Exploring the Viability of Reducing Embodied Carbon Emissions Through Adaptive Reuse of Heritage Buildings in Egypt: The Case of Khedival Cairo

A Thesis submitted in the Partial Fulfillment for the Requirements of the Degree of Masters of Science in Integrated Urbanism and Sustainable Design

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Acknowledgment

"*Thus Far the Lord has helped us*" (1 Samuel 7:12)

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Marco Zaki.

Abstract

Heritage buildings in Egypt are facing significant challenges due to a variety of factors such as inadequate funding and financial limitations, lack of maintenance, and insufficient regulatory frameworks. (Osman, 2018) These buildings, many of which are of immense cultural and historical significance, are at risk of being lost forever if action is not taken to preserve them.

Adaptive reuse is one of the keys to sustain those buildings, and to transfer its cultural and memorial identity for further generations. Adaptive reuse is a strategy not only for preserving, but it can be a part of the urban sustainability and regeneration. (Bullen & Love, 2016) It also can have significant environmental benefits by reducing the carbon footprint of new construction materials and reducing waste generated from demolition. As by repurposing existing structures, energy consumption and demand for new construction materials are reduced, and the environmental impact is minimized. (Fisher-Gewirtzman, 2016)

The recent research work in this area focuses on the reduction of the operational energy of heritage buildings in order to step towards energy efficiency. However, there is a gap in addressing the issue of embodied carbon emissions in the whole life cycle of buildings which addresses the embodied energy of the materials, energy used during construction, and later the operational energy of the building.

This study confirms that the adaptive reuse of heritage buildings, specifically those built between the 19th and 20th centuries, is a viable strategy to help in reaching the decarbonization targets for buildings through dematerialization while preserving cultural and memorial values.

The methodology used in this research utilizes a whole life cycle assessment comparing the carbon footprint of rehabilitating a heritage building to the demolition and reconstruction of a new one in Cairo using LCA tools that take into account environmental impacts such as global warming potential, amount of embodied carbon emissions and the most contributing materials in these impacts. The expected outcome of the study is a method to estimate the embodied energy for rehabilitating heritage buildings using a number of case studies in Khedival Cairo, Egypt.

Keywords:

Heritage Buildings, Preservation, Decarbonization, Adaptive Reuse, Sustainability, Reuse.

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Chapter 1: Introduction

1.1 Background

Egypt, as a developing country, is investing a large capital of money in building new cities and buildings all around the country to attract investors from all around the world, from the new Administrative Capital east of Cairo, to the New Alamein City west of Alexandria. And from East Portsaid in the north, to New Aswan city in the south (NUCA 2022). This main stream focus on building new buildings has resulted in a lack of attention towards the preservation of heritage buildings. But what is the future of these heritage buildings? There is no doubt that Egypt is one of the top cities in the world that passed on many cultures in different periods of times, these of which shaped its identity and formed its rich cultural heritage. (Mustafa, 2021). However, many of these buildings are at risk of demolition and to be lost due to neglection, deterioration, or change in the land use. In some cases, heritage buildings are demolished to pave the way for new developments, erasing pieces of important cultural heritage values and contributing to environmental degradation.

As an alternative to demolition, adaptive reuse has the potential to offer a sustainable solution by repurposing the buildings to new uses and to preserve the cultural value of heritage buildings while reducing the environmental impacts such as embodied carbon emissions and global warming potential, that results from the construction process starting from extracting raw materials, manufacturing to the operation, and disposals.

1.2 Research Contextualization

Khedival Cairo which was known at a time as Paris of the East is a historic district located in the heart of Cairo, Egypt, which contains many heritage buildings. The district takes its name from the Khedive Ismail, who ruled Egypt from 1863 to 1879 and was responsible for the modernization and expansion of Cairo during his ruling period. Khedival Cairo was developed during this period as a new administrative and residential center for the city and was designed to reflect the cosmopolitan and eclectic tastes of the Khedive. (Elshahed, 2019)

Today, in the immense need for sustainable developments and strategies, the district faces challenges due to neglect, decay, and urban development pressures, which threaten its heritage buildings and cultural identity. Efforts are underway to preserve and revitalize Khedivial Cairo, including through adaptive reuse projects and heritage conservation initiatives, which aim to work within the sustainable framework and to ensure that this iconic district continues to thrive as a cultural asset and historical landmark for generations to come.

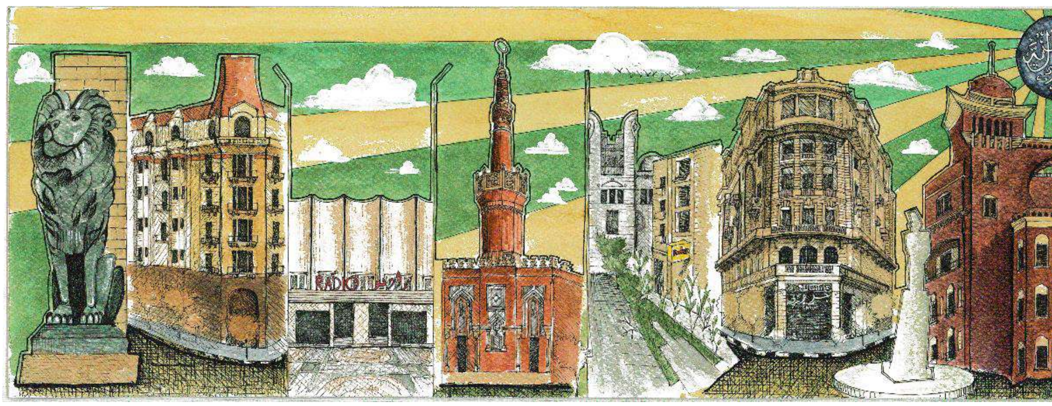
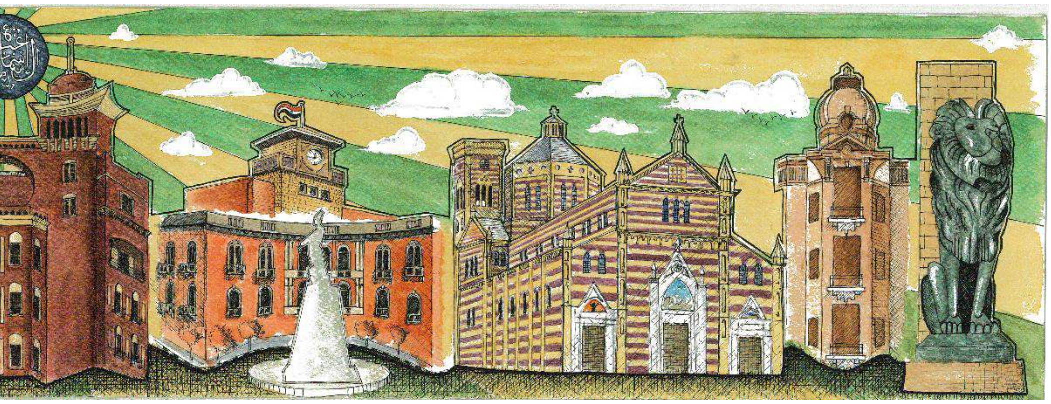


Figure 1 Downtown Cairo heritage buildings. Source: Art work by the Author

1.3 Research Scope

Based on the introduction above, this research is focusing on exploring the environmental benefits that can be achieved from the adaptive reuse approach towards heritage buildings and the technical challenges that might face dealing with heritage buildings to revive it. The first part of the research is identifying the meaning of heritage buildings in Egypt, and what are the criteria for listing those buildings and the reason why heritage buildings were the category chosen in this research, then introducing a wide scope from the literature review's point of view on adaptive reuse in general and adaptive reuse of heritage buildings in specific, identifying the world's most common trends for it. Lastly, the relation between adaptive reuse and sustainability. After that, the second part will be studying the environmental impacts on two real rehabilitated heritage buildings case studies in Egypt through running a life cycle assessment on these two cases, then running the same analysis with another scenario of demolition and rebuild those two buildings to see how can adaptive reuse can be a way for preserving heritage buildings at the same time have the least impact on the environment. Before ending with a discussion about the challenges that was present during the rehabilitation of the two case studies.



1.3.1 Khedival Cairo heritage buildings

The research is mainly focusing on heritage buildings in downtown Cairo (Khedival Cairo) that were built between late 19th century to early 20th century.

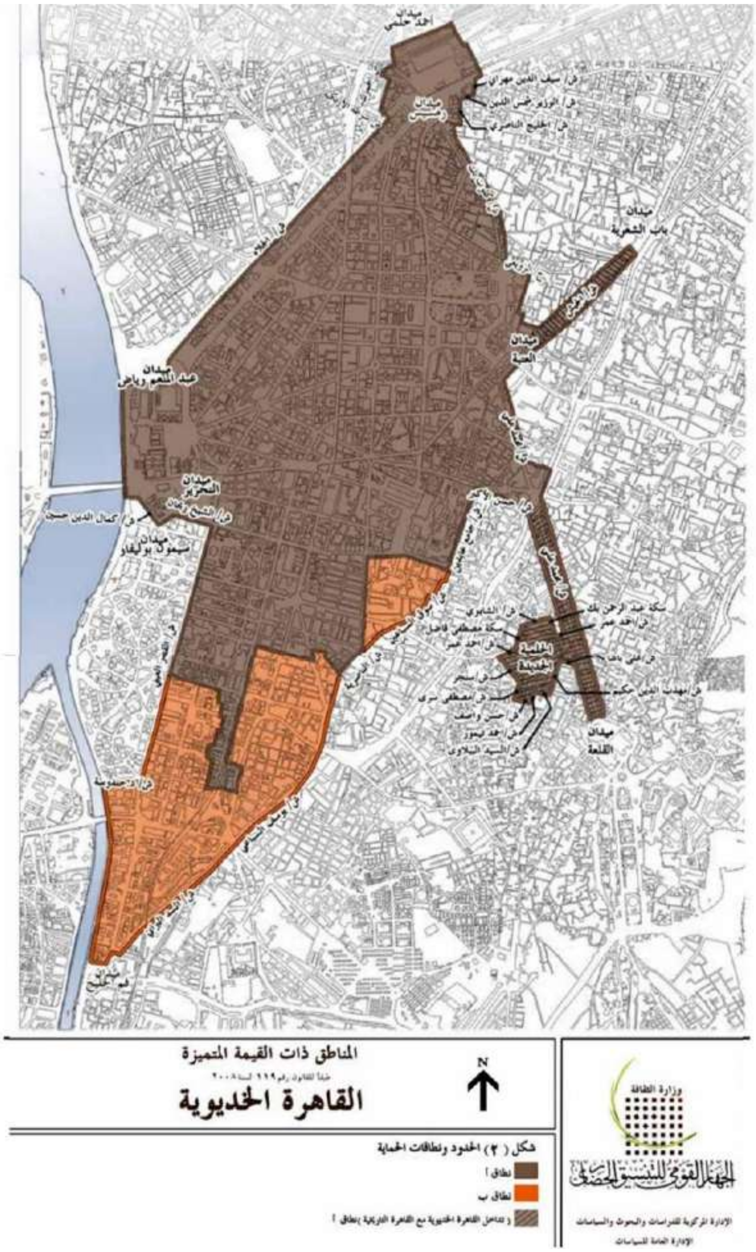


Figure 2 Boundaries of Khedival Cairo. Source (The National Agency for Urban Harmony)

1.4 Research Design

1.4.1 Research Problem

Problem Identification

The decision whether to rehabilitate or to demolish and replace heritage buildings in Egypt is dependent on so many factors such as high architectural or artistic values, association with events that have made a significant contribution to the Egypt's national history, or with the live of persons significant in Egyptian history, and the building should represent an era or significant period of Egypt history, finally to be considered as touristic destination (Law of Urban Harmony No.144 2006)

However, one of the factors that is rarely studied concerning the decision making of rehabilitation in Egypt is the amount of embodied carbon emission the listed heritage building can save compared to demolition and replacement. This is particularly concerning in the realm of the growing recognition of the need to decarbonize and reduce the carbon footprint in the buildings sector which represents from 35 – 40% of the annual carbon emissions worldwide (IEA, 2019). However, instead of investing in preserving heritage buildings through adaptive reuse, all efforts and investments the government are putting into building new cities and buildings.

Academic and Technical Relevance

The research presents an assessment tool that can be used in calculating the environmental impacts for an intervention that may benefit in decision making for stakeholders. That was conducted in the research through life cycle assessment for two real life case studies along with discussing the challenges that faced these projects and how it has been dealt with during the rehabilitation process to give expectations to practitioners and professionals of what kind of obstacles may face these types of interventions. Along with a reality check to highlight the top factors that hinder the Adaptive Reuse approach in the Egyptian context. Lastly, it may contribute in paving the way for further investigations around the embodied energy in materials and how to find new techniques and strategies to reduce it in the Egyptian context.

1.4.2 Research Aim

This Paper aims to compare between the carbon emissions of new construction versus the carbon emissions of Adaptive reuse for heritage buildings in Egypt, that were built between the late 19th and early 20th centuries especially in downtown Cairo (Khedival Cairo). To explore the environmental benefits, potentials of Adaptive reuse. And to study the challenges that might obstacle those projects, and how adaptive reuse can be a strategy to preserve the cultural value for these buildings.

1.4.3 Research Questions

Main Questions

How much embodied carbon emissions can be reduced in adaptive reuse of heritage buildings in Egypt?

Sub Questions

1. What are the benefits of adaptive reuse of heritage buildings in Egypt?
2. What are the challenges in adaptive reuse of heritage buildings?

1.4.4 Research Objective

The main purpose of the research is to: 1- evaluate the carbon savings that can be reached in case of adaptive reuse of heritage buildings compared to demolition and constructing new buildings, 2- to quantify the impact of adaptive reuse of heritage buildings on the environment (carbon footprint), 3- to illustrate a method that can be used for estimating the embodied carbon emissions for rehabilitating heritage buildings in Egypt. And 4- Identify the opportunities that adaptive reuse of heritage buildings in Khedival Cairo can provide in different sectors.

Figure 3 Main research objectives. Source: Author

1.4.5 Research Structure

The research consists mainly of two sections, the first part is surfing through the literature review to provide general understanding about heritage buildings in Egypt and its classifications, adaptive reuse and its relation to sustainability, embodied carbon emissions and its sources in the construction industry. The second part is focusing on conducting the environmental analysis of the two case studies chosen for the research through the life cycle assessment as well as investigating the challenges that were presents in these case studies.

