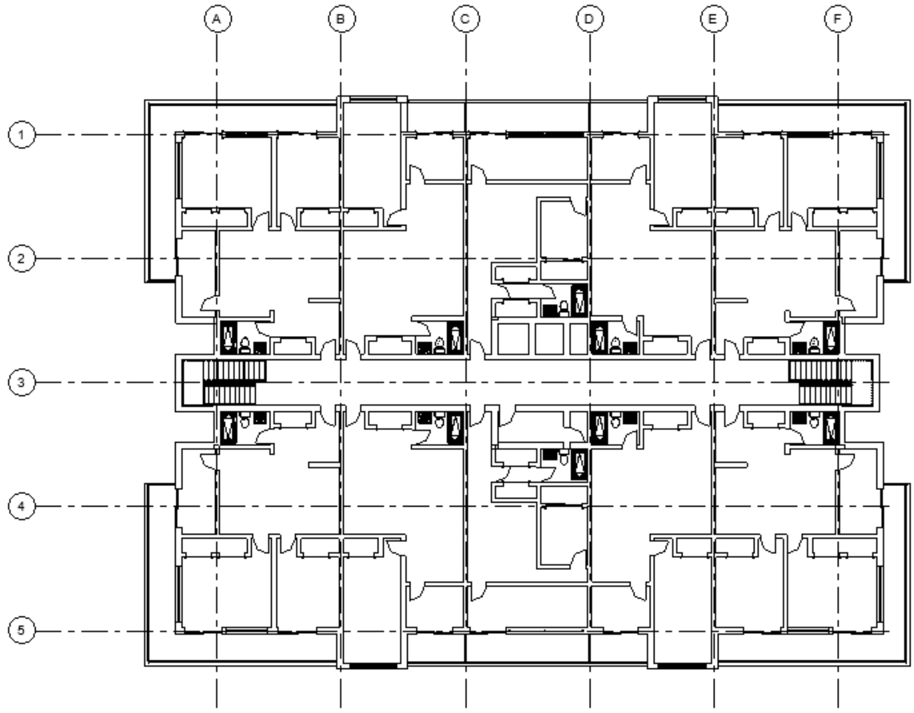

Fig.4. Plan of case study apartment building drawn using Revit Architecture

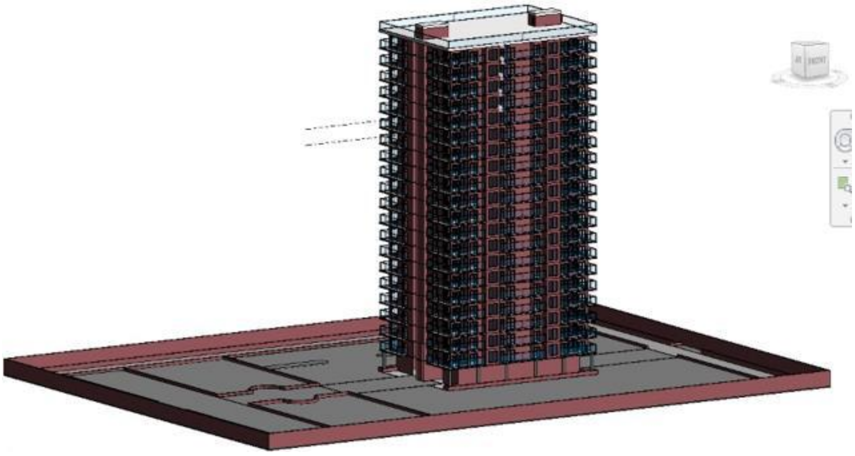

Fig.5. 3D rendering of G+20 storied building using Revit Architecture

4. Results and Discussion

4.1.Environmental Impacts Assessment (EIA)

