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# Utilisation of Green Building Materials in Building Construction for a Sustainable Environment -BIM and LCA Analysis

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## ABSTRACT—

As everyone is aware, the building industry today has the greatest global environmental effect. As a result, the building industry is increasingly implementing technologies that aid in the development of sustainable structures. For this review, we primarily focused on the environmental and economic impacts of the construction, so we came up with the popular method/technology " Building Information Modelling (BIM)" with the "Life Cycle Assessment (LCA)". In this study, a BIM-based model was created. Using that model, we came to certain conclusions about sustainability and the full life cycle of the planned model, from the designed stage to the demolition stage. By utilizing the ONE CLICK LCA Tool, we created an automated life cycle assessment report (LCA) for this review's work. The advantages and disadvantages of the BIM-based model are highlighted in the conclusion. Last but not least, this evaluation aims to contribute to sustainability and minimize environmental consequences in the construction industry by utilizing cutting-edge and novel technologies like building information modeling (BIM).

**Keywords:** BIM, LCA, Green Building Materials.

## Introduction

Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering, and construction (AEC) industries. With BIM technology, one or more accurate virtual models of a building are constructed digitally. They support design through its phases, allowing better analysis and control than manual processes. When completed, these computer-generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized. BIM also accommodates many of the functions needed to model the lifecycle of a building, providing the basis for new design and construction capabilities and changes in the roles and relationships among a project team. When adopted well, BIM facilitates a more integrated design and construction process that results in better quality buildings at lower cost and reduced project duration. This chapter begins with a description of existing construction practices and documents the inefficiencies inherent in these methods. It then explains both the technology behind BIM and recommends ways to best take advantage of the new business processes it enables for the entire lifecycle of a building. It concludes with an appraisal of various problems one might encounter when converting to BIM technology.

To better understand the significant changes that BIM introduces, this chapter begins with a description of current paper-based design and construction methods and the predominant business models now in use by the construction industry. It then describes various problems associated with these practices, outlines what BIM is, and explains how it differs from 2D and 3D computer-aided design (CAD). We give a brief description of the kinds of problems that BIM can solve and the new business models that it enables. The chapter concludes with a presentation of the most significant problems that may arise when using the technology, which is now only in its early phase of development and use.

(From the textbook of BIM Handbook, A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors)

The BIM application process can be used during the design and architecture process to create a clear picture used for better and more integrated designs. The software will be used to foresee problems and coordinate between different contractors and as a way to generate construction documents and processes that will later be implemented during the physical process. It is ideal when there are many trades executing at the same moment or when schedules are compressed. There are multiple applications for BIM so it can be used by the following groups:

- ➢ Architecture
- ➢ Sustainability
- ➢ Structures
- ➢ MEP

- ➤ Construction Management

- ➤ Utilities

- ➤ Road Construction

- ➤ Scheduling

- ➤ Property Management

Industry groups are trying to develop one standardized BIM model that can be used to integrate all different types of modeling systems. By doing this, they will facilitate the coordination and communication in the design-construction-operation team under one single platform. This movement aims to create a single data center, with multiple CAD and specs depending on the discipline you are working for. All data will then come together allowing it to be used for take-offs, analysis, coordination, and important project milestones. This effort will help standardize the process and establish a base that can be used during the bidding process so everyone can be judged using standard guidelines.

**Doing a Life Cycle Assessment required the usage of the following software:**

1) AUTODESK REVIT:

Autodesk Revit is building information modeling software for architects, landscape architects, structural engineers, MEP engineers, designers, and contractors developed by Autodesk. It allows users to design a building and structure and its components in 3D, annotate the model with 2D drafting elements, and access building information from the building model's database. Revit is 4D BIM capable with tools to plan and track various stages in the building's lifecycle, from concept to construction and later maintenance and/or demolition. Charles River Software was founded in Newton, Massachusetts, on October 31, 1997, by Leonid Raiz, and Irwin Jungreis, key developers of PTC's Pro/Engineer software for mechanical design, with the intent of bringing the power of parametric modeling to the building industry (PTC had previously tried and failed to market.