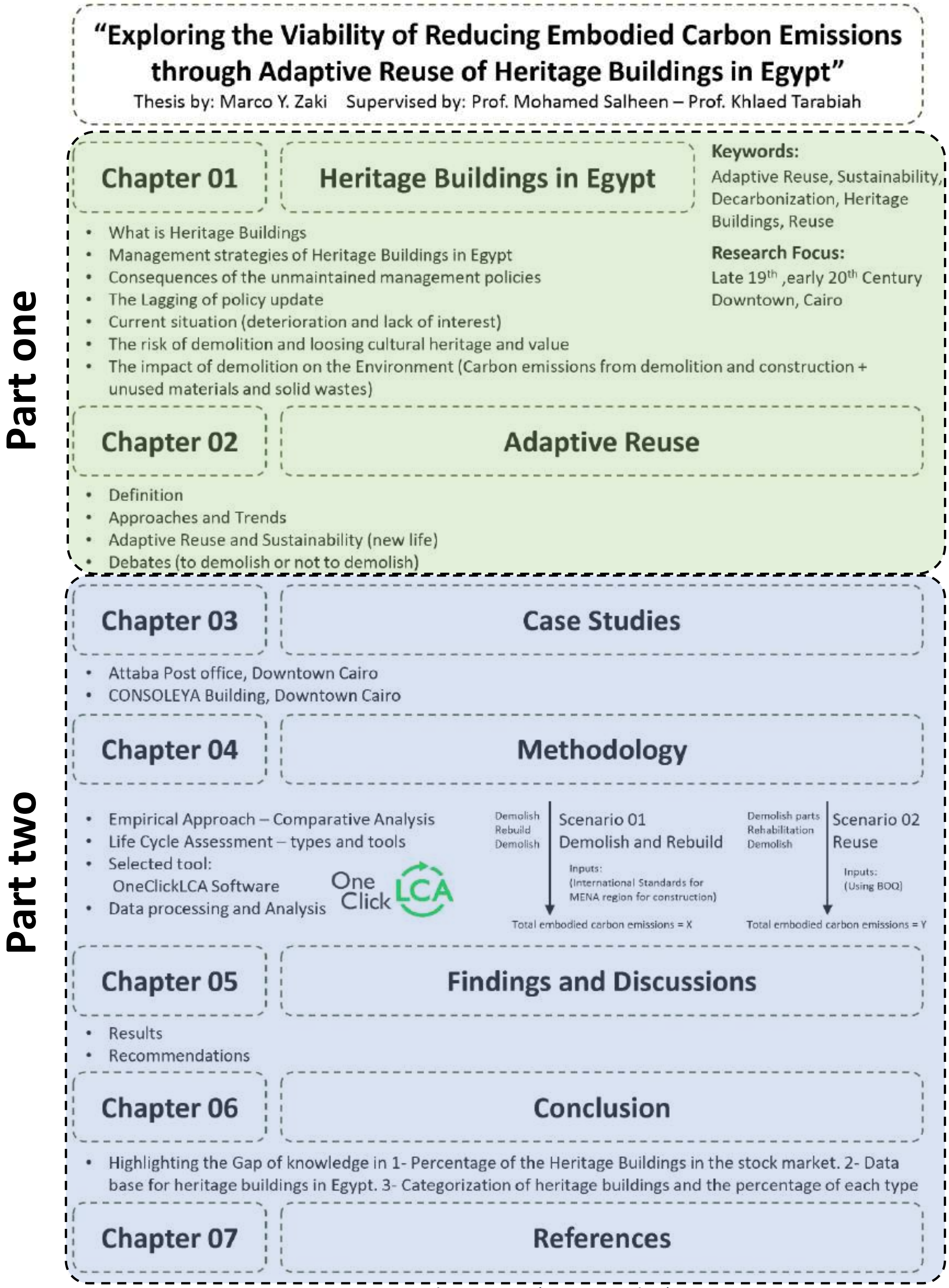


Figure 4 Research structure. (Source: Author)

1.4.6 Research Methodology

Research Instruments and Data Collection Procedures

The Aim of the research is to measure the environmental impacts for two different approaches towards heritage buildings scenarios. And to measure the amount of embodied carbon emissions, global warming potential and the most contributing materials in these impacts for each scenario, and to provide lessons learned from real life rehabilitation projects.

So, the Methodology of this research is to adopt a mixed approach between qualitative measures and comparative analysis in order to address the research questions. The research is mainly divided into three parts, the first part of the study focuses on the literature review and analyzing it. The second part focuses on the comparative analysis approach, and last part focuses on the lessons learned based on the study.

The first scenario in the research is the “Demolish and rebuild” scenario, where the existing building is being demolished completely, then rebuilt. The inputs for this scenario are based on an international construction standards database for the MENA region from One Click LCA software, this scenario will be the baseline, where the changes or improvements will be tracked from overtime and across projects. The second scenario is the “Rehabilitation” scenario, where some parts of the existing building is being demolished or replaced, then rehabilitated, the Inputs for this scenario is based on buildings rehabilitation bill of quantities (BOQs).

The study starts with choosing two different heritage buildings as case studies that were built between late 19th and early 20th centuries and rehabilitated in the area of downtown Cairo, with the activities of (office buildings and mixed use) then running a Life Cycle Assessment where the scope will be (Cradle to grave A1-D) excluding the operational stage (Use stage B1-B5) on a 60 year time span to compare between the amount of embodied carbon emissions consumed for the two case studies on two different scenarios.

Based on the literature review, it was found that there are many software and tools in the market to run a Life Cycle Assessment such as GaBi, Open LCA, Intertek Group Sustainable Minds, SIMA-pro SLCircular Ecology, Solid Forest, Sphere Solution, One Click LCA, Empauer Pty LtdiPoint- System and GreenDelta GmbH Athena software, and more. (BRI, 2023)

The software that was chosen for this research is One Click LCA for its affordability, informative illustrative analysis, and its holistic international data base for most of the materials EPDs and specs. One Click LCA is a web-based software that can be used to run a Whole Building Life Cycle Assessment or to compare buildings materials and assemblies.

Lastly, conclusion will be added based on the data and results of the study, in order to address the potentials, gap of knowledge. As well as recommendations in terms of regulations, educational, and technical measures and actions that can be pointed to fulfil the objective of the research.

Selection of Case Studies

The selection of the case studies was based on two main criteria. First, the data availability for the heritage building since the study is data-based for real life rehabilitated buildings, and second, the building should be matching with the listed heritage buildings criteria by the law of the "Boundaries and foundations for the preservation of distinguished value areas. Historical and Khedivial Cairo areas - Cairo Governorate, which were adopted by the Supreme Council for Planning and Urban Development, by decision number “27/06/22/14” In 2006.

1.5 Limitations of the Research

In this research work, there are some limitations that can be potentially covered in the future works. These limitations are: First, the absence of data base for heritage buildings in Egypt, which could have given the research more chance to clarify the percentage that the heritage buildings represent in the Egyptian buildings stock market. Second, it is important to mention that there are no enough specifications for Egyptian construction market materials to conduct the life cycle assessment with accurate numbers. So, in order to get an estimated results to show patterns, the materials specifications including the carbon emissions were gathered based on One click LCA software international data base for MENA region.

Figure 5 Saiid Halim Palace – Downtown, Cairo (Source: Author)

Chapter 2: Literature Review

2.1 Introduction

This literature review aims to investigate the relevant and existing research studies in three main areas, which are: (a) Heritage buildings in Egypt, (b) Adaptive reuse, where the most popular trends are reviewed, along with debates to demolish or not to demolish, as well as studying the approach of adaptive reuse as a sustainable strategy for decarbonization of buildings and reducing the embodied carbon emissions results from the construction; and (c) Life cycle assessment as a tool to help in the decision making process regarding the adaptive reuse approach.

2.2 Heritage Buildings in Egypt

2.2.1 Context

Mohamed Ali's era who ruled Egypt from (1805 to 1848) witnessed various architectural styles from the European architects whom were chosen by Mohamed Ali to envision his desire to modernize the built environment in Cairo. After the explosion in the population in the second half of the twentieth century, a lot of historic buildings were led to be deteriorated. Not only this, but since the 1950s, the rent act enforced were insufficient, and resulted in very minor rent increase annually (see Figure 5). Which led to instability in the economic condition. For that, redevelopment and demolition were the way out of this grading down financially for the owners for such buildings. (Elsorady, 2011)

Timing	Law description and/or conservation initiative	Generation of immediate inferences
1805–1850	During the reign of Mohammed Ali, the protection of antiquities was extremely modest and had little effect.	No clear criteria exist in Egypt, i.e. of historic and artistic merit. No grading and no clear registration.
1912: Law 4	This year marked the passage of the first antiquities law, Law 4, defining Ancient Monuments.	This law was very much in favour of ancient Egyptian monuments.
1951: Law 215	This year marked the passage of the first general legislation in Egypt issued by King Farouk and the Department of Antiquities (Law 215) regulating various types of antiquity dating up to the end of the Khedive Ismail period.	The law was triggered to address the problem of the smuggling of antiquities. The complications of this mission did not enable the Department of Antiquities to address the conservation of the cultural heritage of later periods properly. The management of such resources stopped at registration.
The 1950s Rent Laws	These have been enforced since 1952. Rents have dropped so much that landlords known as slum lords cannot maintain their properties.	Because of low rents, owners prefer to demolish and opt for commercial redevelopment.
1972	The Department of Antiquities (DOA) has interested several European countries in cultural and archaeological institutions in Cairo.	The adaptation and rehabilitation philosophy adopted by foreign conservation institutes and some local architects and conservationists offers a long-term solution to the problems of conservation in Egypt.
The establishment of the National Organisation for Urban Harmony in 2001	The National Organisation for Urban Harmony (NOUH) is affiliated to the Egyptian Ministry of Culture. Part of its mission lies in the preservation of the architectural and urban features specific to every area.	The National Organisation for Urban Harmony in Cairo is a central authority for all Egyptian governorates. It forms another listing re-evaluation committee different from the first local listing committee, and re-evaluates the status of buildings nationwide.

Figure 6 Law description and/or conservation initiative and the generation of different immediate inferences. Source (D.A. Elsorady 2011)

2.2.2 Definition and Classification

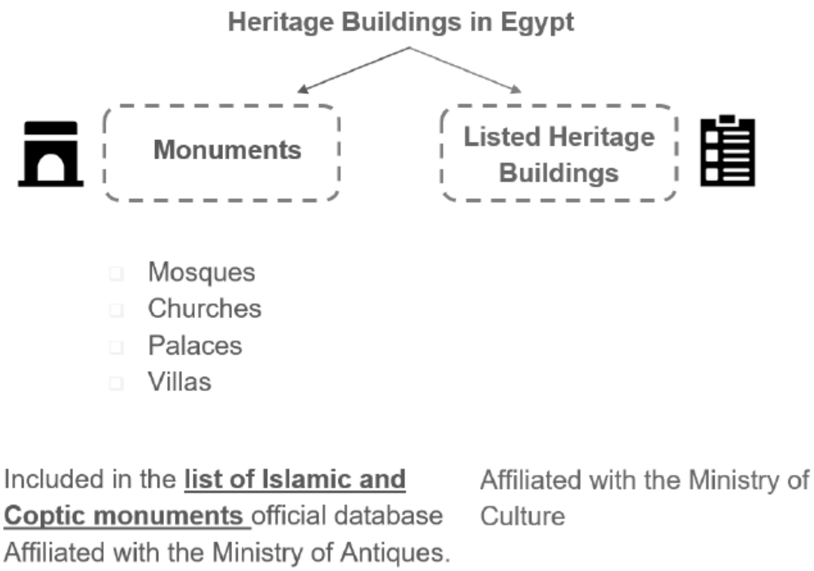


Figure 7 Heritage Buildings classifications. Source (Egyptian law of preservation no. 117 of 1983)

Based on Cambridge dictionary, A heritage building is a building of high historical or artistic value that is under public protection or protected from alteration or destruction.

In Egypt, heritage buildings can be classified into two main categories: Monuments and Listed Heritage Buildings, and each of them have its own criteria in order to be listed in those categories.

First type is: Monuments, which includes mosques, churches, palaces and villas that are present in the list of Islamic and Coptic monuments official database affiliated with the Ministry of Antiquities. (The Egyptian law of preserve the monuments no. 117 of 1983) The criteria for those buildings are: first, if it is a product of an Egyptian civilization or from the arts, science and religious that are produced on Egypt's land from pre-historic time to before one hundred years ago.

Second, if it has an archeological or artistic or a historical value which represents the aspects of the Egyptian civilization in a specific period or other civilizations that had been held on Egypt's land. (The Article No.1 from The Egyptian Law of preserve the monuments No. 117 of 1983)

And the second type of heritage buildings are: the Listed Heritage Buildings Which is affiliated by the Ministry of Culture, and its criteria are: first, the buildings must have high architectural or artistic values.

Second, the building should have been associated with events that have made a significant contribution to the Egypt's national history.

Third, the building should have been associated with the live of persons significant in the Egypt's history.

Fourth, the building should represent an era or significant period of Egypt History and lastly, the building that is considered as touristic destination (Figure 06).

2.2.3 Current condition

In fact, although many heritage buildings in Egypt fulfils the criteria for Listed heritage buildings, not all of them are used or in a good condition. Instead, many of them suffers from neglect, and not taking attention to be preserved, re-used or maintained. The reasons behind the current condition of heritage buildings in Egypt are varied, and it can be summarized in: lack of preservation technical education, lack of maintenance, absence of heritage protection laws and regulations, lack of cultural knowledge and architectural awareness, insufficient rent act (very minor rent increase annually) which is not satisfying for the owner, buildings misuse and changing activities and structural challenges (Figure 08).

Figure 8 Said Halim Pasha palace. Status: Vacant and vulnerable to deterioration. Source: Author

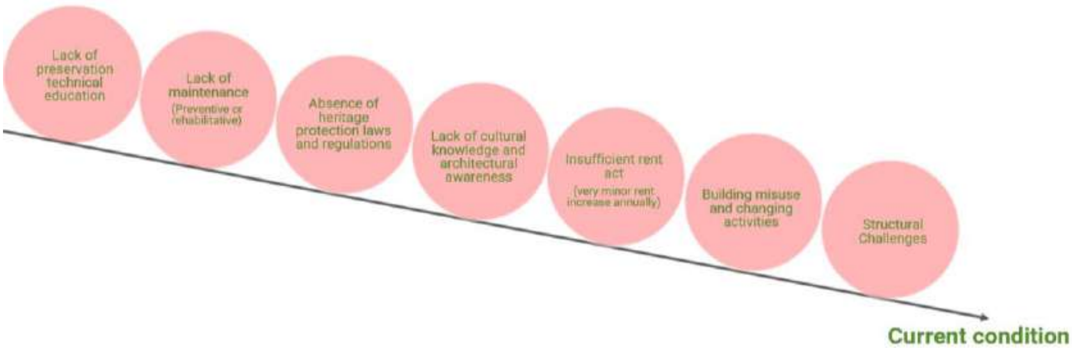


Figure 9 Factors that resulted in the current condition of Heritage Buildings in Egypt. Source: NOUH, Illustrated by: Author

2.3 Embodied Carbon Emissions

The embodied carbon emissions are an important factor of the environmental impact of the construction industry. It refers to the amount of carbon used to produce a material through its Whole life cycle stages from production, transportation and assembly of building materials. Embodied carbon emissions are the carbon footprint of constructing a building. These emissions contribute in around 11% of the total carbon emissions globally. It can sometimes refer as upfront carbon as it is released before the building begins to operate. (Council, 2019)

2.3.1 Sources of Embodied Carbon Emissions

It is well known that the Carbon emissions produced during the process of construction is one of the major factors that contribute to the climate change issues. As the carbon footprint in Buildings sector increased 40% (27% from operation and 11% from construction) (IEA: International Energy Agency, 2022). To reach around 37% of the total energy and CO_2 emissions from the process in 2021. (UNEP, 2022). In spite of the fact that the construction sector will not stop anyways due to the demand from the population growth and the need of expansion, especially in a developing country such as Egypt. However, this creates challenges to find alternative ways to minimize the Embodied carbon emissions production.