This study aims to evaluate the environmental implications associated with the development of multi-story apartment buildings. To achieve this, the life cycle assessment (LCA) method is an appropriate and efficient approach to analyze the impact of the building on the environment. This method considers the numerous characteristics and potential consequences of different stages of the building lifetime, including product consumption, manufacturing processes, consumption, and end-of-life (EoL) processes. Each of these stages involves specific actions, and the prerequisites and procedures for conducting an LCA analysis are established in the ISO 14040 and ISO 14044 standards.Several commercial software programs are available for LCA analysis, and in this study, the one-click LCA software is utilized in conjunction with Revit Architecture for the life cycle assessment of a 20-story modeled apartment building. The software calculates the building's energy and water usage throughout its entire lifetime to determine its embodied energy. The application also computes measurable values for environmental consequences such as global warming potential (GWP), ozone depletion potential (ODP), eutrophication potential (EP), and acidification potential (AP).In this study, the "cradle-to-grave" boundary is utilized, considering all the influencing factors, including GWP, AP, ODP, POCP, EP, and ADP, which can significantly affect the LCA study outcome. This evaluation technique assesses the effects at every step of the product's life cycle, including raw material extraction from natural resources, transportation, consumption, regeneration, and disposal. The study focuses on a building with an expected design life of 60 years to evaluate the environmental consequences throughout its lifetime.

The traditional method of life cycle assessment (LCA) requires more expertise and time to complete, making it less commonly utilized in projects. However, empirical research can be facilitated through the use of the "One Click LCA" tool. This tool is connected to the required standards for the LCA process and can be utilized to carry out the life cycle phases A1 to D from cradle to grave. Environmental effect categories, such as acidification potential, global warming potential (GWP), ozone depletion potential, eutrophication potential, and biogenic carbon storage potential, can be empirically investigated with a single click using One Click LCA.The One Click LCA tool is compatible with the BIM software Revit Architecture, which facilitates the integration of LCA into the design process. Figure 6 illustrates the overall environmental impact of the G-20 storied apartment building construction in terms of equivalent CO2 emission. The overall equivalent CO2 emission resulting from the construction is 9582 kg CO_2 e/m^2, placing it in the red category (G) since the CO2 emission exceeded 680 kgCO_2e/m^2.

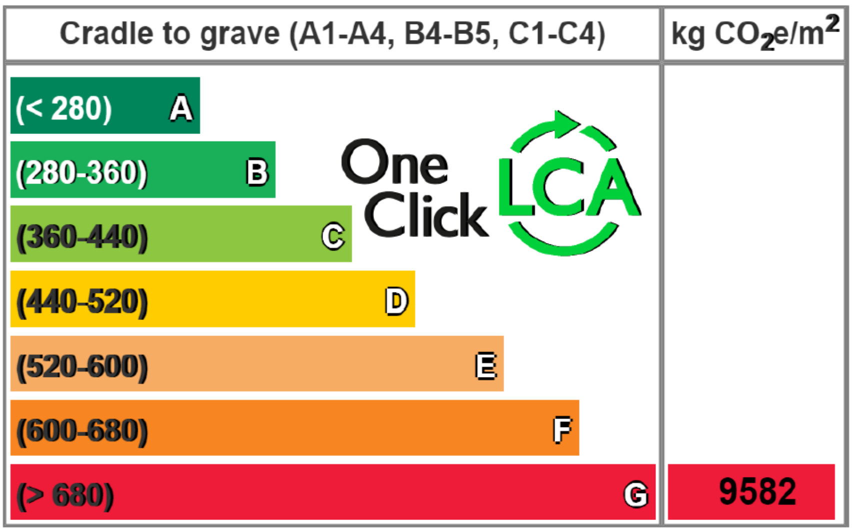

Fig.6. Embodied Carbon benchmark (CBM)

Table 1.Environmental impact measures for individual phases of G+20 storied building

Parameters Units per m^2		**GWP** kg CO_2- equiv	**ODP** kg CFC-11- equiv	**AP** kg SO_2- equiv	**EP** kg $(po_4)^3$-equiv
Product (Material & construction)	A1-A3	93.10%	92.80%	49.50%	91.00%
	A4	01.60%	03.20%	00.30%	00.70%
	A5	01.20%	00.80%	00.50%	00.30%
Use Stage	B1-B5	00.00%	00.00%	22.50%	00.00%
	B6	03.20%	00.40%	26.20%	06.40%
EoL Stage	C1-C4	02.10%	03.60%	00.90%	01.80%
Total		9582	325	36.5	9.5

