Life Cycle Assessment of Structure Using Revit and Tally Plugin Software

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Abstract

The modern digital tools based on Building Information Modelling [BIM] provide the potential to facilitate environment performance assessments of buildings. Various tools that use a BIM model for automatic quantity take off as basis Life Cycle Assessment [LCA] have been developed recently. This research simplifies the calculation of the initial embodied energy for commercial office buildings. The result is improved integration of Life Cycle Assessment of building materials into the early stages of the building design process. This thesis research proposes that BIM will make calculating building material quantities easier to simplify LCA calculations, to improve their integration into existing sketch design phase practices, and building design decisions. A 3D model is developed in Revit architecture software, the study is carried out to know the impact of materials on the environment by means of mass, acidification potential, eutrophication potential, global warming potential, ozone depletion potential, smog formation potential, primary energy demand, non-renewable energy demand, renewable enery demand to understand impact materials on environment, the function of BIM and corresponding data control stages of LCA.

Keywords : **Environment, environmental impact, Life Cycle Assessment, software**

I. INTRODUCTION

The building sector consumes a large amount of energy in different stages of construction and generates huge quantities of waste and green gases. Life Cycle Assessment (LCA) is a tool used to assess the energy consumption and its impact on environment. In LCA analysis, various stages of a product, process, service, etc., are taken into account. The assessment starts from the extraction of raw material, its processing, manufacturing, distribution, useful life, and finally recycling or its disposal [1, 2]**.** LCA is an accepted method of assessing the environmental performance of buildings. Building Information Models (BIM) is a 3D digital model which helps to design the project and construction process coordination in a better way which results in reduced costs, and a higher building efficiency for projects.

The main objectives of the project are:

1) To analyze the structures of LCA using Revit software.

2) To collect the energy consumed data of each material using the software.

From the various researches which have been studied, the main usage of the software is that it can be used to estimate and reduce emissions during LCA. Different materials used for construction have different properties and emissions which can be reduced. Thus, the age of the structure can be predicted before construction. These are some of the uses of the software in construction [3, 4].

II. METHODOLOGY

This analysis describes a whole building performed for

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Fig. 1. Life Cycle Analysis

normal building using LCA tools. Tally analysis accounts for the whole cradle to grave lifecycle, which includes manufacturing of materials, their use, maintenance and replacement, and end-of-life cycle. It includes the material energy, as well as the energy consumed during the entire lifespan of the building [5, 6]. Adopting Building Information Modelling (BIM) in the process enhances the energy performance of buildings.

The following sections explain the case-study building and the detailed procedures in each LCA. Building Information Modelling (BIM) was used to evaluate the embodied impact on environment, and constructed a database of the impact factors of the embodied environmental impact of the major building materials by adopting an LCA based approach. The 3D model was developed using Revit software and then integrated into LCA [7,8].

III. LIFE CYCLE ASSESSMENT PROCESS

The LCA consists of four main stages:

1) Goal definition (ISO 14040): The basis and scope of the evaluation are defined.

2) Inventory Analysis (ISO 14041): A process tree is created in which all processes from raw material extraction to waste water treatment are mapped out and connected; mass and energy balances are closed (all emissions and consumptions are accounted for).

3) Impact Assessment (ISO 14042): Emissions and consumptions are translated into environmental effects which are grouped and weighted.

4) Improvement Assessment/Interpretation (ISO 14043): Areas for improvement are identified.

IV. LIFE CYCLE INVENTORY

A. Product

This includes raw material extraction and processing, e-transportation, manufacturing, and assembly. The product stage scope is listed for each entry, detailing any specific inclusions or exclusions that fall outside of the cradle to grave scope.

B. Transportation

This include transportation from the manufacturer to the building site during the construction stage and can be modified.

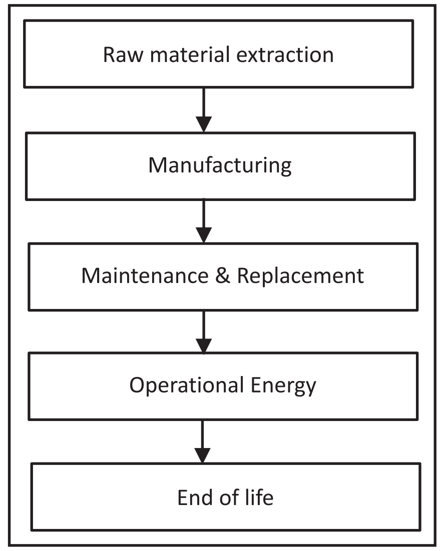

Fig. 2. Life cycle Inventory

C. Construction Installation

This includes the anticipated or measured energy and water consumed onsite during the construction installation process, as specified by the modeler.