In fact, there are various tools for measuring embodied carbon emissions, these tools including life cycle assessment (LCA), which is a comprehensive method to evaluate the environmental impact of a material or a product, including stages of manufacturing, use and disposal. And Environmental Product Declaration (EPDs), which are standardized documents carried out by the manufacturers with information about a specific product with its environmental impacts. (Golnaz, Ali Bahadori -, Marco, & Anastasia, 2021). Both LCA and EPDs are widely used in the construction market to measure the embodied carbon emissions. The LCA method typically includes four stages, first: identify goal and scope, second: inventory analysis which involves quantifying both the inputs and outputs of the system. This includes identifying the materials inputs required for the assessment, third: impact assessment stage, which involves evaluating the potential environmental impacts of the system. This stage includes assessing the potential impact on ecosystems, natural resources and human health. Lastly: the interpretation stage, which involves analyzing and presenting the results of the LCA study in order to identify the hotspots in the LCA where largest environmental impacts occur, and exploring improvement opportunities. (Lewis, Huang, Carlisle, & Simonen, 2021). Each stage in the product/material lifecycle contributes to the total embodied carbon emissions. However, the amount of carbon contained is not the same for all stages, but contributes to the total amount of carbon released over the life of the product/material. The first stage is the product stage (A1 – A3): this stage represents the process of extraction of raw materials, transportation to the manufactured site and being manufactured. The next stage is the construction stage (A4 - A5): Where materials are being transported to the construction site, then being installed or assembled. (B1 – B5) Use stage: after the product is fixed or building being built, this stage represents the actual use, maintenance, repair, replacement and

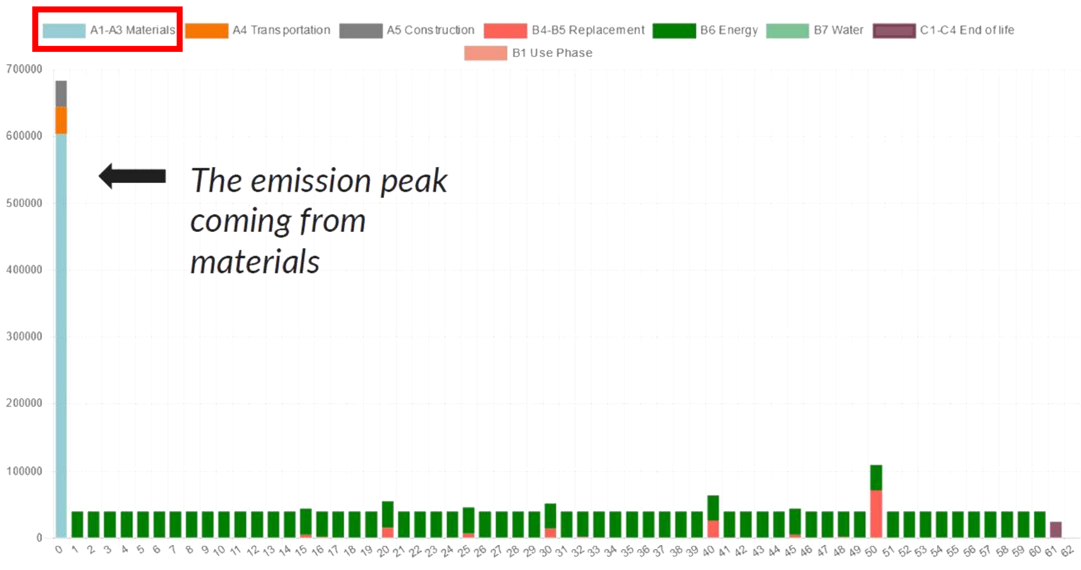


Figure 10 Emissions over time (60 Years span) (Source: Helena, Level(s) pilot, calculated using One Click LCA)

refurbishment of the product/material. Lastly, (C1 – C4) End of life stage: it represents the deconstruction and demolition, transport, waste processing and disposal. Life cycle assessments can be categorized into (from cradle to gate) (A1 – B5) or from (cradle to grave) (A1 – C4).

Researches showed that across an average of 60 years life span for a building, the Product stage (A1-A3) which happens before the building is built (year 0) is the highest stage that consumes embodied carbon emissions across the life cycle, where it reaches almost 10 times the carbon emissions of each of the other stages, as energy consumed to extract raw materials from different natural resources, then transport to the manufacturing site, and finally being manufactured. (Helena, 2020).

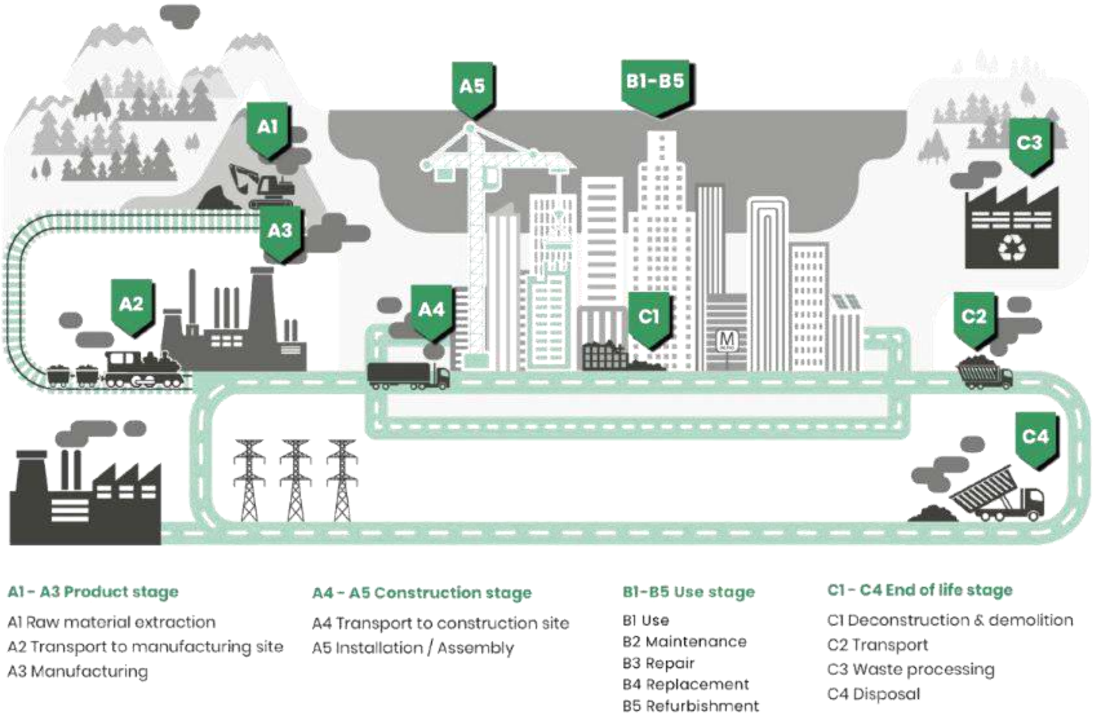


Figure 11 Sources of Embodied Carbon across the construction lifecycle (Source: OneClick LCA)

2.3.2 Actions to reduce embodied carbon emissions

In the time we are living in, with the climate change as one of the top challenges facing the world, it is crucial for industries to shift the paradigm towards more sustainable solutions and strategies in order to reduce their carbon footprint and mitigate load of carbon emissions in our planet. In fact, many countries around the world started to take actions towards reducing their carbon footprint in order to reach zero carbon by the year 2030 (LETI, 2020). Researches are ongoing nowadays to explore and test many strategies in that context. However, these strategies are all mainly revolving around some primary actions (Figure 11), which are: build less, build light, build wise, build low carbon, build for the future, build collaboratively (LETI, 2020).

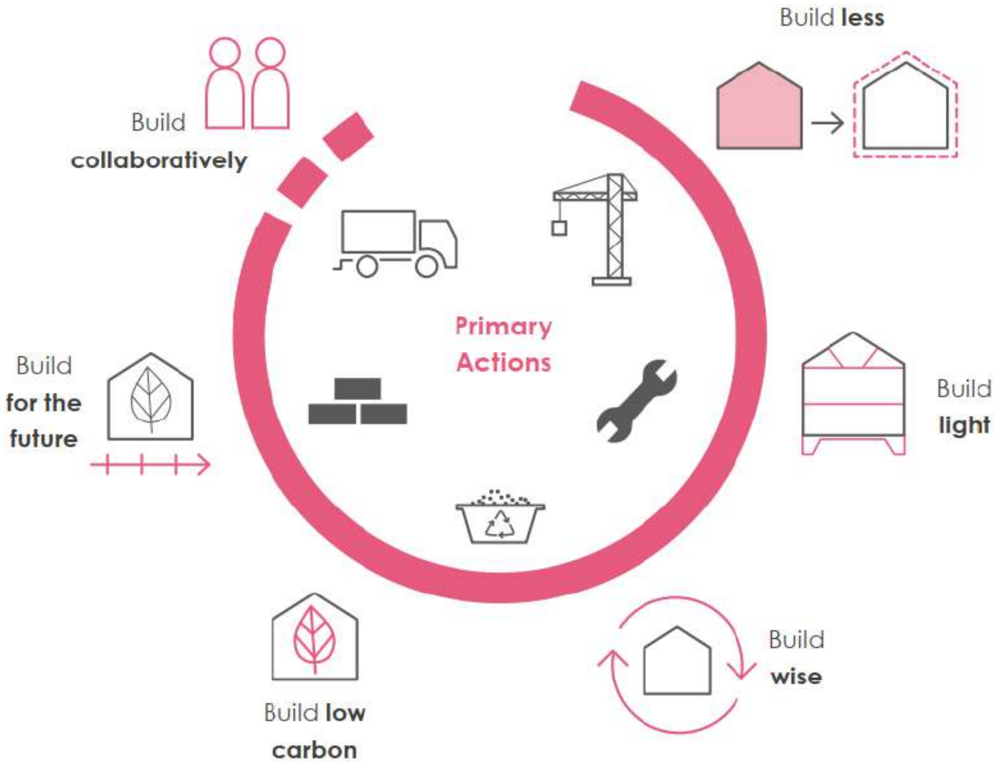


Figure 12 Primary Actions to the Climate Emergency Design Guide
Source: (London Energy Transformation Initiative 2020)

The first action (**Build less**): refers to putting in consideration some points such as reusing or refurbish the existing buildings before thinking about building new buildings, look for materials on or nearby the site of the project, design spaces to be shared for multi-functionality, and check if all the proposed materials are necessary or some can be excluded

The second action (**Build light**): refers to considering the building structure in the following aspects: reducing the long spans, if possible, and reduce the dead loads weights where possible.

The third action (**Build wise**): refers to using materials efficiently to ensure longevity. Some of the efficiency options is to design for a repeating module, prioritize the site analysis activity at the beginning of any project, along with identifying ways to reduce embodied carbon, some of these possibilities include: looking for existing structures that can be reused or be a source of recycled materials, looking for locally sourced materials, this will reduce transportation to site. Lastly, to reduce the amount of removed soil from site by designing around the topography existed.

The fourth action (**Build low carbon**): refers to reviewing material specifications and take decisions to reduce the high embodied carbon materials usage, consider using renewable or natural materials, check for solutions such as "Design for Manufacture and Assembly" and check its potential on reducing embodied carbon.

The fifth action (**Build for the future**): refers to assessing adaptability and end of life. The aim is to consider future uses for the building, and expand its adaptability opportunities. Using of Mechanically fix systems instead of systems relying on adhesive fixes, this will enable them to be reused or recycled after de-assembly, supporting a circular economy. Lastly, to avoid using additional coatings for materials as possible, which can reduce the opportunities for the material to be recyclable.

The last action (**Build collaboratively**): refers to getting the whole team of design along with the client to be involved in the solutions, and to take decisions based on the data driven by the rule of thumb in the early stages of design.

It was shown in the previous researches around the Embodied Carbon Emissions from the construction sector that the peak of the emissions along the life cycle of any building comes in (Year 0) (A1 – A3) which is the year that include the raw materials extraction, transportation to the manufacturing site and manufacturing the materials itself. Here comes the potential of the adaptive reuse, where the number of materials that will be needed to retrofit the building could be much lesser – which means much less embodied carbon emissions – than the number of materials needed to completely demolish the building then starting a new (Year 0) to a new building. Instead, expanding the life span of the heritage buildings using less materials could be much more sustainable environmentally. And to reach the quest of embodied carbon reduction, the "build less, build clever" (Hill, Dalzell, & Allwood, 2020) and the "reuse and retrofit" approaches can save up to 50% emissions compared to new constructions, mainly for the reason of reducing the demand for materials such as concrete and steel. It can be observed on a scale of embodied carbon emissions how the "build less" strategy is valid. Without modifications for existing building, there will be no emissions, and as the intervention increases, the carbon

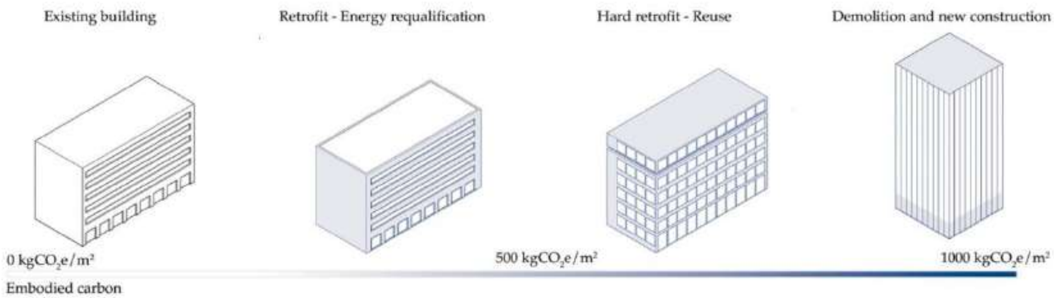


Figure 13 Embodied carbon emissions proportionally to the level of the intervention. Source (Besana, D.;Tirelli,D., 2022)

emissions increase as well, reaching its maximum in case of demolition and rebuild.

2.4 Adaptive Reuse

2.4.1 Introduction

After demonstrating the classifications and definitions of the heritage buildings in Egypt, and its current condition, and previewing the sources of the embodied carbon emissions in the construction industry along with the primary actions to reduce those emissions as a foundation for the research topic. It is fundamental to highlight the potential of the heritage buildings to be reused, through the adaptive reuse approach, in order to mitigate the carbon footprint of construction industry, along with preserving the cultural and memorial value of these buildings. (DEH, 2004)

2.4.2 Main trends and concepts

Adaptive reuse is not a new approach, in fact it returns to the early years of existence, where man used caves as shelter. The same idea is applied in today's-built environment when the structure of existing buildings is extended to fit a new purpose, since it can no longer be used for the same activity or program. This type of use can be referred to in the Literature by multiple terms such as: rehabilitation, refurbishment, retrofitting, remodeling, renewal, repair, restoration, reconstruction, renovation, preservation, modernization, maintenance, extension, conversion, or conservation. While all of the previous terms refer to the same notion of practice which is to reuse the building in a way that serve a new purpose based on the need of today. However, each term is defining a specific scope (Wong, 2016). The following section is dedicated to define these terms in a chronological order to highlight the distinction of each term.