Table 1 presents the findings of a life cycle assessment (LCA) study conducted on a G+20 storied apartment building using the BIM technique and One Click LCA assessment tool. A reference building was created using building-specific solutions and parameters, and the carbon footprint of the materials used in the building was calculated with the One Click LCA tool. The LCA method assesses the environmental impacts of the building's construction phase from raw material acquisition to final disposal in a structured manner. The study excluded foundations, parking structures, and external areas, and the results showed that the building's energy usage during construction was high, with emissions exceeding 680 kg $CO_2e/m^2/a$. The study assessed various environmental effect categories, including acidification potential, global warming potential, ozone depletion potential, and eutrophication potential.

4.2. Global Warming Potential (GWP)

The principle of global warming potential is used to balance the exchanges of various greenhouse gases within ecosystems, such as carbon dioxide, methane, and nitrous oxide.Methane stores more heat per molecule than carbon dioxide, meaning that it has a greater potential for global warming.Methane is another potential greenhouse gas. It has a 25-fold greater global warming potential than CO_2. he study investigated the impact of various factors, such as raw materials, transportation, energy, and end-of-life, on the GWP of a G+20 storied building, as depicted in Figure 7. The results reveal that raw materials account for the largest GWP impact (93.1%), followed by transportation (1.6%), energy (3.2%), and end-of-life (2.1%).

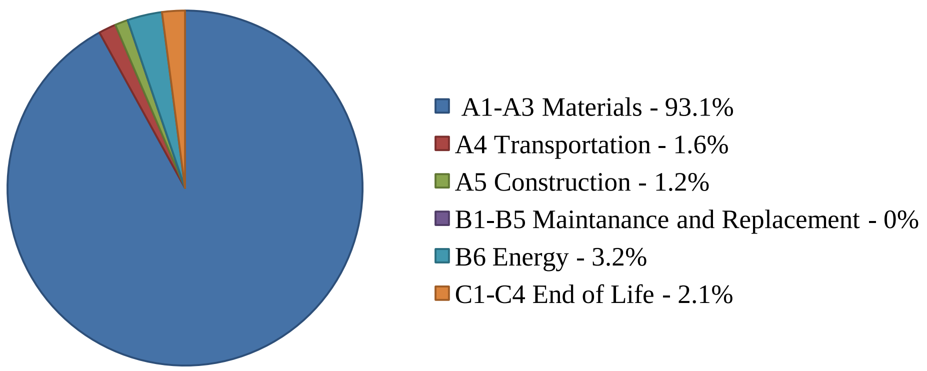

Fig. 7. Global Warming Potential—contribution of raw materials, transportation, and energy

4.3. Ozone Depletion Potential (ODP)

ODP is an environmental impact that signals the depletion of the ozone layer in the atmosphere. The presence of halocarbons in the atmosphere diminishes this layer by breaking down the ozone molecules present and thereby reducing it.A number of climatic changes that may have an influence on ecosystems and human health are brought on by the stratospheric ozone layer's depletion. These changes include an increase in the quantity of radiation, such as UV radiation, that may reach the Earth's surface. ODP is measured as the equivalent of one kilogram of CFC-11 (trichlorofluoromethane). The results of the ODP impact assessment for the G+20 storied building are shown in Figure 8. Sand is identified as the raw material that contributes the most to the ODP impact, accounting for 92.8% of the overall effect of the reference mortar. The production of mortar contributes to 0.4% of the ODP impact, while the remaining 6.8% is attributed to transportation and end-of-life care.