D. Maintenance and Replacement

This includes the end of life treatment of the existing products as well as the cradle to grave manufacturing and

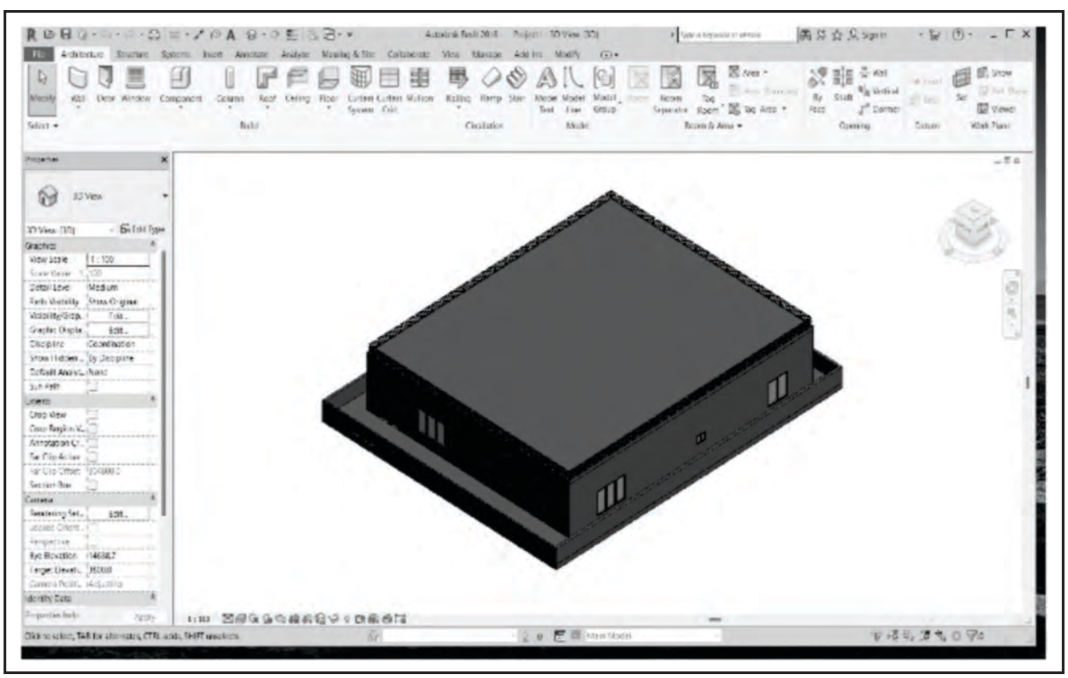

Fig. 3. Revit 3D model

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4]	Use Stage [B2-B5]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq)	2,655	95.66	1,921	685.5	63.64
Acidification (kg SO_2eq)	12.54	0.4432	13.01	2.752	-0.5548
Eutrophication (kg Neq)	1.164	0.03609	1.661	0.5852	-0.02592
Smog Formation (kg O_3eq)	186.5	14.65	174.4	19.75	-6.41
Ozone Depletion (kg CFC-11eq)	1.111E-005	3.276E-012	1.111E-005	2.967E-011	3.522E-007
Primary Energy (MJ)	63,997	1,391	45,703	2,654	-4,388
Non-renewable Energy (MJ)	50,421	1,358	33,142	2,483	-2,730
Renewable Energy (MJ)	13,579	33.64	12,579	173.3	-1,667
Environmental Impacts / Area					
Global Warming (kg CO_2eq/m^2)	5.670	0.2043	4.102	1.464	0.1359
Acidification (kg SO_2eq/m^2)	0.02678	9.465E-004	0.02777	0.005877	-0.001185
Eutrophication (kg Neq/m^2)	0.002485	7.707E-005	0.003547	0.00125	-5.535E-005
Smog Formation (kg O_3eq/m^2)	0.3983	0.03128	0.3724	0.04218	-0.0137
Ozone Depletion (kg CFC-11eq/m^2)	2.373E-008	6.996E-015	2.373E-008	6.336E-014	7.522E-010
Primary Energy (MJ/m^2)	136.7	2.971	97.60	5.667	-9.4
Non-renewable Energy (MJ/m^2)	107.7	2.899	70.77	5.302	-5.83
Renewable Energy (MJ/m^2)	29.00	0.07183	26.86	0.3701	-3.56