Recently acquired Reflex software to the construction sector). With funding from venture capitalists Atlas Venture and North Bridge Venture Partners, Raiz, and Jungreis hired several software developers and architects and began developing Revit in C++ on the Microsoft Windows platform. In 1999 they hired Dave Lemont as CEO and recruited board members Jon Hirschtick, founder of SolidWorks, and Arol Wolford, founder of CMD Group. Revit can be used as a very powerful collaboration tool between different disciplines in the building design sphere. The different disciplines that use Revit approach the program from unique perspectives. Each of these perspectives is focused on completing that discipline's task. Companies that adopt the software first examine the existing workflow process to determine if such an elaborate collaboration tool is required. Autodesk sells Building Design Suites which each include a different selection of software packages. Revit is included in the Premium and Ultimate suites. With the release of Revit 1906, Autodesk dropped support for 32-bit Windows. The latest software REVIT 2021 supports 64-bit Windows.

2) STAAD PRO:

In 1997 The REL (Research Engineer International) company developed this software. After 8 years in 2005, the REI was brought by Bentley System Company which is situated in California, USA. The full form of STAAD PRO is Structural Analysis and Design Program. With the help of analysis, we can get results of stress, deflection, etc. With the help of design, we can able to find adequate member size and Reinforcement detailing. Today, STAAD Pro is one of the most popular and widely used software for structural analysis and design across the globe by Civil engineers. It supports all types of various steel, concrete, and timber design codes. Using STAAD Pro, civil engineers can design any type of structure, and later share the synchronized model data with the entire design team.

3) ONE-CLICK LCA:

One of the Building Life Cycle Metrics software, One Click LCA, makes it simple to compute environmental impacts like carbon footprint, life cycle assessment, and life cycle costing in a matter of minutes. Low-carbon buildings, eco-design, green building credits, and infrastructure can all benefit from the application of One Click LCA. It has the highest BREEAM LCA rating and complies with more than 40 green building certification programs, including LEED.

One Click LCA is a leading Life Cycle Assessment and Environmental Product Declaration (EPD) generation software for the construction industry. One Click LCA helps to decarbonize building and infrastructure projects, create product EPDs, benchmark low-carbon products, and projects, and to create corporate greenhouse gas reports. It is used in more than 130 countries, includes the world's largest construction sector database, and supports over 60 standards and certifications One Click LCA to conduct whole-life carbon assessments for all new developments, refurbishments, and Category A fit-outs. The assessments are performed across all the project stages from planning to completion. Addressing the lifecycle impact of buildings and their materials is at the heart of what we do. Decarbonizing construction requires a whole-life carbon approach to be taken across the value chain. We support both the demand- and supply- side of the industry to inform decision-making, and we are committed to minimizing our emissions by considering life-cycle impacts One Click LCA's high-impact research, policy, and thought-leadership is shaping carbon reduction strategies in the building and construction sector. Making carbon assessment & LCA easy and affordable Our vision is that the construction industry will manage carbon as it manages cost. This means measuring, reporting, and reducing carbon are default parts of business practices. And we provide practical solutions to make this happen.

## BENEFITS OF BIM

BIM provides benefits by integrating teams, workflows, and data throughout the full project lifecycle from design and engineering to construction and operations—to achieve better ways of working and better outcomes.

Revit is extremely useful because of its capacity to generate design blueprints, improve team communication, and integrate time-saving features. Revit offers various benefits that competing BIM software used in a building does not have. Another advantage of utilizing Revit for the building is its long-term viability. Working with BIM software eliminates the need for designers to draught drawings on paper and discard them. They may try out different solutions without wasting office resources. Utilizing Revit for notes and team interactions reduces the need for memos and other paper products and even more methodology for research. Based on a thorough examination of the pertinent literature, this study presents an overview of BIM research in developing countries.