The first term **rehabilitation** is defined by ICOMOS as the modification of an existing building to modern or contemporary function that might involve adaptation for a new use. (ICOMOS, ICOMOS APPLETON CHARTER, 1989). While in 1995 the U.S. Secretary of the Interior (Weeks & Grimmer, 1995) defines it as the process of possibly making use compatibly for a property through additions, repair or alteration while preserving its architecture, cultural and historical values. While (Douglas, 2006) defines it as the need to add or alter to a historical property to meet the changing functions while preserving its historical character. While (Watson, 2008) defines it as an upgrade in an old building element such as adding a new mechanical system for air conditioning with appropriate controls to the property.

The second term **refurbishment** is defined by (Douglas, 2006) as overhauling or modernizing a building to meet an acceptable functional condition. But without any major non-structural nature improvements. With giving room for exceptions for extensions. While (Watson, 2008) defines it as an approach that change in building performance. Another definition by (Giebleler & Kahlfeldt, 2009) as the adaption of a building to new technical regulations or for meeting current standards, it can be implemented based on a change in the user's demands. (Giebeler, 2009) adds that refurbishment term lies between maintenance and conversion, as it does not involve a major change to the interior layout or the loadbearing structures.

The third term **retrofitting** was defined by (Douglas, 2006) as redesigning and rebuilding existing property or subsystems to incorporate new technology, meet new requirements, or provide performance not envisioned in the original design. In other words, retrofitting is replacing a component with a new component that was not yet available at the time of the original design.

The fourth term **remodeling** means to make new building that restores an older use or former state of another building. (Douglas, 2006)

The fifth term **renewal** can be defined as the improvements and repairs of a recent constructed property that can regain or exceed its former performance (Douglas, 2006). While in 2008 historic England from the England's Historic

Buildings and Monuments commission defines it as thoroughly dismantling and replacing the elements of the place for structures where the acoustic unit is usually re-installed. (EHBMC, 2008)

The sixth term **repair** was defined by (Ruskin, 1889) as taking care of the monument, so there is no need to restoring them. Another definition by the British Standards Institution (BS7913, 1998) as the work beyond the maintenance regular scope, in order to return a property or artifact to good condition without restoration or alteration. While on the other hand, (Douglas, 2006) defines it as the mending of damaged parts of an item to be restored by replacement or renewal to an acceptable condition. This approach is associated with buildings components that were damaged through misuse. (EHBMC, 2008) defines it as the work beyond the maintenance regular scope, in order to fix defects that were caused due to damage, decay or use, that can include minor adaptation in order to obtain sustainable outcome, without restoration or modification. Lastly, it was defined by (ICOMOS, New Zealand, 2010) as using appropriate material that can be identical or closely similar to a damaged or decayed fabric to repair it.

The seventh term **restoration** was firstly defined by (quincy, 1832) as the re-establishment of a damaged building parts to be upgraded to its original working order. This often fills a gap to know some traces of the building or an element in the building in order to rediscover the original order. Another definition by (Viollet-le-duc, 1875) clarifies that restoration of a building is a different thing than to repair, or to preserve it, or rebuild it. But to restore a building means to put it in a completeness condition that have never existed before at any given time. (Morris, 1877) defines the term restoration in a metaphoric way as a strange idea, that contains the possibility of peeling from a building this, that and other parts of its history, whiling keep the hand at some points, and leave it still even as it was once. While another definition by (Ruskin, 1889) to the term restoration as the highest destruction a building can suffer, he sees that it is impossible to restore architecture that once was great or beautiful. (Brandi,

1963) defines restoration as the function recovery of a product under any kind of intervention. It is the appreciation of the material form of the work of art historically, and aesthetically, with an intention to transmitting to the future. (Charter, 1964) defines the aim of restoration as to reveal the value of the monument aesthetically and historically, respecting its original material and authenticity. In 1995, the U.S. Secretary of the Interiors defined it as the process of portraying the character, form or features of a building as it was appearing from a period of time due to removal of some features from different period of time, and reconstructing the missing characters, with the allowance of upgrading the mechanical or electrical or plumbing systems or other works required by the code to keep the building well-functioning within the restoration process. While (Douglas, 2006) defines the restoration term as bringing back the original state or appearance of an item, this approach may be included after a building or number of buildings of architectural or historical value face a disaster such as fire. (EHBMC, 2008) defines restoration as reviving an earlier known state of a place based on compelling evidence, not guesswork. Another definition by (Giebeler, 2009) as the finishing of an incomplete structure. While (ICOMOS, New Zealand, 2010) defines the restoration as a process that typically includes assembly, and may also include removal of debris impacting the cultural value of the place. Restoration means put back in place by reassembling and restoring the known early form, or by removing elements that affect the value of the heritage. Another definition by (ICOMOS, The Burra Charter, 2013) as restoring a site to a known previous state by consolidating or reassembling existing elements without introducing new material. The Indian National Trust for Art and Culture Heritage defined restoration as an appropriate conservation strategy to restore the integrity of an architectural heritage or to complete a fragmented 'whole' property. The goal should be to convey the meaning of heritage in the most effective way possible. It may include reunification of displaced persons and dismembered people, structural components and suspected construction or replacement missing or severely damaged areas of fabric. Restoration with comprehensive documentation is required before and after work in order to make interventions based on understanding of resources and its background, and conforming to contemporary local practice handy crafts. (INTACH, 2016)

The eighth term **reconstruction** was defined by the British Standards Institution (BS7913, 1998) as reconstruction of the design of a building or artefact, or of something that existed or happened in the past, based on written or physical evidence. Another definition by (Douglas, 2006) as restoring missing or missing parts of properties for the purpose of interpretation. Reconstruction was also defined by the U.S. Secretary of the Interiors in 2006 as the act or process of reproduction with something new, or building the exact shape and details of vanished buildings, structures or an object or part of it that appeared at a certain point in time. (Giebeler, 2009) defines it as reconstructing structures that no longer exist. (ICOMOS, New Zealand, 2010) defined it as it differs from restoration by the introduction of technology, as new materials replace lost materials. It means to reconstruct as close as possible to the previous documented form, using new materials. While (ICOMOS, The Burra Charter, 2013) defines the reconstruction as different from restoration by the use of new material. It is returning a place to an earlier relevant state. The Indian National Trust for Art and Cultural Heritage defines it as interpreting the original meaning of putting the resources in a modern context and strengthen their bond with society. (INTACH, 2016)

The ninth term **renovation** was defined by (Douglas, 2006) as modernizing old buildings and restoring them to an acceptable condition, which may involve conversion work. While defined by (Giebeler, 2009) as renovation does not add anything new to the building stock or replace the old with the new. Rather, proper renovation preserves the value and functionality of existing buildings.

The tenth term **preservation** was defined as a term that is widely equated with 'conservation' or 'restoration' in some cultures, but when viewed in this perspective, it can be viewed as a contemporary art that maintains a living contact with past cultural works. It can be seen as expressing a method. (Philppot, 1972). Another definition by (Fitch, 1990) as means that the artifact remains in the same physical condition as when it was received from the curatorial institution. Nothing is added or removed from the aesthetic body of the artifact. (Weeks & Grimmer, 1995) defines preservation as the act or process of applying the necessary measures to preserve the existing form, integrity and materials of a historical property. The work involves preliminary measures to protect and stabilize assets is generally focused on the ongoing maintenance and restoration of historic objects and structures rather than large-scale replacement or new construction work. And adding new skins is out of the treatment scope; however, restoration of asset functionality requires limited and careful modernization of mechanical, electrical and plumbing systems, and other legally mandated work. Appropriate in the context of monument protection projects. While (Douglas, 2006) defines it as the act of stopping the deterioration of buildings and monuments using sensitive and empathetic restoration techniques. Preservation means "the state of reviving a building or artifact, whether by historical accident or by a combination of conservation and active protection." It can also be defined as "the act or process of applying the measures necessary to preserve the existing form, integrity and material of historical property" (Weeks & Grimmer, 1995) The focus of historic preservation is the maintenance and restoration of existing historical materials, as well as preserving the shape of the property as it has evolved over time. Includes protection and stabilization measures. (ICOMOS, New Zealand, 2010) defines preservation as means to repair a place with changes as little as possible. Later, it was defined by (ICOMOS, The Burra Charter, 2013) as maintaining a place to avoid deterioration and bring it back to its early existing state. It was then defined by (Interiors, 2016) as the maintaining and restoring of an existing historic building including the materials and shapes of properties that evolve over time.

The eleventh term **modernization** was defined as adapting the building to current standards imposed by users, society and/or legal requirements. (Douglas, 2006)

The twelfth term **maintenance** was defined by (ICOMOS, ICOMOS APPLETON CHARTER, 1989) as an ongoing effort to extend the life of resources without causing irreversible or harmful interference. Another definition by the British Standards Institution (BS7913, 1998) as actions to keep or restore the item to a state where it can perform its desired function. While (Douglas, 2006) defines it as the combination of all technical and administrative measures, including surveillance measures, intended to maintain or restore the object to a condition capable of performing its required functions. Maintenance is the daily work required to keep the structure of buildings in good condition. In other words, regular, ongoing work to ensure that fabrics and engineering services meet minimum standards. (EHBMC, 2008) defines it as the regular routine work necessary to keep the fabric of the place in good condition. While it was defined by (Watson, 2008) as a repair and/or replacement work to update or restore part of a building. (ICOMOS, New Zealand, 2010) defines maintenance as the regular and continuous protection of a place to prevent decay and preserve cultural heritage values. (ICOMOS, The Burra Charter, 2013) then defined it as the continuous protection given to a place with care to its settings.

The thirteenth term **extension** was defined by (Douglas, 2006) as expanding the capacity or volume of a building vertically by increasing its height/depth, or laterally by increasing its floor plan area. And defined by (Watson, 2008) as works with horizontal and vertical enlargements. (Giebeler, 2009) defined it as a new construction directly related to the use of an existing building.

The fourteenth term **conversion** was defined by (Douglas, 2006) as the act of improving the suitability of buildings for similar uses or different types of occupancy (mixed or single use). Another definition by (Watson, 2008) as work with changes in functions and uses such as a conversion of office buildings and adaptation to residential use. (Giebeler, 2009) defined conversion as transformations that always affects building structures. These extend the concept of retrofitting to include interventions in load-bearing components and interior design.

The fifteenth term **conservation** was defined by (Charter, 1964) as the approach that always facilitated by the fact that they are used for socially useful purposes. It was then defined by the British Standards Institution as the measures taken to ensure the survival or future preservation of buildings, cultural property, natural resources, energy, or anything else of perceived value (BS7913, 1998). Another definition by (Berducou, 1990) as all means used in intervening in an object or property trying to prolong its existence as long as possible. (ICOMOS, Nara Document on Authenticity, 1994) defined conservation as all efforts aimed at understanding the cultural heritage, knowing its history and significance, ensuring its material protection and, where necessary, presenting, restoring and enhancing its value. (Where cultural heritage means monuments, buildings and sites of cultural value within the meaning of Article 1 of the World Heritage Convention). (Jokilehto, 1999) defined it as an approach that is characterized above all by a radical change in values in today's society, a paradigm based on relativity and new concepts of historicity. Another definition by (Butterworth-heinemann, 1999): conservation refers to the overall subject of the management and treatment of precious artifacts, both movable and immovable, although preservation has a different meaning than restoration in this field. Conservation in this particular sense has two aspects: First, environmental management to minimize deterioration of crafts and materials. Second, treatment to stop deterioration and, if possible, stabilize against further deterioration. (Douglas, 2006) defined conservation as preserving buildings by allowing a certain level of positive change. It was then defined by (EHBMC, 2008) as the process of managing change at key sites in the environment in a way that best preserves heritage values while identifying opportunities to reveal or enhance those values for present and future generations. (Watson, 2008) defined conservation as preserving existing buildings and their facilities and equipment as-is for the future. Or restoration that can contain any repair to return a fabric, component, or accessory to an acceptable standard. Another definition by (ICOMOS, New Zealand, 2010): The purpose of conservation is to cherish cultural heritage. Conservation means all the processes of understanding and caring for a place in order to protect its cultural heritage value. Conservation is based on respect for the existing structure, relevance, meaning and use of the place. It requires a careful approach that requires as little work as possible and maintains authenticity and integrity so that the place and its value can be passed on to future generations. (ICOMOS, The Burra Charter, 2013) defines it as all the processes necessary to maintain a monument place in order to maintain its cultural significance. Lastly, the Indian National Trust for Art and Cultural Heritage defined the purpose of conservation as to preserve the importance of architectural heritage and sites. Meaning exists in both tangible and intangible forms. (INTACH, 2016)

After reviewing Adaptive reuse main trends and concepts, the following section will discuss the relation between Adaptive reuse and sustainable development pillars, Environmental, Social and Economical.

2.4.2 Adaptive Reuse and Sustainability

Adaptive Reuse is an architectural approach that not only aims to breath a new life into empty historical buildings to preserve it cultural value, but it also impacts the domains of the sustainable development (Li , Zhao, Huang, & Law, 2021). A set of major benefits for Adaptive reuse in sustainability were indicated in the Literature review. These sets are: Environmental, Environmental – Economic, Economic, Economic – Social, Social, Social – Environmental and can be identified as follows:

Sustainable development pillar	Contribution of Adaptive Reuse in each pillar	Potential values
Environmental	Raise the Environmental Condition	Reduce the pollution by the reuse approach
		Improve Infrastructure networks through reusing of Heritage buildings
		Reduce Energy demand and carbon emissions
		Limiting urbanization by reusing the existing non-used buildings
Environmental - Economic	Use less	Use less resources, energy and emissions
		Increase demand for existing adapted maintained buildings
		Recover embodied energy in buildings over a long period of time
		Stimulate empty neighborhoods
Economic	Enhance the economy	Growth of economy
		Cost-effectiveness
Economic - Social	Revive assets	Extending the building lifecycle
		Converting un-used real estate to community resources value
Social		Increase sense of place, identity and cultural continuity
		Preserve heritage for new generations
		Enhancing the built environment aesthetic vision
Social - Environmental	Preserve land	Decreasing urban slump and consumption of land
		Revitalization and maintenance of historic district and architectural and technological innovation

Table 1 The relationship between sustainable development pillars and the potential benefits of Adaptive reuse. Source: (Othman, Elsaay, 2018)