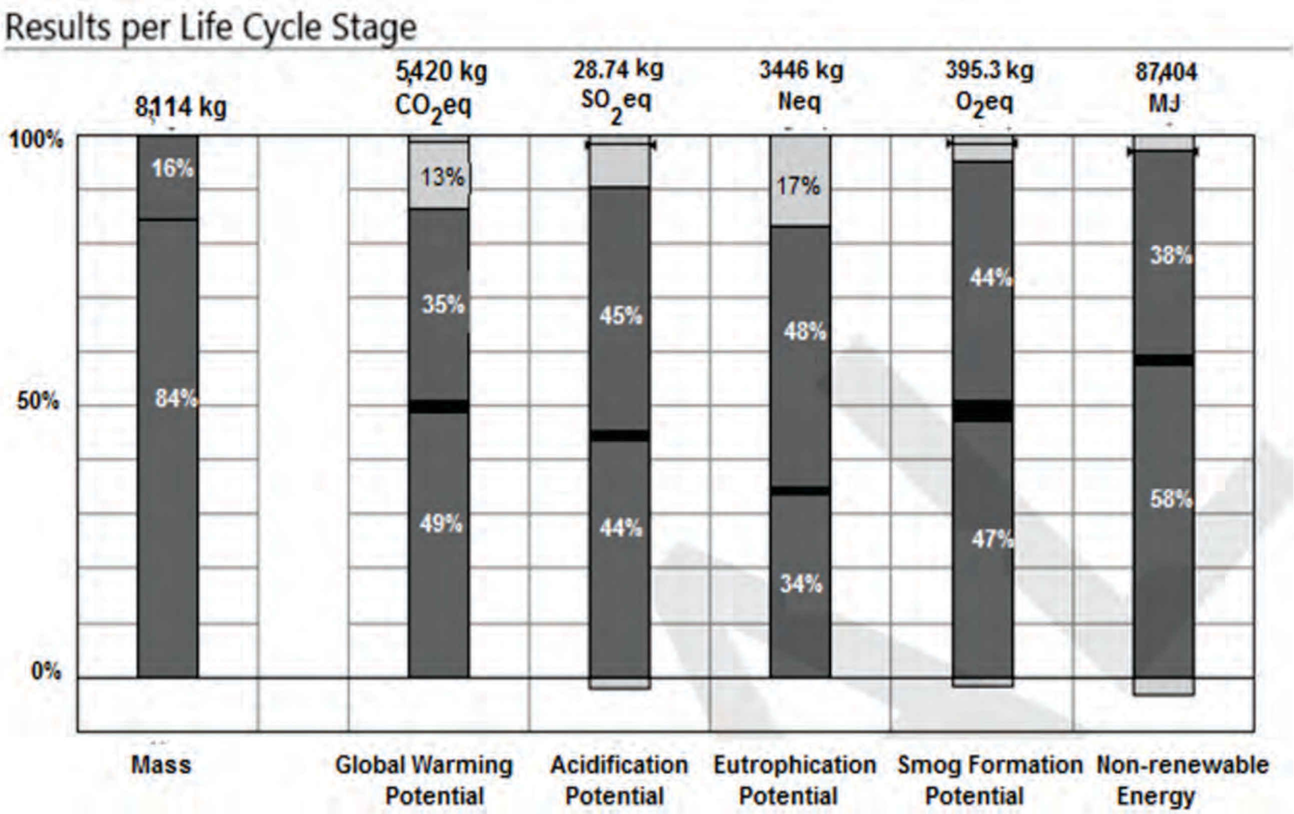

Fig. 4. Lifecycle stages and their emission potential

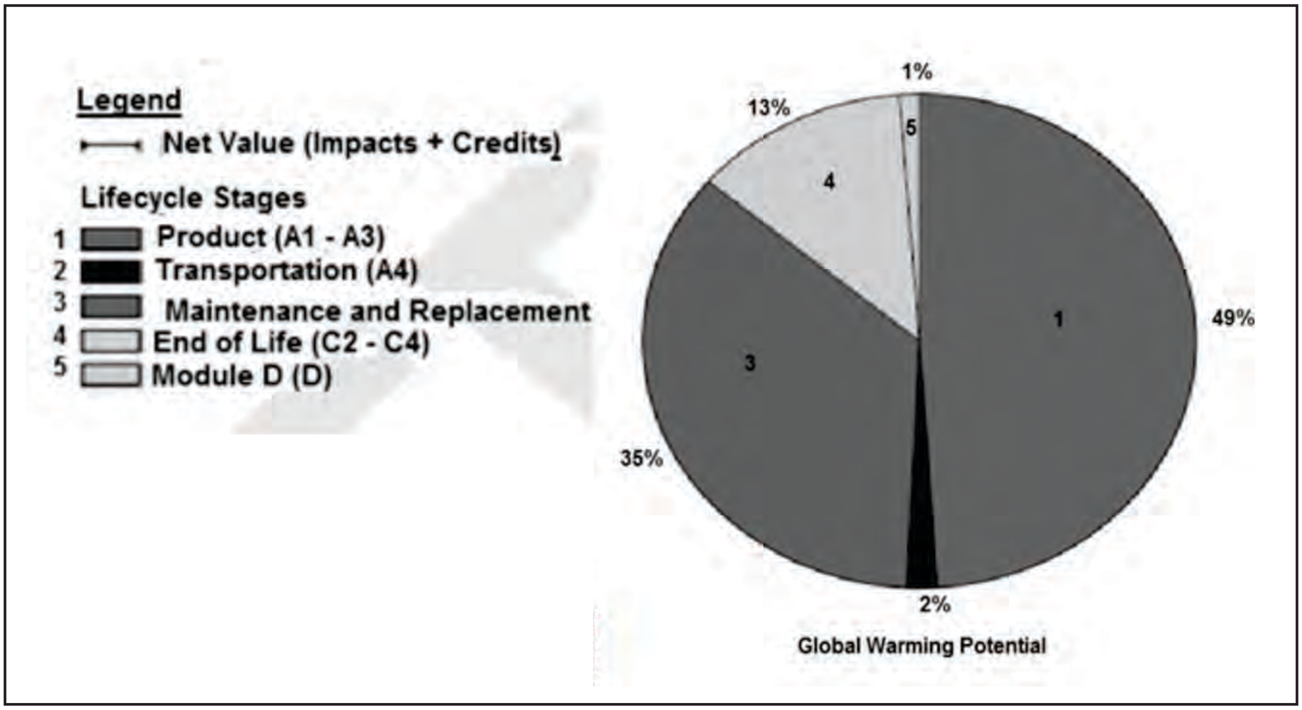

Fig. 5. Global Warming Potential

transportation to site of the replacement products. The service life is specified separately for each product. Refurbishment of materials marked as existing or salvaged by the modeler is also included.

E. Operational Energy

This is based on the anticipated or measured energy and natural gas consumed at the building site over the lifetime of the building as indicated by the modeller.

F. End of Life

This includes the relevant material collection rates for recycling, processing requirements for recycled materials, incineration rates, and landfilling rates. The impacts associated with landfilling are based on average material properties, such as plastic waste, biodegradable waste, or inert material.

G. Tally application

The Tally application allows architects and engineers working in Revit software to quantify the environmental impact of the building materials for whole building analysis as well as comparative analysis design options. While working on a Revit model user can define relationships between the normal and the analyzed one.

The steps which are followed are:

1) The 3D plan of the structure in Revit is executed in the software.

2) The entire structure is selected.

3) The next step is to move to add-ins and select the tally option and in that the full building study.

4) The next step is to select the project name and the full building details.

5) The next step is that the individual structural requirements are selected and entered.

6) The individual structural details are selected and thus, provided with respect to tally details as well.

7) The next step by selecting the details of structure and the edit definition option the Revit details are entered in the tally details by selecting it.

8) The next step of each item is specified as per the drawings and type of materials and thus, entered.

9) In the next step, the internal details with detailed specification are to be entered.