## LIFE CYCLE ASSESSMENT(LCA):

The lifecycle assessment (LCA) is a tool that can be used effectively in evaluating various renewable energy sources for their sustainability and can help policymakers choose the best energy source for specific purposes. The choice of allocation method is very important in assessing the sustainability of energy sources as different allocation methods respond to the present differently. The present chapter is an effort to highlight the importance of LCA for renewable energy The purpose of LCA is to compile and evaluate the environmental consequences of different options for fulfilling a certain function, and it is a uni-verbally accepted approach to determining the environmental consequences of a particular product over its entire production cycle. The LCA methodology can be useful to acquire a comprehensive knowledge of the environmental impacts generated by industrial products during their whole life cycle. LCA can play a useful role in the public and private environmental management of products as this may involve both an environmental comparison between existing products and the development of new products. LCA has been the method of choice in recent years for various kinds of new technologies for bioenergy and carbon sequestration. The ''holistic'' nature of LCA depicts both its major strength and, at the same time, its limitation. The broad scope of analyzing the complete life cycle of the product can only be achieved at the expense of simplifying other aspects. LCA of renewable energy production systems requires a careful design regarding the goal and scope definition and choice of the functional unit.

## OBJECTIVES:

- To create a G, G+1, G+3 storey apartment building using the REVIT.

- To perform structural analysis of G, G+1,G+3 storey apartment building using STAAD-PRO.

- Performing the LCA of G, G+1, G+3 storey apartment building using one click LCA software.

- To identify the major contributors to environmental effects.

- To determine the consequences by substituting the material that is the principal contributor to the impacts with other materials available on the market.

- To analyze the environmental impact reduction strategies using green materials.
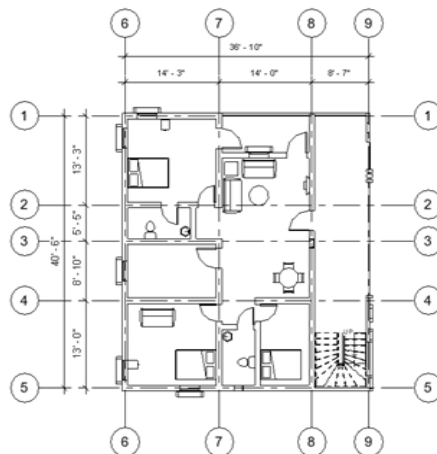
## MODELLING

*Fig 1: Floor Plan*

The Autodesk Revit software is a sophisticated Building Information Modeling (BIM) application that operates similarly to architects. The application simplifies the design process by utilizing a central 3D model in which modifications are done in a single view. Update all views as well as the printed sheets.

The goal of the Autodesk Revit Foundations for Architecture book is to teach you how to develop a comprehensive 3D architectural project model that includes walls, doors, windows, components, floors, ceilings, roofs, and stairs, as well as the essential tools that most architectural users require. This involves learning how to utilize the user interface and the fundamental sketching, editing, and viewing tools.
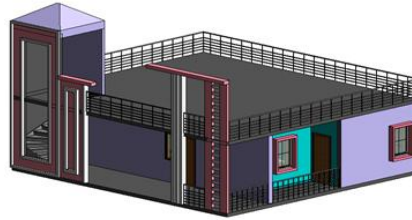


Fig 2: Architectural View

The Structural Analysis Toolkit for Autodesk Revit software is a collection of tools that aid in the Building Information Modeling (BIM) process and enable structural engineers to evaluate structures from inside the Revit environment. The following elements are included in the toolkit: Revit structural analysis.
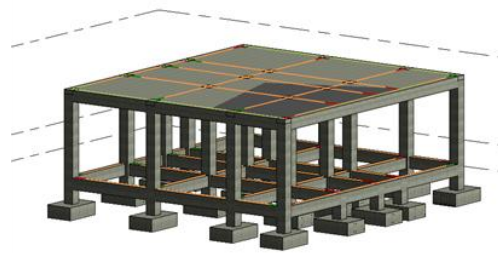


Fig 3: Structural view

STAAD.Pro Physical Modelers use physical modeling to simplify the process of modeling a structure, which more precisely depicts the process of producing a model. Beams and surfaces are represented in the model at the scale that they would appear in the real world.

Steps to be considered for analysis and design

    i.    Modeling of building.

    ii.    Applying the load cases.

    iii.    Analysis of building.

    iv.    Designing of building.

    v.    Checking the results for reinforcement details.
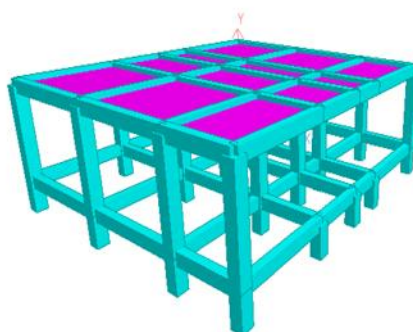
    vi.    Foundation design by STAAD Pro.