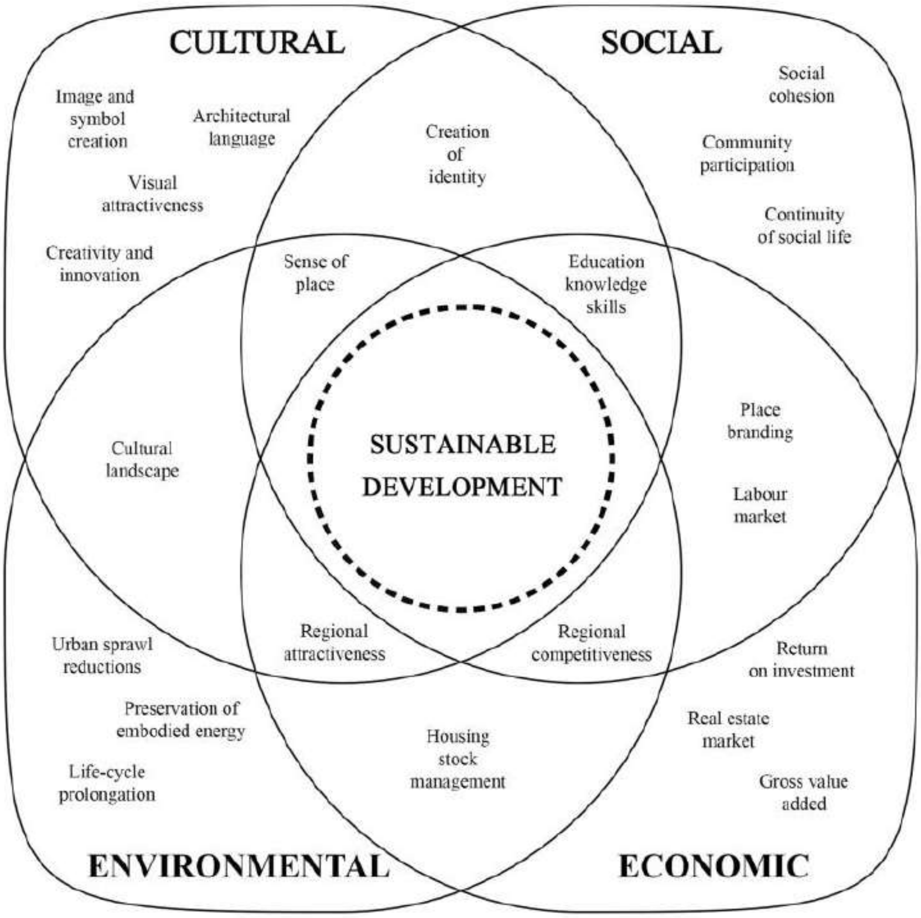


Figure 14 The holistic hour-domain approach diagram. Source: (Europa Nostra, 2015)

(Yung & Chan, 2011) defines adaptive reuse as a form of sustainable urban renewal as it expands the life of the building instead of destroying or demolishing it, as well as, having environmental, social and economic benefits for the whole world. According to a study made by the National Trust for Historic Preservation, it was shown that the Adaptive reuse approach can create job opportunities, and reduce carbon emissions. It can have significant benefits economically and environmentally. (Frey, Dunn, & Cochran, 2011)

(Schmidt III, Eguchi, & Austin, 2009) defines adaptive reuse as the ability of a building to respond and reflect on the necessary development for the user's requirements and to be able to constantly change effectively, hence maximizing its value during its life period.

While (Fiorani, 2017) defines adaptive reuse in her book: Conservation – Adaption saying that adaptive reuse is the process of transforming the building function entirely in which the function is the most obvious change, but other changes can be made as well, such as adjusting orientation, the relation between spaces; some parts can be added to the building and others can be demolished, it is not only important to preserve the physical values of the building, but also another important aspect to be considered is the immaterial importance. Which is especially important in buildings that have a symbolic significance and a spirit of place. In summing, the design has to create a harmony in form, function and spirit.

In some cases, adaptive reuse can be the only way to properly manage, expose and interpret the structure of a building while making better use of the building itself. When a building no longer lives up to its original use, reuse through adaptation may be the only way to maintain its heritage significance. (RAIA, 2004)

From the above we can conclude that adaptive reuse is the approach of reusing an old or abandoned heritage building, in order to meet the contemporary needs, preserving and increasing its value by increasing its life cycle which will lead to the sustainability of the heritage buildings.

However, the decision on which whether to reuse a heritage building or not depends on a complex set of criteria and considerations such as market trends, heritage, architectural assets and location (Bullen & Love, 2016). Based on a study made by (Bullen & Love, 2016) to study the factors that affect the adaptive reuse decision process, it was shown that the highest factor that affect the adaptive reuse decision process is the "Environmental sustainability", followed by "Heritage significance", then "meeting sustainable development benchmarks". (Figure 13) This means that although the Environmental sustainability can be one of the top benefits of the Adaptive reuse, however, it is not the main player in the decision making of whether to reuse or to demolish the heritage building.

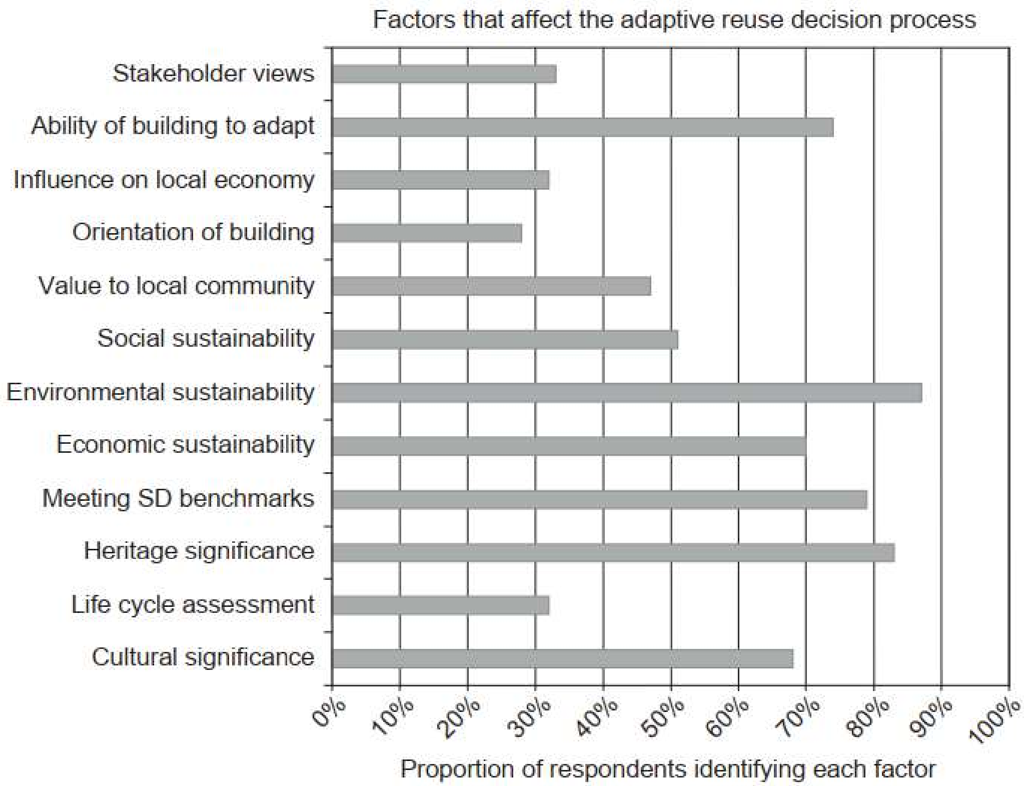


Figure 15 Factors affecting adaptive reuse decision making. Source: (Bullen & Love, 2016)

From the literature, it was shown that on both the local and international level, the decision making of building adaption is complex (Othman & Mahmoud, 2020), (Blakstad 2001 & Douglas 2006) as it involves many stakeholders each with different perspective. These stakeholders are owners, investors, developers, policy makers, marketers, users/occupants and regulators (Kincaid, 2002). Not only the decision has different stakeholders involved, but also each one contributes at different stage during the process with different level of influence or impact. In fact, decisions that are made early in the process generally have an ongoing impact throughout the project. For example, a decision to change usage affects all subsequent decisions. Furthermore, the ability to influence stakeholder decisions can be categorized as either direct or indirect. Another level is added if the stakeholder is intended to be a resident or user. In this case, decisions have a day-to-day impact on ongoing business operations. Stakeholder motivations that influence decision making vary. For example, a developer who intends to sell a property after adjustment will experience different impact factors than if it intends to retain the property in the developer's property portfolio. In summary, stakeholders are diverse and exert varying degrees of influence at different stages. (Wilkinson, Remoy, & Langston, 2014)

Decision-makers	Affiliations and Professionals	Stage in Adaptation where decisions are made
Users	Owners, individual users, occupiers	-
Developers	Organizations that invest, production and marketing.	Early stage
Investors	Professionals who have capital to invest, banks, independent investors, insurance companies, pension funds.	Early stage
Policy makers	Federal and local government departments	Indirect impact at all stages
Marketeers	Real estate brokers, Surveyors, stakeholders	During the design process or construction stage
Regulators	Local authorities, heritage building surveyors, planners, fire engineers	During the design process or construction stage
Producers	Facility manager, architects, engineers, suppliers, structural and mechanical engineers	During feasibility, design and construction stages

Table 2 Decision-makers in building adaptation. Source: (Wilkinson, Remoy, &Langston, 2014)

After reviewing the adaptive reuse contribution to sustainability, along with the complexity nature for its decision making, the next section will review the literature around the debate whether to demolish or not to demolish the heritage buildings.

2.4.3 Debates: to demolish or not to demolish

During reviewing the literature about the Adaptive reuse approach, there was a lot of debate around the topic for over hundred years (Power, 2008). Whether it is important to preserve the significance of the heritage building or to give a chance for other properties to use the land to construct a project that can benefit people such as commercial projects or social housing buildings that potentially can generate revenue for the local economy (Kihato, 2019). However, the evidence whether the adaptive reuse is the most environmentally is unclear. (Power, 2008)

In fact, the decision to demolish the non-used heritage buildings is derived from the challenges facing this approach. The major challenges are structural performance issues, compliance with codes of buildings and regulations, lack of interest from the government sector, lack of awareness, and high maintenance costs. It also includes outdated construction data, lack of incentives, and lack of decision-making and stakeholder involvement., this perspective views the non-used heritage buildings as outdated, and unable to serve a practical purpose that fulfills today's needs. Adding that most of these buildings are often in disrepair condition and should require a significant amount of money in order to be maintained. (Kilpatrick, 1980). While in terms of the environmental performance, the desired standards of new buildings may not be reached in case of the adaptive reuse of heritage buildings. Based on Wilkinson, Bullen and Love, in commercial buildings, adaptive reuse may be uneconomical and it may reach a point where it is unsuitable for functional change. (Wilkinson et al. & Bullen and Love, 2011)

However, there are many studies made on the benefits of the Adaptive reuse of heritage buildings. One of these studies focused on the positive effects of adaptive reuse on sustainability objectives, these effects were identified as follows: provision of value to local community, extending the building life cycles, reducing demolition of buildings, reduction of resources consumption, economic viability of reused buildings, less energy for material production, eco-efficiency of reused buildings, retention of visual amenity and retaining the sense of place (Wilkinson et al. & Bullen and Love, 2011)

Environmental impacts such as carbon footprint, acidification, eutrophication and more, that comes through embodied energy from materials which is responsible for 11% of the global carbon emissions can dramatically be reduced in case of the Adaptive Reuse of heritage buildings (Helena, 2020).

In fact, the feasibility of adaptive reuse of heritage buildings were shown in many studies and actions that were took by decision makers. It was argued by (Power, 2008) that upgrading the UK buildings stock to high environmental standards can be achieved with lower financial cost than demolition while saving a significant amount of carbon emissions.

In conclusion, the decision to demolish or to reuse heritage buildings is and will continue to be debatable. We need to look at the bigger picture and see the argument from a holistic point of view for a more sustainable future.

Chapter 3: Case Studies

3.1 CONSOLEYA Building
3.1.1 Brief History

Consoleya building was built in 1928, on the beaux arts architectural style nested in the heart of downtown. It is named after the council as it was the home for French council in Cairo, Egypt before it was moved to Giza. After that, the building stayed vacant until a real estate development bought it to rehabilitate it as a co-working space and entrepreneur's hub.

Figure17 CONSOLEYA Building (Source: El Ismaelia Development)

Figure 16 CONSOLEYA Interiors (Source: al-ismailia)

3.2 Attaba Post Office Building
3.2.1 Brief History

This landmark building was established in 1931 by King Fouad, the post office headquarter in Attaba square occupies a rare documents, letter and artifacts second door museum which was established in Feb. 1934 that displays the development of the country's postal service. (Egyptian Streets, Eltigani, 2018)

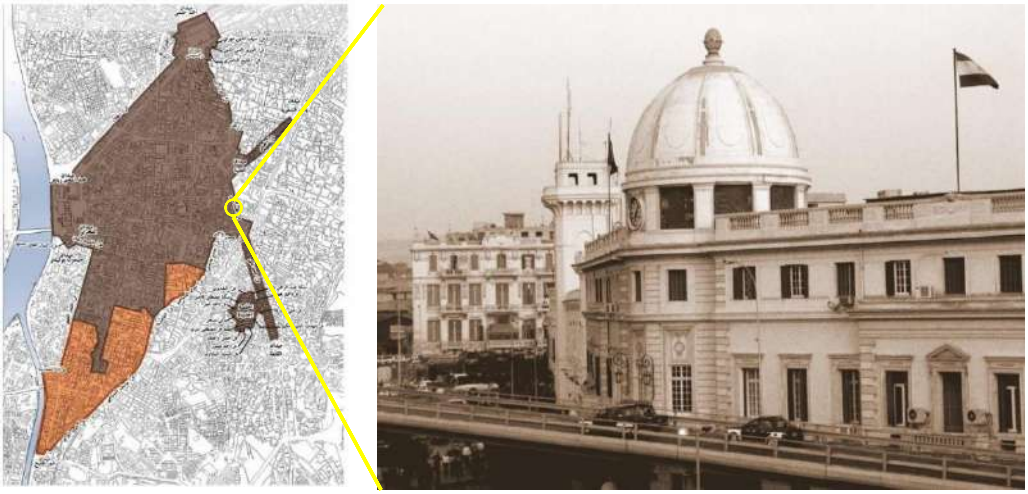


Figure 21 Attaba Post office HQ (Source: Flickr- Nermz)

Figure 20 Attaba Post office HQ Interiors (Source: Alahram)