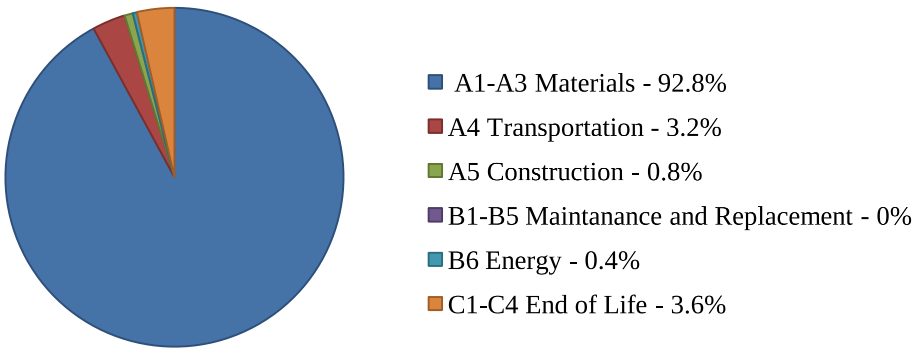

Fig. 8. Ozone depletion potential—contribution of raw materials, transportation, and energy

4.4.Acidification Potential

The environmental implications of acidification are one of the world's most important environmental concerns today. The pH factor falls and the acidity increases when acids are released.The quantity of SO_2 equivalent per kilogramme is used to calculate the impact of AP. The AP is the EI that evaluates the quantity of gases that contribute to soil acidification, acidification of ground and surface waters, and impacts on wildlife, ecosystems, and built environments. Acidification is mainly caused by sulphur dioxide (SO_2), nitrous oxides (NOx), and reduced nitrogen (NHx).

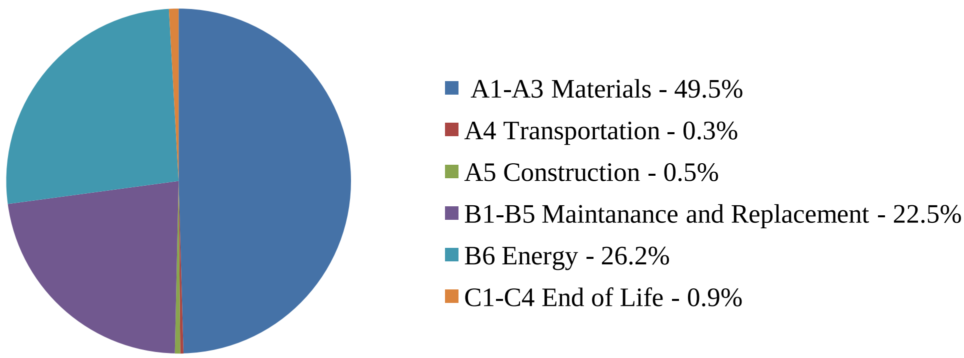

Fig. 9. Acidification potential—contribution of raw materials, transportation, and energy

In Figure 9, the impact of raw materials, transportation, and mortar production on the acidification potential (AP) of a G+20-story building is shown. The analysis reveals that raw materials are the major contributor, accounting for 49.5% of the total AP impact. Maintenance and replacement are the next highest contributor, accounting for 22.5% of the impact. Energy usage contributes 26.2%, and admixtures account for 3%. Raw material transportation has a minor impact of 0.8% on the total AP effect, while mortar manufacture contributes to the remaining 0.9% of the impact.

4.5. Eutrophication Potential (EP)

EP refers to the environmental effect that causes nutrient enrichment in soil or water. The nitrogen and phosphorus from polluted emissions, wastewater, and fertilisers that produce excessive algal and plant growth are to blame for this enrichment. The excessive development of microorganisms in water lowers the rates of oxygen and sun energy, resulting in plant and groundwater pollution in terrestrial eutrophication. Cement is the raw material with the highest influence on the EP impact in render mortars in a cradle-to-gate boundary study, as indicated in Fig. 10. 91% of overall EP effect is accounted for by cement, sand, and admixtures.