Fig 4: STAAD Model

## RESULTS AND DISCUSSIONS

**ONE-CLICK LCA ANALYSIS:**

Choose the project as the net carbon emission for residential buildings in the LCA for the carbon emission calculation. The necessary information should be provided, including the building's annual energy usage and details such as the number of stories and size of the property. Use. gbxml file to import residential building data into the one-click LCA. Cross-examine the imported data, localize the design conditions for the net carbon emission, and provide the net carbon emission results. Findings will be presented as bar charts and pie charts that show the building's net carbon emissions from the beginning of construction to the end of destruction.

**THE ACTUAL MATERIALS USED:**

FOUNDATION

- Ready-mix concrete, normal strength, generic, C25/30 (3600/4400 PSI) with CEM III/A, 60% GGBS content (280 $kg/m^3$; 18.7 $lbs/ft^3$ total cement)

- Reinforcement steel (rebar), generic, 0% recycled content (only virgin materials), A615

COLUMNS

- Reinforcement steel (rebar), generic, 0% recycled content (only virgin materials), A615

- Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 0% recycled binders in cement (400 $kg/m^3$ / 24.97 $lbs/ft^3$)

WALLS

- Clay brick

BEAMS

- Ready-mix concrete, normal strength, generic, C30/37 (4400/5400 PSI) with CEM III/A, 60% GGBS content in cement (300 $kg/m^3$; 18.7 $lbs/ft^3$ total cement)

- Reinforcement steel (rebar), generic, 0% recycled content (only virgin materials), A615

SLABS

- Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 0% recycled binders in cement (400 $kg/m^3$ / 24.97 $lbs/ft^3$)

- Reinforcement steel (rebar), generic, 0% recycled content (only virgin materials), A615.
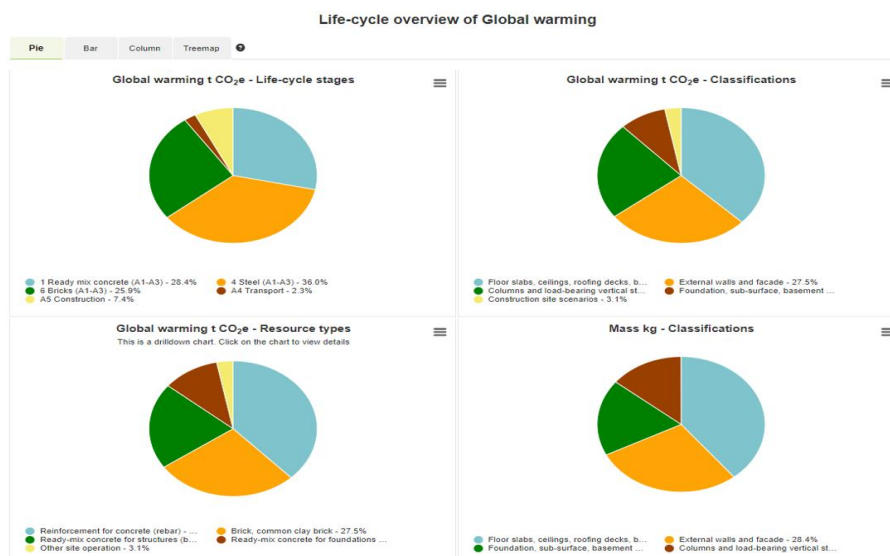

Life-cycle overview of Global warming

Fig 5: Life-Cycle overview of Global warming(actual materials)
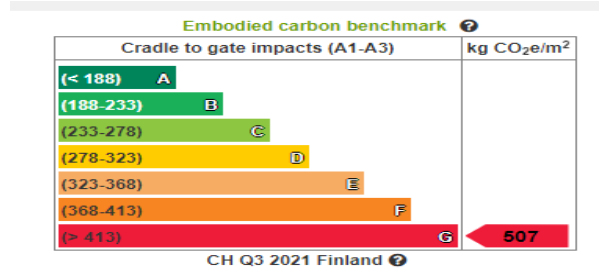