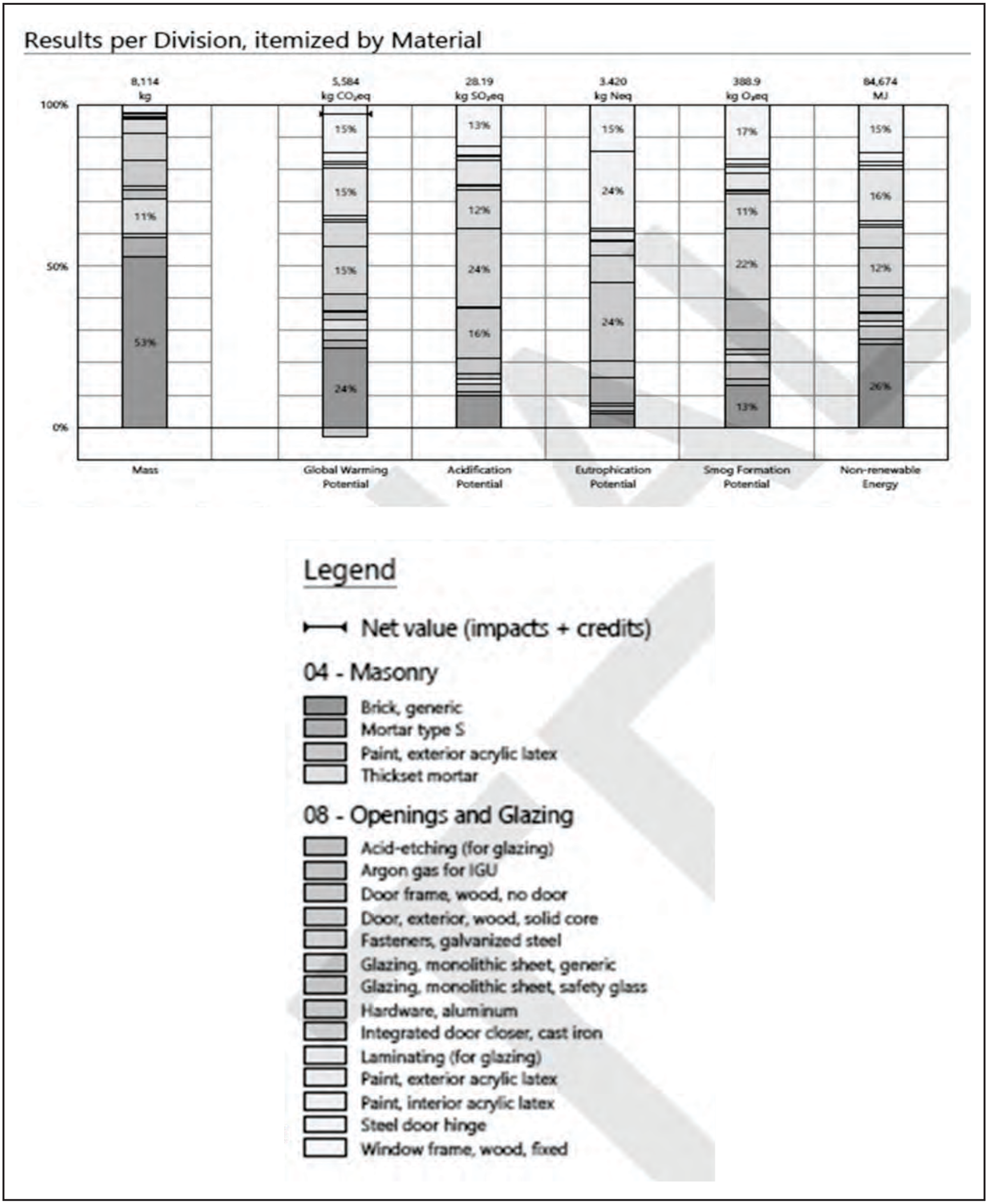

Fig. 6. Results by Division, Itemized by Material

10) The final step is to click on the save report option and thus, the PDF with the total details of each material is downloaded. It has the details of energy consumed by each material and thus, executed to different trails.

The Revit 3D model was generated and analyzed. The results are obtained in the PDF format with the LCA data and the materials data and energy utilized in it.

Environmental Impacts per Full Building Life Gross area: 468.28 m²

Building Life: 60 years

The results indicate each environmental factor and each material utilized in the construction.

V. SOFTWARES USED

A. Autodesk AutoCAD

AutoCAD is a commercial Computer-Aided Design (CAD) and drafting software application. AutoCAD is used in industry, by architects, project managers, engineers, graphic designers, city planners, and other professionals.

Use of this software in our project is as follows:

1) This software is much similar to Autodesk Civil 3D but has user-friendly interface to avoid complication with reduction of some features.