Chapter 4: Methodology

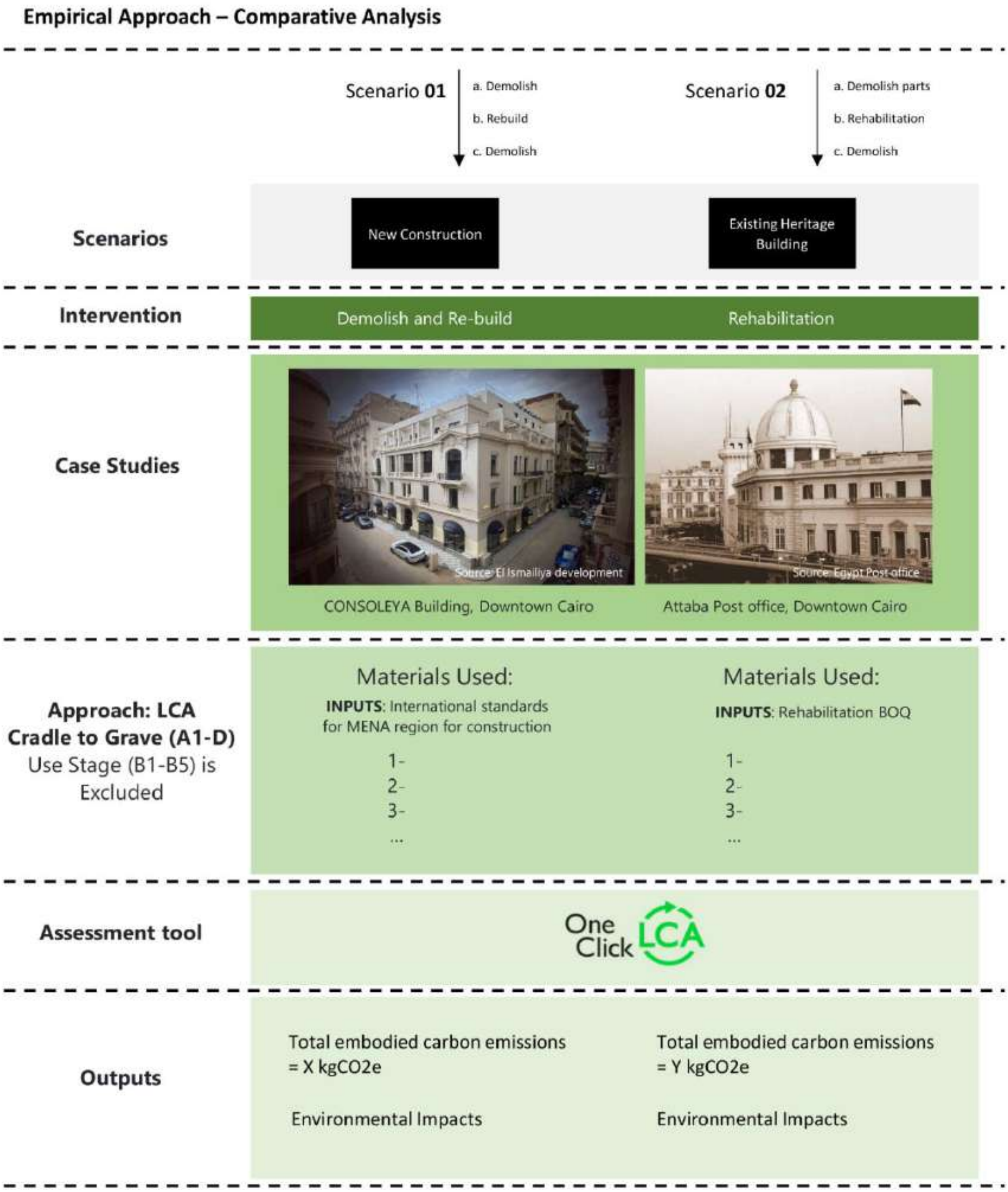


Figure 23 Research Methodology (Source: Author)

A life cycle assessment will be running on two local case studies in Downtown, Cairo. Those buildings are CONSOLEYA, and El Attaba Post office. For each case study, two scenarios will be studied. The first scenario is to demolish the existing building and building new one, while the second scenario is rehabilitation of the existing building.

The LCA approach is cradle to grave (A1-D), excluding the operational phase (B1-B5), so both scenarios are studied on three main phases. The first phase is to demolish whole or part of the building, the second phase is to rebuild or refurbish, and the third phase is to demolish at the end of life.

The output of assessment will be the total amount of embodied carbon emissions in each scenario, in order to explore the percentage that adaptive reuse of heritage buildings can save compared to demolition and rebuild a new building. In addition to the environmental impacts for each scenario such as carbon footprint, eutrophication, acidification, ozone depletion and so on and so forth, to have a broader look on the effect of adaptive reuse approach on the environment in a more holistic perspective.

After previewing the key life cycle assessment software programs in the market based on the Business research Insights report (BRI, 2023), these tools are: GaBi, Open LCA, Intertek Group Sustainable Minds, SIMA-pro SLCircular Ecology, Solid Forest, Sphere Solution, One Click LCA, Empauer Pty LtdiPoint-System and GreenDelta GmbH Athena software.

One Click LCA software was selected for this research based on its accessibility, affordability, illustrative outputs that are easy to read and most importantly have enough data base for the MENA region to cover any gaps in the data available.

Data Preparation

In each scenario, embodied carbon benchmark will be calculated and global warming potential will be compared to identify the quantity of CO2 that can be saved in each case study between the two scenarios. There are two main sources for the data, the first source is the international standards for MENA region for construction based on One Click LCA data base. This will be used for scenario 01. On the other hand, scenario 02 data source will be from the bill of quantities for materials used in the process of rehabilitation.

The embodied carbon benchmarks (Figure 23) measurements are based on the EN 15978/ISO 21930 standards. It includes life-cycle stages (A1-A3), (A4), and (C1-C4). It is the results of material quantity inputs which was made by users of OneClick LCA software. (One Click LCA, 2022)

Scenario 01 (Demolition and rebuild) results are the baseline that the scenario 02 (Rehabilitation) will be compared to, in order to see how much embodied carbon emissions can be saved in the case of Adaptive reuse.

Scenario 01 – Demolish and Rebuild

International standards for MENA region for construction (OneClick LCA database)

Scenario 02 – Rehabilitation

BOQ for materials used in the process of Rehabilitation

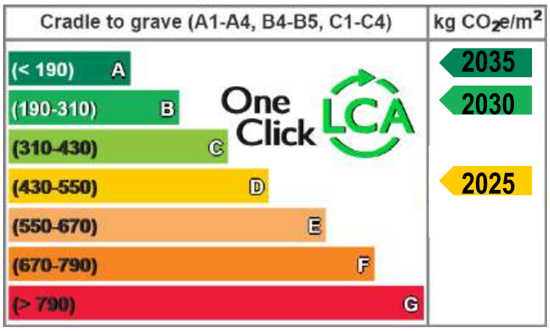


Figure 24 International carbon Benchmark Target till 2035 (Source: One Click LCA)

There are five main steps required in order to run a life cycle assessment, the first step is: Data Extraction and processing (raw data). Second: Quantity calculations (building bill of materials) for all elements: (external walls, floors, walls, roofs, internal partitions, doors and windows). Third step is: Material Mapping (Modified bill of materials) Sorted in four main parts: (1) the finishing (2) the roof (3) concrete structure (if any) and masonry (4) the steel structure (if any). Final step is the data input into LCA tool through the (Output bill of materials). However, due to the limited availability of most of the materials specifications and environmental impact, materials database was based on One click LCA software.

Case study 01 Analysis: CONSLOEYA
Scenario 01:

The area of the building was added to the Carbon designer tool by One Click LCA, then based on its data base, technical details were generated based on the MENA region standards which includes: Building dimensions, structures (foundations, ground slab, structure, enclosure, finishes and services)

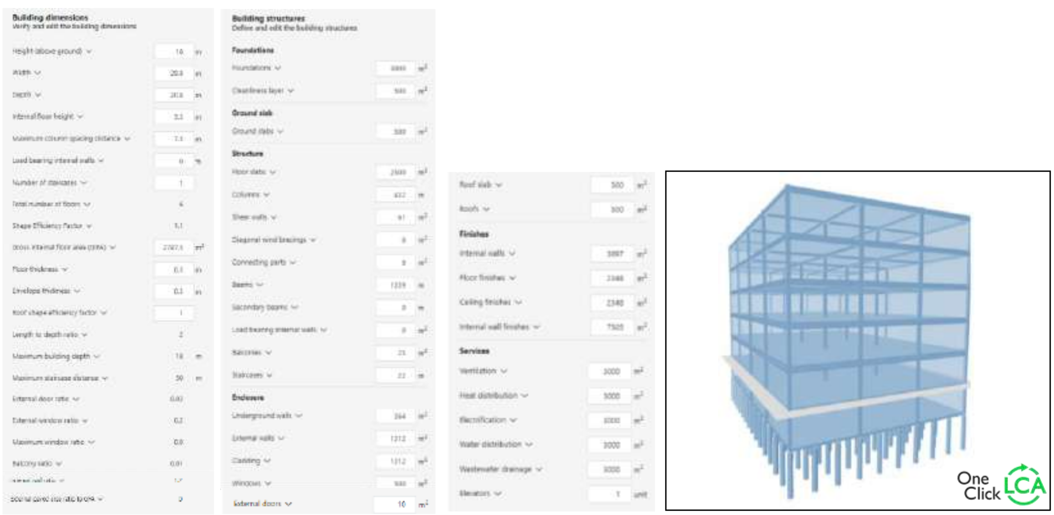


Figure 25 Case study 01 Scenario 01 data input on One click LCA software for scenario 01

Building Dimensions	**Quantity**	**Unit**
Height (Above ground)	18	m
Width	29.6	m
Depth	20.8	m
Internal floor height	3.3	m
Maximum column space distance	7.5	m
Load bearing internal walls	0	%
Number of staircases	1	
Total number of floors	6	
Shape Efficiency Factor	1.1	
Gross internal floor area (GIFA)	2,787.5	m2
Floor thickness	0.3	m
Envelope thickness	0.3	m
Roof shape efficiency factor	1	
Length to depth ratio	2	
Maximum building depth	18	m
Maximum staircase distance	50	m
External door ratio	0.02	
External window ratio	0.2	
Maximum window ratio	0.9	
Balcony ratio	0.01	
Internal wall ratio	1.7	
External paved area ratio to GFA	0	
Building structures	Quantity	Unit
Foundations		
Foundation	3000	M2
Cleanliness layer	500	M2
Ground slab		
Ground slab	500	M2
Structure		
Floor slab	2500	M2
Columns	432	m
Shear walls	91	M2
Diagonal wind bracings	0	M2
Connecting parts	0	M2
Beams	1339	m
Secondary beams	0	m
Load bearing internal walls	0	M2
Balconies	25	M2
Staircases	22	m
Enclosure		
Underground walls	364	M2
External walls	1312	M2
Cladding	1312	M2
Windows	500	M2
External doors	10	M2

Roof slab	500	M2
Roofs	500	M2
Finishes		
Internal walls	3097	M2
Floor finishes	2348	M2
Ceiling finishes	2348	M2
Internal wall finishes	7505	M2
Services		
Ventilation	3000	M2
Heat distribution	3000	M2
Electrification	3000	M2
Water distribution	3000	M2
Wastewater drainage	3000	M2
Elevators	1	unit

Table 3 Case study 01 scenario 01 data entry based on Carbon Designer tool in One Click LCA

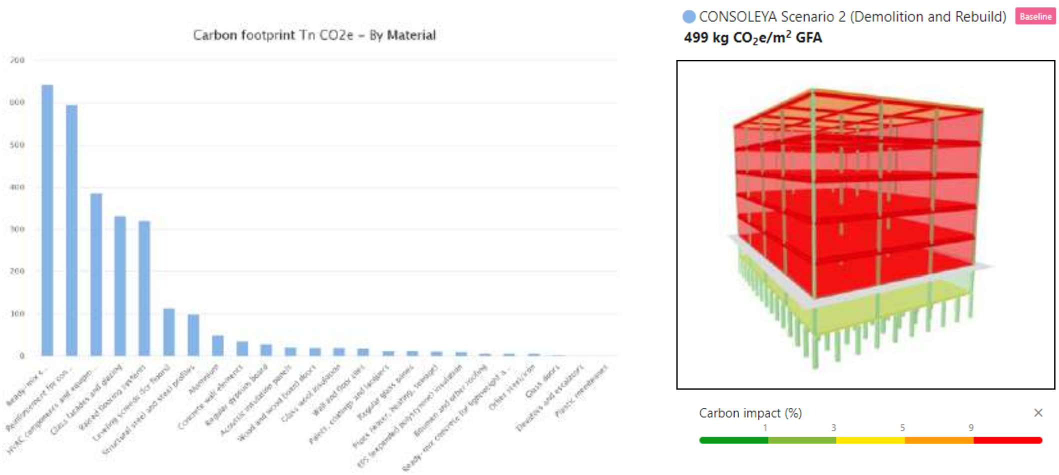


Figure 26 Highest materials consuming CO2 in Case study 01 Scenario 01

Item	**Value**	**Unit**	**Percentage %**
Ready-mix concrete for external walls and floors	640,000	Kg CO2e	24.57%
Reinforcement for concrete (rebar)	595,000	Kg CO2e	23.12%
HVAC components and equipment	390,000	Kg CO2e	16.34%
Glass facades and glazing	322,000	Kg CO2e	13.42%
Raised flooring systems	305,000	Kg CO2e	10.92%
Other resource types	310,000	Kg CO2e	11.63%

Table 4 Case study 01 Scenario 01 highest materials consuming CO2

After the data entry for scenario 01 (Demolition and rebuild), the hot spots were identified and it was shown that the highest three materials consuming carbon emissions are (Ready-mix concrete, Reinforcement for concrete slabs and HVAC components and equipment).

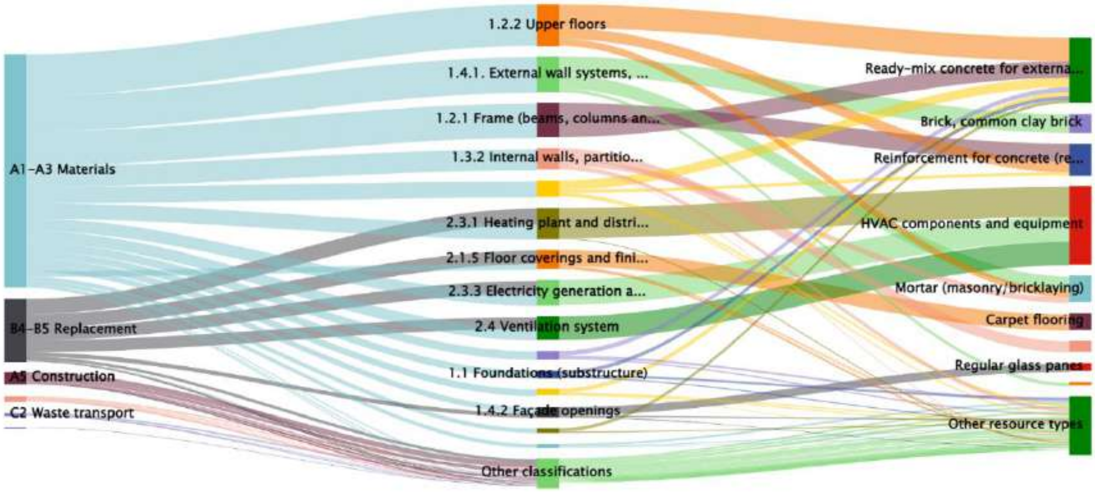


Figure 28 Case study 01 Scenario 01 Sankey diagram, Global warming

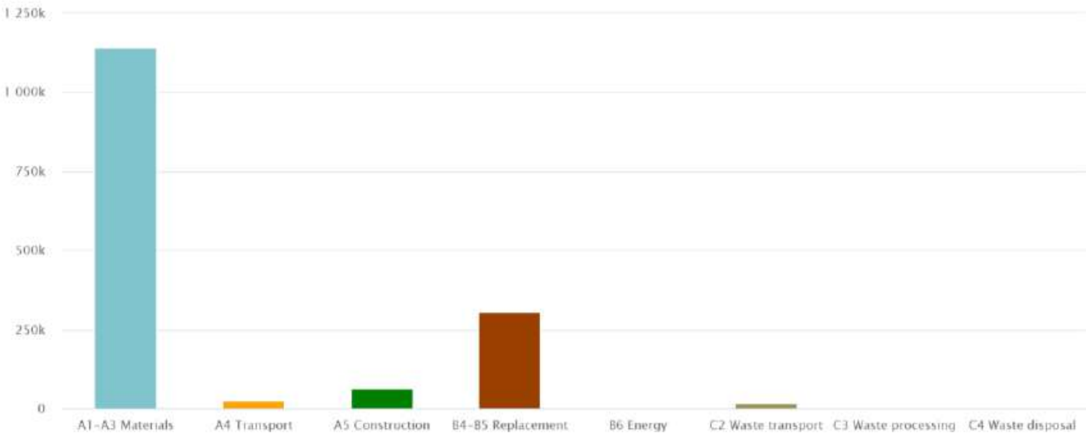


Figure 27 Case study 01 Scenario 01 Global Warming kgCO2e - Life cycle stages

Item	Value	Unit	Percentage
A1-A3 Materials	1,200,000	kgCO2e	73.55%
A4 Transport	27,000	kgCO2e	1.71%
A5 Construction	63,000	kgCO2e	3.97%
B4-B5 Replacement	310,000	kgCO2e	19.37%
B6 Energy (Excluded)	0	kgCO2e	0.0%
C2 Waste transport	18,000	kgCO2e	1.13%
C3 Waste processing	1,500	kgCO2e	0.09%
C4 Waste disposal	2,800	kgCO2e	0.18%