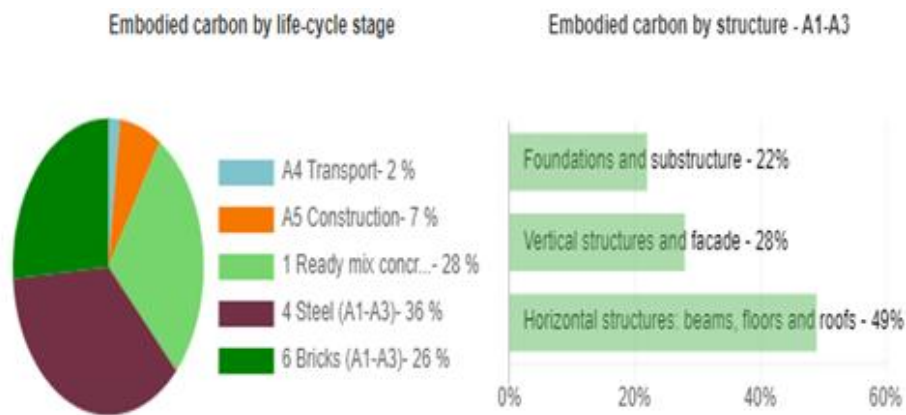Fig 6: Embodied carbon bench mark (actual materials)



Fig 7: a) Embodied carbon by life-cycle stage. b) Embodied carbon by structure.

## THE ALTERNATE MATERIALS USED:

FOUNDATION

- Ready-mix concrete, normal strength, generic, C25/30 (3600/4400 PSI) with CEM II/B-V, 20% fly ash content (280 kg/m$^3$; 17.5 lbs/ft$^3$ total cement)
- Reinforcement steel (rebar), generic, 60% recycled content, A615

COLUMNS

- Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 10% (typical) recycled binders in cement (400 kg/m$^3$ / 24.97 lbs/ft$^3$)
- Reinforcement steel (rebar), generic, 60% recycled content, A615.

WALLS

- Reclaimed brick

BEAMS

- Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 10% (typical) recycled binders in cement (400 kg/m$^3$ / 24.97 lbs/ft$^3$
- Reinforcement steel (rebar), generic, 60% recycled content, A615

SLABS

- Ready-mix concrete, normal strength, generic, C30/37 (4400/5400 PSI) with CEM III/A, 50% GGBS content in cement (300 kg/m$^3$; 18.7 lbs/ft$^3$ total cement)

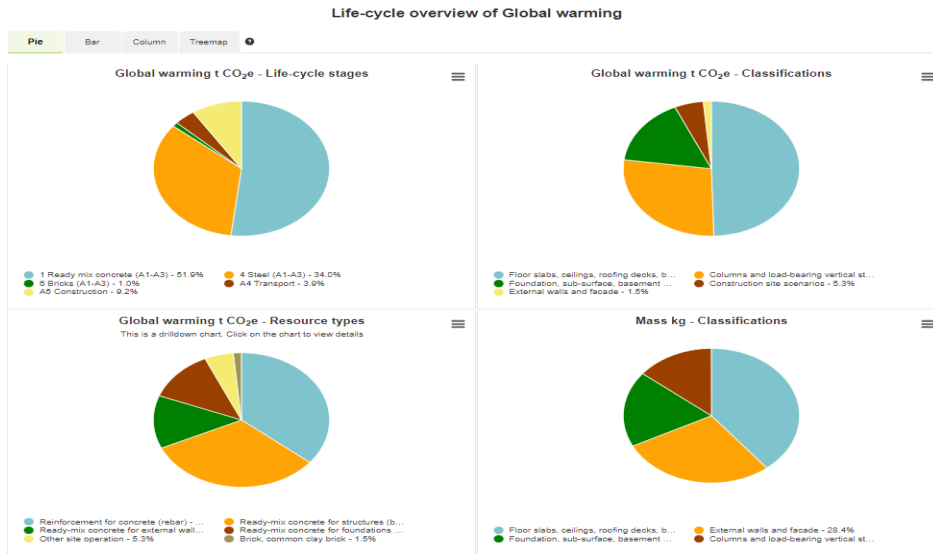- Reinforcement steel (rebar), generic, 60% recycled content, A615.