2) Here the components/equipments which are manually designed based on requirement using IS standard code, that is, IS 4925:2004 and IS 4926:2003 are drawn to show detailed sectional view.

3) Hence, finally the detailed drawings involving plans, elevations, and cross sections of structure are obtained through this software.

B. Autodesk Revit

Autodesk Revit is a Building Information Modelling (BIM) software which helps architects, structural engineers, and MEP engineers to arrive at an energy efficient model.

Use of this software in this project was as follows:

1) This software was used in the final phase of the project for the purpose of obtaining 3D modelling.

2) Multiple levels of plans were created in AutoCAD and transferred to create 3D models, and also render 3D realistic required view or walkthrough that are too aesthetical for the representation of our project and also to provide clear conclusion for the project.

3) The LCA analysis is done using this software.

C. Tally® Plugin Revit Software

Tally® is an Autodesk Revit application that quantifies the environmental impact of building materials for analysis. The Tally software examines and compares the overall sustainability of different building material options for the construction industry. In a Revit model, the user can define relationships between BIM elements and construction materials from the Tally database.

The result is Life Cycle Assessment (LCA) on demand, which is an important layer of decision-making within the same time frame, pace, and environment that building designs are generated. Tally helps to quantify the embodied environmental impacts of building or materials on land, air, and water systems.

VI. CONCLUSION

From the present study, it is observed that with the help of Revit software, quantities of materials can also be prepared while developing the 3D model; this would help in reducing the time taken to quantify the materials and the components required. This study has given insights into the need of BIM–LCA including visual interface, transparency of data, flexibility of data sources, automation, easy access to evaluate design solutions, and improve the environmental performance of buildings. The impact of construction materials on the environment has been estimated using Tally software whereby effective management, the impact of these materials on the ecosystem can be reduced.

AUTHORS' CONTRIBUTION

Gurudath R. conducted the studies on LCA with Revit Software under the guidance of Dr. Geena George and prepared the draft transcript. Dr. Geena George worked on the draft and revised the draft and together finalize the article.

CONFLICT OF INTEREST

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in the manuscript.

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REFERENCES

[1] M. Balouktsi, T. Lützkendorf, M. Röck, T. Passer, T. Reisinger, and R. Frischknecht, "Survey results on acceptance and use of Life Cycle Assessment among designers in world regions : IEA EBC 2020," in *IOP Conf. Ser.: Earth Environmental Sci.*, vol. 588, 1.06 – 1.10, doi: 10.1088/1755-1315/588/3/032023.

[2] C. Bueno, and M. M. Fabricio, "Comparative analysis between a complete LCA study and results from a BIM-LCA plug-in.2018," *Automat. Construction*, vol. 90, pp. 188-200, Jun. 2018, doi: 10.1016/j.autcon.2018.02.028.

[3] Y.-W. Lim, H. Majid, A. Samah, M. Ahmad, D. Ossen, M. Harun, and F. Shahsavari, "BIM and genetic algorithm optimization for sustainable building envelope design," *Int. J. Sustain. Dev. Planning*, vol. 13, no.1, pp. 151–159, 2018, doi: 10.2495/SDP-V13-N1-151-159.

[4] Y.-W. Lim and H. A. Majid, "BIM-based sustainable building design process and decision-making," in *Int. Conf. Res. Innov. Inform. Syst.*, ICRIIS, Langkawi, Malaysia, 2017, doi: 10.1109/ICRIIS.2017.8002488.

[5] B. Soust-Verdaguer, C. Llatas, and A. García-Martínez, "Critical review of BIM based LCA method to buildings," *Energy Buildings*, vol. 136, pp. 110–120, 2017, doi: 10.1016/j.enbuild.2016.12.009.

[6] S. Jadhav and A. N. Ghadge, "Application of Building Information Modeling in construction projects: A critical review," *Int. J. Eng. Res.*, vol. 5, no. 1, pp. 26–31, 2016, doi: 10.17950/ijer/v5i1/007.

[7] S. Soltani, "The contributions of Building Information Modeling to sustainable construction," *World J. Eng. Technol.*, vol. 4, no. 2, pp. 193–199, 2016.

[8] G. George, B. Suresh, and M. G. Priuthvishree, "A study on embodied energy of various building blocks in the construction industry," *AMC Indian J. Civil Eng.*, vol. 3, no. 2, Dec. 2020, doi: 10.17010/ijce/2020/v3i2/156366.

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