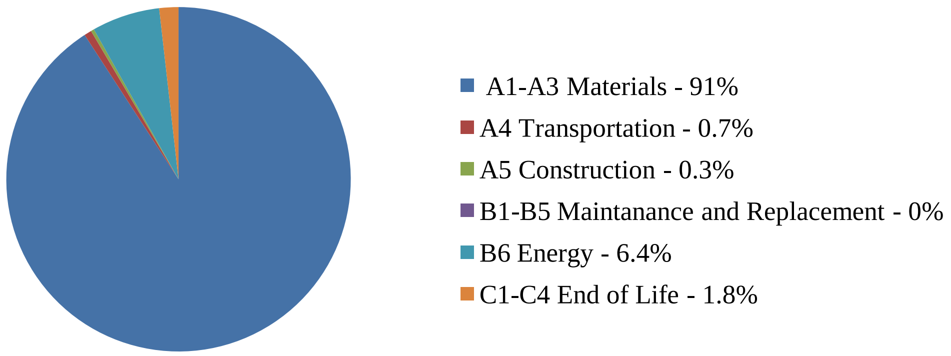

Fig. 10. Eutrophication potential—contribution of raw materials, transportation, and energy

5. Adopting Green Materials

In this study, the adoption of green materials was explored as a means to reduce the environmental impacts of constructing a G+20 storied apartment building. The analysis revealed that the overall equivalent CO2 emission resulting from the building's construction was 9582 $kgCO_2e/m^2$. To mitigate this impact, green materials were incorporated into the One Click LCA tool, which resulted in a reduction of equivalent CO2 emissions to 1167 $kgCO_2e/m^2$, as depicted in Figure 11. This represents an 87% reduction in the building's environmental impact. However, it is worth noting that even with the adoption of green materials, the CO2 emissions were still greater than the recommended limit of 680 $kgCO_2e/m^2$, placing the building in the red category (G) in terms of environmental impact.

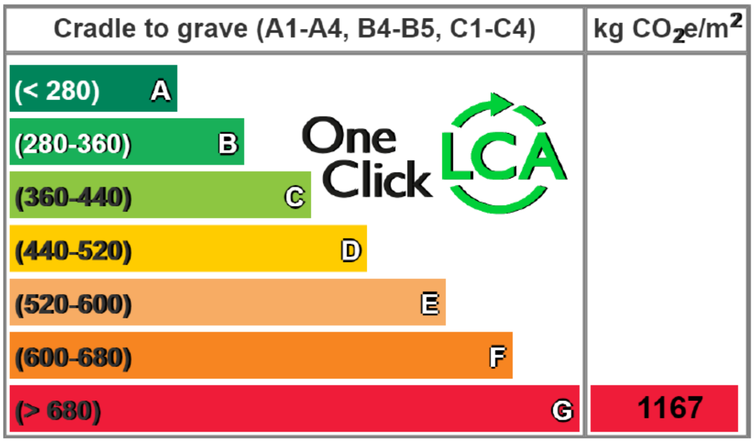

Fig.11. Embodied Carbon benchmark (CBM)

Table 2 displays the LCA findings of a G+20-stored apartment building using the green building materials utilising BIM methodologies and the LCA evaluation application with One Click LCA. The obtained results indicate that the product (material and construction) has the most significant impact on GWP, ODP, AP, and EP, with a contribution of 59.10%, 44.60%, 49.50%, and 48.30%, respectively. The use stage also has a considerable impact, with B1-B5 and B6 contributing 16.00% and 20.10% to GWP, 3.00% and 7.40% to ODP, 22.50% and 26.20% to AP, and 23.00% and 27.30% to EP, respectively. The end-of-life stage has the least impact on all parameters. The use of green materials reduced the equivalent CO2 emission by 87% from 9582 $kgCO_2e/m^2$to 1167 $kgCO_2e/m^2$, but the value still falls into the red category (G) since it exceeds 680 $kgCO_2e/m^2$.

Figure 12 to 15 represents the global warming potential, ozone depletion potential, acidification potential, and eutrophication potential due to the different life cycle stages of the building.