Fig 8: Life-Cycle overview of Global warming(alternate materials)
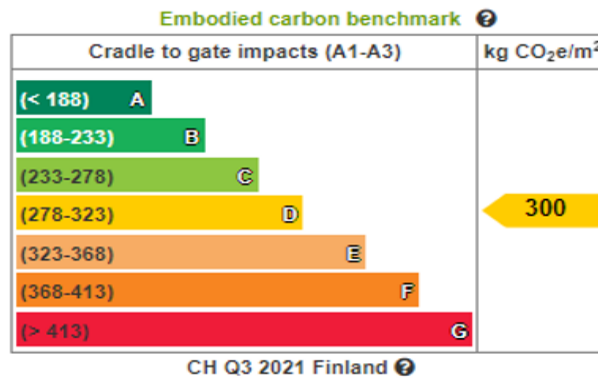


Fig 9: Embodied carbon bench mark (alternate materials)
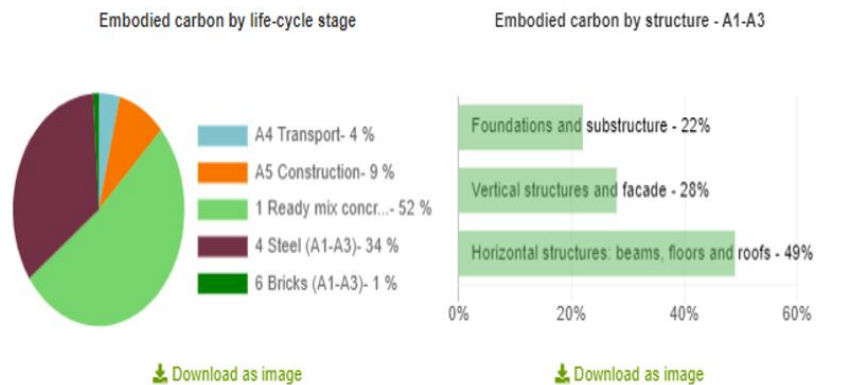


Fig 10: a) Embodied carbon by life-cycle stage.   b) Embodied carbon by structure.

For actual materials, the carbon equivalent from the concrete of quantity 179 tons is 144 kg $CO_2$e/m^2 and from steel of quantity, 8 tons is 182 kg $CO_2$e/m^2. The carbon equivalent from clay brick of quantity 73 tons is 132 kg $CO_2$e/m^2.For alternate materials, the carbon equivalent from concrete of quantity 179 tons is 156 kg $CO_2$e/m^2 and from steel of quantity, 8 tons is 102 kg $CO_2$e/m^2. The carbon equivalent from a reclaimed brick of quantity 73 tons is 3 kg $CO_2$e/m^2.

## Conclusion

Building Information Modelling has a high potential to promote the use of the LCA method during the preliminary design stages since it simplifies all the necessary steps for the implementation of an LCA study. BIM is the first step of a digital revolution, which is taking place in the construction industry, making it easier to define and compare the performance of different design scenarios. The use of BIM to promote the practical use of LCA should be faced as an important study topic to improve and foster new results, to assist a holistic view of the built environment, and consider a cradle-to-cradle approach in the design of a more sustainable built environment. This study presented the results from the use of two different BIM-integrated LCA software. This comparison is intended to increase the knowledge about BIM application on LCA as well as to understand how much the LCA assessment process can be optimized. The LCA approach is a tool for lowering carbon emissions in the construction industry. This tool can be used to calculate a structure's overall carbon emissions as well as the component or type of material responsible for the building's contribution to greenhouse gas emissions. According to the conclusions of the study, the bulk of carbon emissions occur at the stage of a building's development when it is being rebuilt, and the components that contribute the most to carbon emissions include floors, beams, columns, and slabs. The use of a One-click LCA BIM login with the building Life Cycle Assessment (LCA) approach plays a crucial role in reducing the embodied carbon and the operational carbon of each of the construction materials from cradle to site and during the construction stage. The results from this study demonstrated and assessed how to estimate the embodied carbon from material extraction to construction stages and during the construction process.

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