Table 5 Case study 01 Scenario 01 Global Warming kgCO2e - Life cycle stages

On the left, the Sankey diagram (Figure 28) shows the distribution of each life cycle stage, and the link between each material and its line of production and usage, while on the bottom left chart (Figure 27) , carbon emissions for each life cycle stage were calculated with the product stage (A1-A3) as the highest stage consuming emissions equals to 73.55% from the total emissions along the life cycle stages, on the right side chart (Figure 29) , materials were classified showing the amount of emissions for each classification. The highest classification consuming carbon after "other classifications" is the "upper floors"

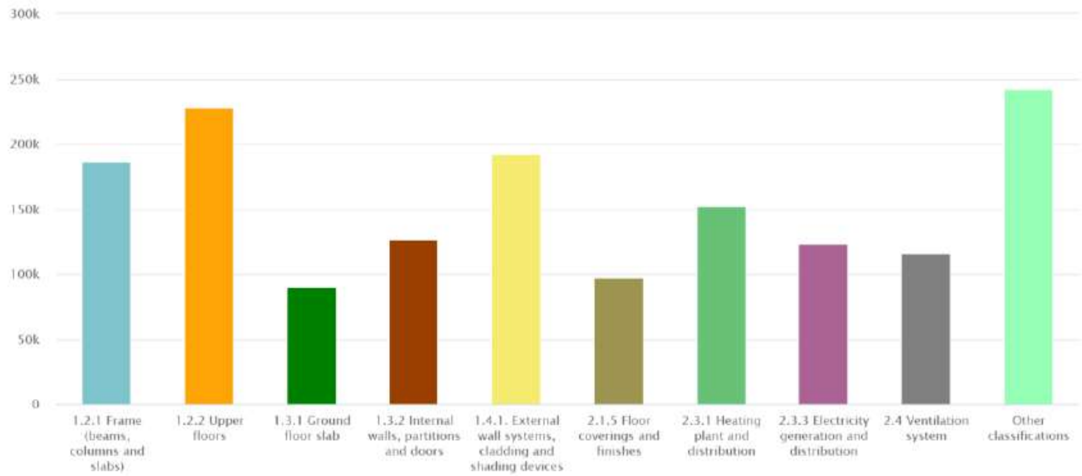
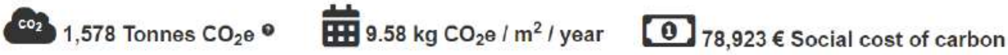


Figure 29 Case study 01 Scenario 01: Global warming Kg CO2 e - Classifications

Item	Value	Unit	Percentage
1.2.1 Frame (beams, columns and slabs)	210,000	kgCO2e	13.23%
1.2.2 Upper Floors	230,000	kgCO2e	14.43%
1.3.1 Ground floor slab	90,000	kgCO2e	5.67%
1.3.2 Internal walls, partitions and doors	130,000	kgCO2e	8.06%
1.4.1 External wall systems, cladding and shading devices	190,000	kgCO2e	12.17%
2.1.5 Floor covering and finishes	97,000	kgCO2e	6.17%
2.3.1 Heating plant and distribution	150,000	kgCO2e	9.66%
2.3.3 Electricity generation and distribution	120,000	kgCO2e	7.83%
2.4 Ventilation system	120,000	kgCO2e	7.33%
Other classifications	240,000	kgCO2e	15.45%

Table 6 Case study 01 Scenario 01 Global Warming kgCO2e - Classifications



As shown in the analysis of scenario 01 for the first case study, the embodied carbon benchmark grade is (E) with 552 kg CO2e/m2, and the highest amount of GWP is from (A1-A3 Materials) 1,120k kg CO2e

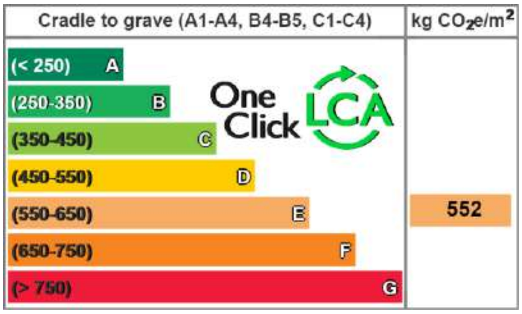


Figure 30 Case study 01 Scenario 01 Carbon benchmark

In conclusion, the overall amount of embodied carbon emissions for CONSOLEYA building (Scenario 01 – Demolish and rebuild) is equals to 1,578 Tonnes CO2e.

After analyzing the first scenario (Demolish and rebuild) on the first case study, the same tools were used to analyze the second scenario (Rehabilitation) where the bill of quantities for the materials used in the rehabilitation process were entered manually to extract the following outputs: First, the Sankey diagram (Figure 31) which shows the distribution of materials and the amount of carbon emissions from each life cycle stage to the specific material. Second, classifications of materials (Figure 32). Third, emissions from each life cycle stage (Figure 33). And lastly, the carbon benchmark for the second scenario (Figure 34).

Scenario 02: The area of the building was added on One Click LCA software, then the Bill of quantities for the rehabilitation were added manually on the software.

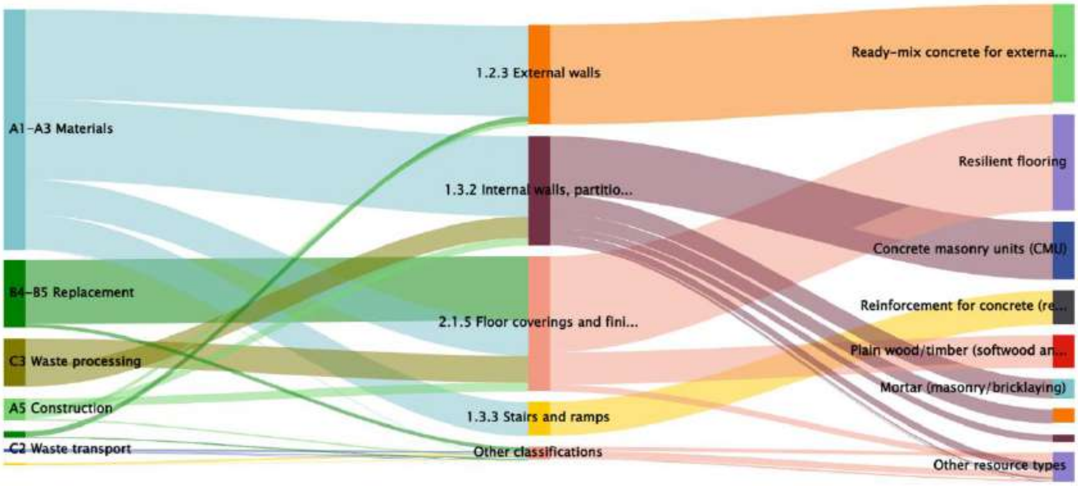


Figure 31 Case study 01 Scenario 02 Sankey diagram, Global warming

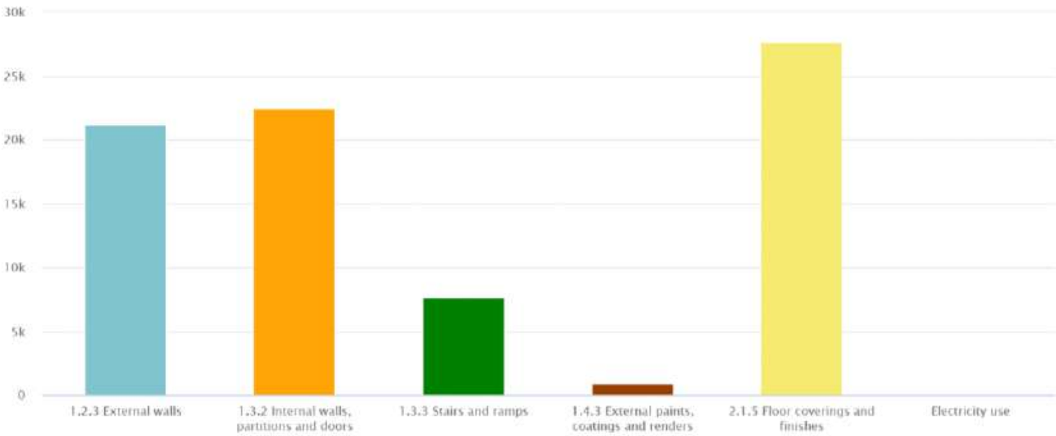


Figure 32 Case study 01Scenario 02 - Global warming kg CO2e - Classifications

Item	Value	Unit	Percentage
1.2.3 External walls	21,000	kgCO2e	26.5%
1.3.2 Internal walls, partitions and doors	22,000	kgCO2e	28.14%
1.3.3 Stairs and ramps	7,600	kgCO2e	9.56%
1.4.3 External paints, coatings and renders	970	kgCO2e	1.21%
2.1.5 Floor coverings and finishes	28,000	kgCO2e	34.59%
Electricity use (Excluded)	0	kgCO2e	0.0%

Table 7 Case study 01 Scenario 02 Global warming kg CO2e - Classifications

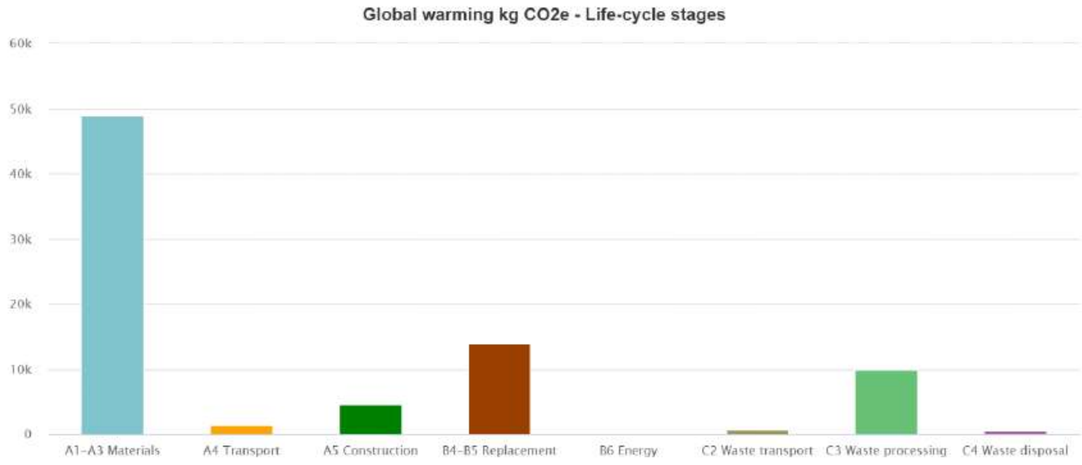
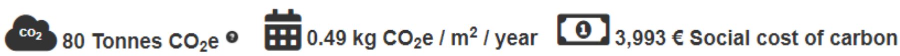


Figure 33 Case study 01 Scenario 02 - Global warming kg CO2e – Life cycle stages

Item	Value	Unit	Percentage
A1-A3 Materials	49,000	kgCO2e	61.35%
A4 Transport	1,400	kgCO2e	1.7%
A5 Construction	4,500	kgCO2e	5.66%
B4-B5 Replacement	14,000	kgCO2e	17.4%
B6 Energy (Excluded)	0	kgCO2e	0.0%
C2 Waste transport	740	kgCO2e	0.93%

Table 8 Case study 01 Scenario 02 Global warming kg CO2e - Life cycle stages



In scenario 02 for the first case study, the embodied carbon benchmark grade is (A) with 27 kg CO2e/m2, the highest amount of GWP is from (A1-A3 Materials) 48.5k kg CO2e

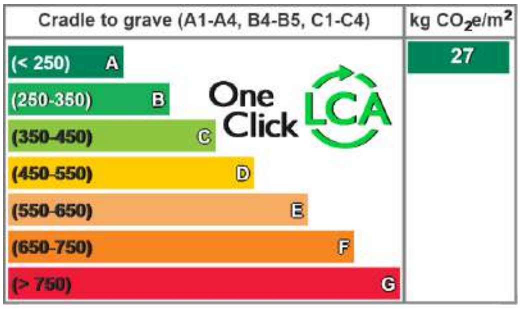


Figure 34 Case study 01 Scenario 02 Carbon benchmark

In conclusion, the overall amount of embodied carbon emissions for CONSOLEYA building (Scenario 02 – Rehabilitation) is equals to 80 Tonnes CO2e.