Table 2.Environmental impact measures of G+20 storied building with green materials

Parameters Units per m^2		**GWP** kg CO_2- equiv	**ODP** kg CFC-11- equiv	**AP** kg SO_2- equiv	**EP** kg $(po_4)^3$-equiv
Product (Material & construction)	A1-A3	59.10%	44.60%	49.50%	48.30%
	A4	01.00%	05.90%	00.30%	00.30%
	A5	01.40%	08.50%	00.50%	00.50%
Use Stage	B1-B5	16.00%	03.00%	22.50%	23.00%
	B6	20.10%	07.40%	26.20%	27.30%
EoL Stage	C1-C4	02.30%	09.90%	00.90%	01.00%
Total		1167.0	39.6	4.4	1.2

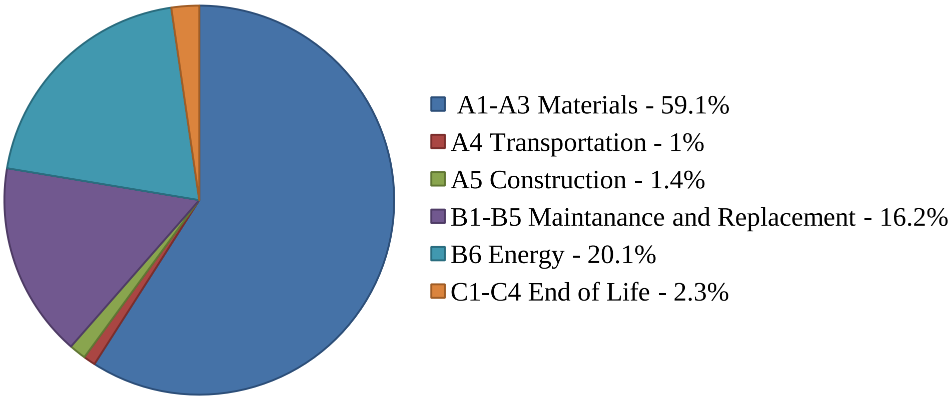

Fig. 12. Global Warming Potential—contribution of raw materials, transportation, and energy

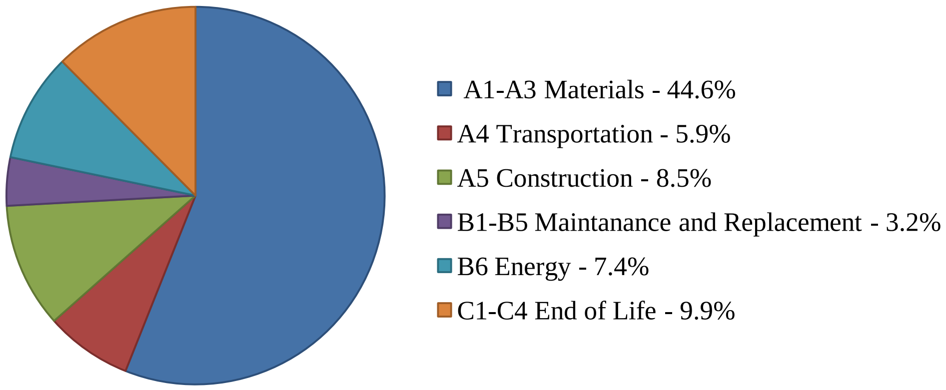

Fig. 13. Ozone depletion potential—contribution of raw materials, transportation, and energy

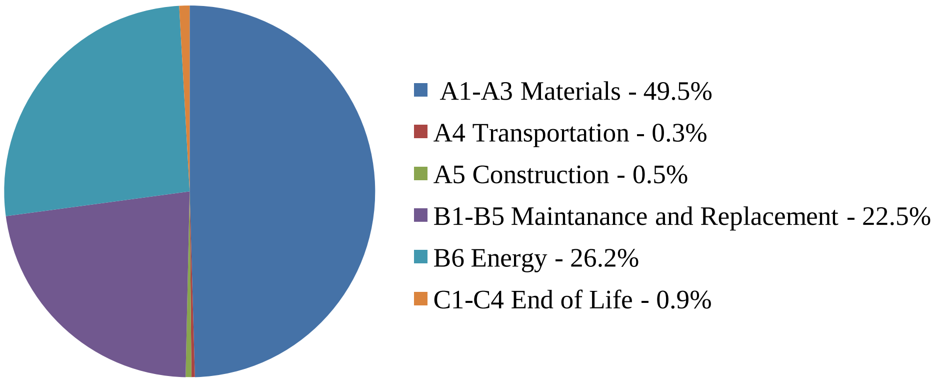

Fig. 14. Acidification potential—contribution of raw materials, transportation, and energy

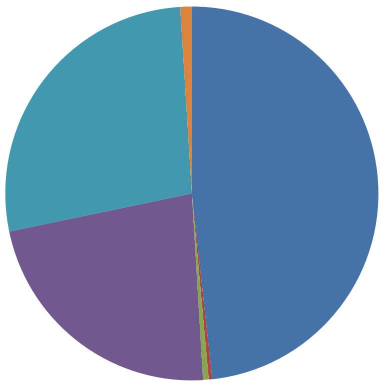

Fig. 15. Eutrophication potential—contribution of raw materials, transportation, and energy

The use of green materials in building construction and maintenance has shown to have a significant impact on reducing CO2 emissions. The impact of CO2 emissions during A1-A3 stages is predominantly due to raw material production, such as cement and fine aggregate. The study found that green materials account for 59.1% of the overall GWP impact, 44.6% of the total ODP effect, 49.5% of the total AP impact, and 48.3% of the total EP impact, which is significantly lower compared to traditional construction methods.

This study aimed to evaluate the environmental impact of a 20-story apartment building using Building Information Modeling (BIM) and Life Cycle Assessment (LCA) techniques. Two scenarios were compared: traditional building construction and construction with green materials. The results indicated that the use of green materials significantly reduced the building's environmental impact in terms of carbon emissions, ozone depletion potential, acidification potential, and eutrophication potential. Furthermore, the analysis demonstrated that the product manufacturing stage (A1-A3) accounted for roughly 94.7% of total carbon emissions, while the building operation and maintenance (B1-B7) phase only contributed 3.2% of the total. Lastly, the end-of-life stage, also referred to as the demolition stage (C1-C4), accounted for approximately 2.1% of the total carbon emissions. Based on these results, governments can focus on reducing carbon emissions by addressing the product manufacturing phase of buildings.

6. Conclusion

Finally, this study focuses on the sustainability and execution of construction projects in terms of their effects on the environment and methods for attaining sustainability. The G+20 story building was examined in our study, and the results showed that it was a high-quality, employable building substance with substantial energy and material content.The construction of a multi-story building may necessitate time and energy. With a projected design life of 60 years, this project's "cradle to grave with alternatives" framework takes into account the environmental effect of all contributing elements, including GWP, ODP, AP, and EP. This analysis is done utilising LCA and the ideas of building information modelling.The overall equivalent CO_2 emission due to the construction of G-20 storied apartment building is 9582 kg CO_2 e/m^2. It is fall on the red category (G) which is greater than 680 kgCO_2e/m^2. Similarly, the ozone depletion potential, acidification potential, and eutrophication potential are 325kg CFC-11- equivalent, 36.5 kg SO_2- equivalent, and 9.5 kg (po4)3- equivalent respectively. It was observed that more than 90% environmental effects are due to the raw construction materials extraction, process, and supply and transportation stage which is called as product manufacture stage.

The case study was extended to investigate equivalent CO_2 emission by adopting green building materials. The equivalent CO_2 emission was decreased from 9582 kg CO_2 e/m^2 to 1167 kg CO_2 e/m^2. The green materials reduces the environmental impacts up to 87% According to the findings, green materials account for 59.1% of overall GWP impact, 44.6% of total ODP effect, 49.5% of total AP impact, and 48.3% of total EP impact. The values are much lower than the values of building constructed with the traditional process. Because the study discovered that raw materials have the greatest environmental impact, research into eco-friendly brick manufacturing using locally available materials can be conducted. Such materials do not need to be transported to a remote location to be manufactured, reducing the environmental impact of transportation. Furthermore, the empirical research with One Click LCA and building information modelling helps to understand the environmental impacts quantitatively. The research will be extended with each and every building material with its environmental impacts.

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