CONSOLEYA Scenario 01 and scenario 02 comparison

This section puts together both scenarios: scenario 01 (demolish and rebuild) and scenario 02 (refurbishment) for case study 01 in comparison, to highlight both the different environmental impacts of each scenario such as (carbon footprint, bio carbon storage, ozone depletion potential, acidification, eutrophication, formation of ozone of lower atmosphere, and more), and calculate the amount of embodied carbon emissions that can be saved in case of scenario 02 (refurbishment)

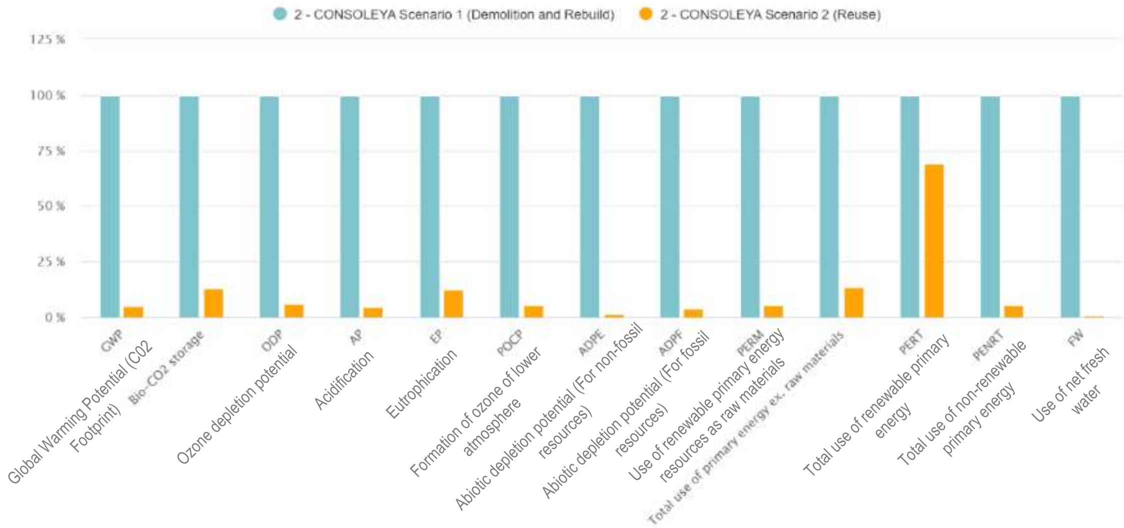


Figure 35 Case study 01 Environmental Impacts for Scenario 01 versus Scenario 02

Environmental Impact	Definition	Scenario 01	Scenario 02	Savings
Global Warming Potential (CO2 footprint)	How much heat a greenhouse gas traps in the atmosphere.	100%	05%	95%
Bio-CO2 storage	Processes in which CO2 originating from biomass is captured and stored.	100%	13%	87%
Ozone depletion potential	Represents a relative value that indicates the potential of a substance to destroy ozone gas	100%	05%	95%
Acidification	Refers to compounds' precursors to acid rain. These include sulfur dioxide (SO2), nitrogen oxides (NOx), nitrogen monoxide (NO), nitrogen dioxide (N2O), and other substances.	100%	04%	96%
Eutrophication	Eutrophication is the enrichment of nutrients in a certain place causing toxic bacteria. It can be aquatic or terrestrial.	100%	13%	87%

Formation of ozone of lower atmosphere	This is called Smog formation.	100%	05%	95%
Abiotic depletion potential (For non-fossil resources)	The over-extraction of minerals, fossil fuels and other non-living, non-renewable materials which can lead to exhaustion of natural resources	100%	03%	97%
Abiotic depletion potential (For fossil resources)	The removal of abiotic resources from the earth, or the depletion of non-living natural resources.	100%	05%	95%
Total use of non-renewable primary energy	Coal, petroleum, and natural gas. Carbon is the main element in fossil fuels	100%	05%	95%
Total use of renewable primary energy	Geothermal, solar, wind, tide and wave sources.	100%	70%	30%
Use of net fresh water	Achieving an overall reduction in water use	100%	02%	98%

Table 9 Case study 01 Environmental Impacts comparison between Scenario 01 and Scenario 02

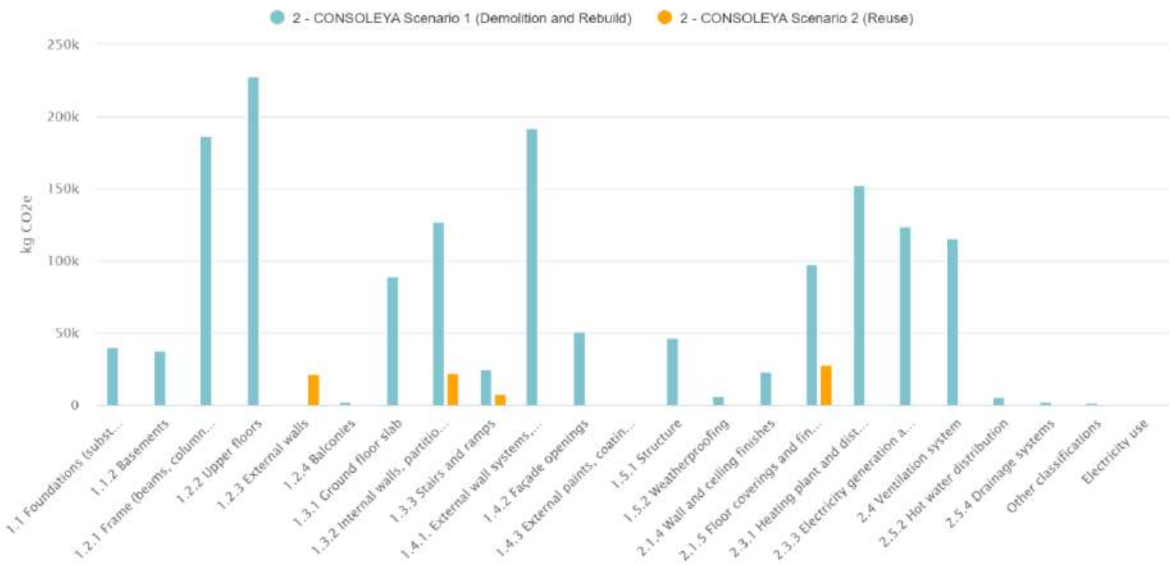


Figure 36 Case study 01 Classifications for Scenario 01 versus Scenario 02

Element	Scenario 01	Scenario 02	Savings	Unit
A1-A3 Materials	1,200,000	49,000	96%	kgCO2e
Total amount of carbon emissions	1,578	80	95%	Tonnes CO2e

Table 10 Case study 01 Scenarios carbon emissions comparison

Case study 02 Analysis: Attaba Post office

Scenario 01: The area of the building was added to the Carbon Designer tool by One Click LCA, then based on its data base, technical details were generated based on the MENA region standards which includes: Building dimensions, structures (Foundations, Ground slab, Structure, Enclosure, Finishes and Services)

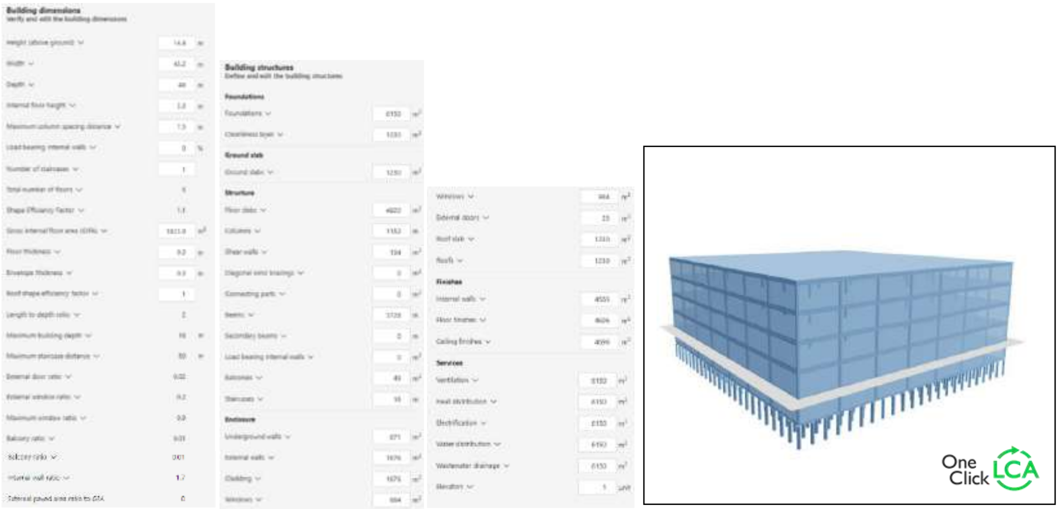


Figure 37 Data input on One click LCA software for scenario 01

Building Dimensions	Quantity	Unit
Height (Above ground)	14.4	m
Width	45.2	m
Depth	48	m
Internal floor height	3.3	m
Maximum column space distance	7.5	m
Load bearing internal walls	0	%
Number of staircases	1	
Total number of floors	5	
Shape Efficiency Factor	1.1	
Gross internal floor area (GIFA)	5,823.9	m2
Floor thickness	0.3	m
Envelope thickness	0.3	m
Roof shape efficiency factor	1	
Length to depth ratio	2	
Maximum building depth	18	m
Maximum staircase distance	50	m
External door ratio	0.02	

External window ratio	0.2	
Maximum window ratio	0.9	
Balcony ratio	0.01	
Internal wall ratio	1.7	
External paved area ratio to GFA	0	
Building structures	Quantity	Unit
Foundations		
Foundation	6150	M2
Cleanliness layer	1230	M2
Ground slab		
Ground slab	1230	M2
Structure		
Floor slab	4920	M2
Columns	1152	m
Shear walls	134	M2
Diagonal wind bracings	0	M2
Connecting parts	0	M2
Beams	3728	m
Secondary beams	0	m
Load bearing internal walls	0	M2
Balconies	49	M2
Staircases	18	m
Enclosure		
Underground walls	671	M2
External walls	1676	M2
Cladding	1676	M2
Windows	984	M2
External doors	25	M2
Roof slab	1230	M2
Roofs	1230	M2
Finishes		
Internal walls	4563	M2
Floor finishes	4696	M2
Ceiling finishes	4696	M2
Services		
Ventilation	6150	M2
Heat distribution	6150	M2
Electrification	6150	M2
Water distribution	6150	M2
Wastewater drainage	6150	M2
Elevators	1	unit

Table 11 Case study 02 scenario 01 data entry based on Carbon Designer tool in One Click LCA

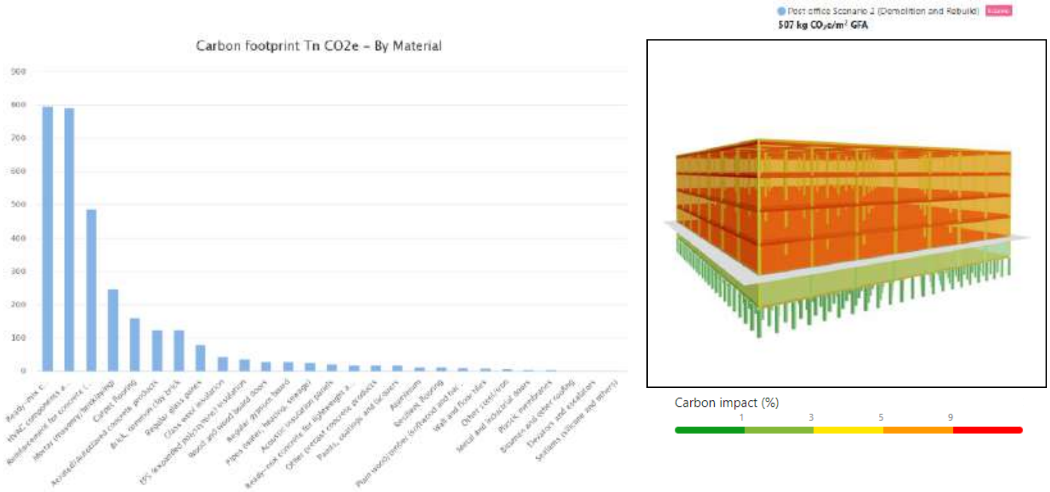


Figure 38 Case Study 02 Scenario 01 Highest materials consuming CO2 in case study 02

Item	Value	Unit	Percentage %
Ready-mix concrete for external walls and floors	800,000	Kg CO2e	24.49%
HVAC components and equipment	790,000	Kg CO2e	24.73%
Reinforcement for concrete (rebar)	490,000	Kg CO2e	15.27%
Mortar (masonry/bricklaying)	250,000	Kg CO2e	7.71%
Carpet flooring	160,000	Kg CO2e	5.05%
Aluminum frame windows	160,000	Kg CO2e	5.02%
Aerated/Autoclaved concrete products	120,000	Kg CO2e	3.88%
Brick, common clay brick	120,000	Kg CO2e	3.87%
Glass wool insulation	43,000	Kg CO2e	1.34%
Other resource types	310,000	Kg CO2e	11.63%

Table 12 Case Study 02 Scenario 01 Highest materials consuming CO2 in case study 02

After the data entry in case study 02 for scenario 01 (Demolition and rebuild), the hot spots were identified and it was shown that the highest three materials consuming carbon emissions are (Ready-mix concrete, HVAC components and equipment and Reinforcement for concrete (rebar)).

The following diagrams are the Sankey diagram (Figure 40) which shows the distribution of materials and the amount of carbon emissions from each life cycle stage to the specific material, classifications of materials (Figure 39), emissions from each life cycle stage (Figure 41) and the carbon benchmark for the first scenario (Figure 42)

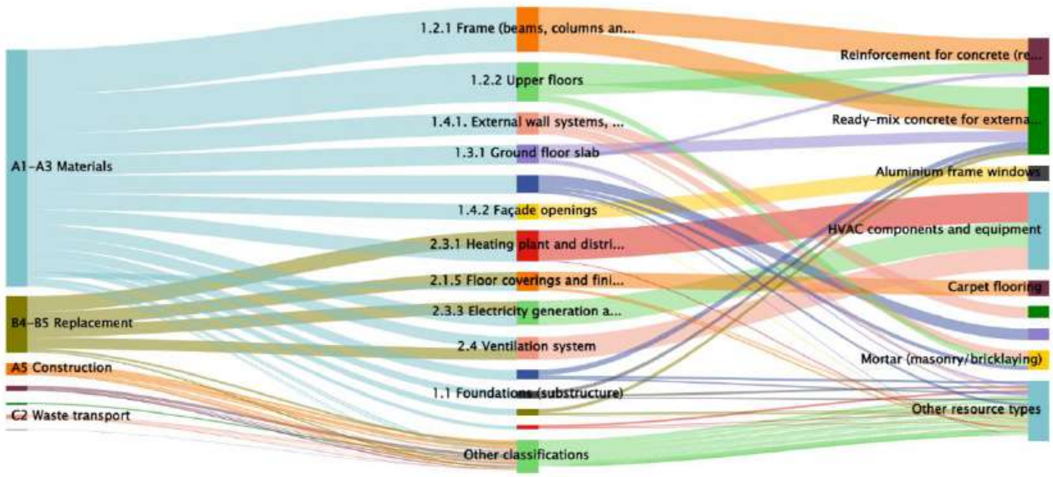


Figure 40 Case study 02 Scenario 01 Sankey diagram, Global warming

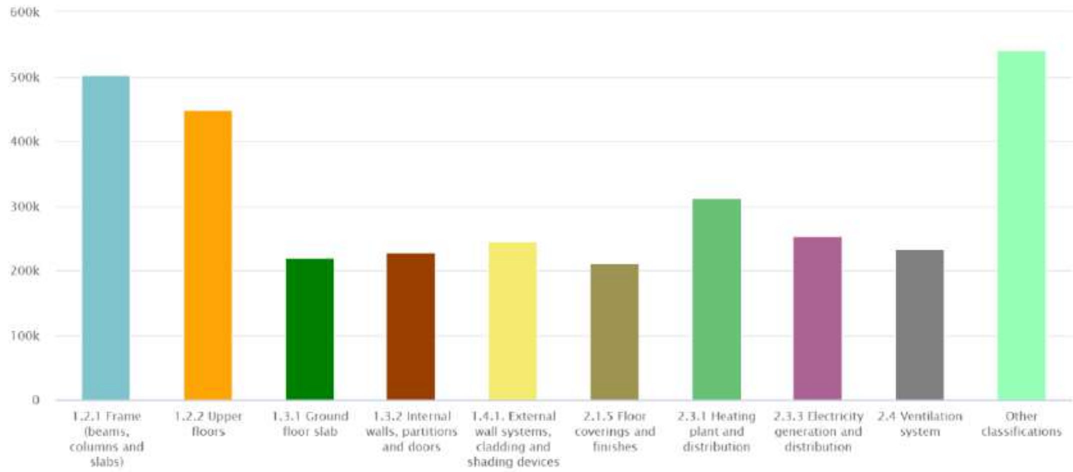


Figure 39 Case study 02 Scenario 01 Global warming kg CO2e - Classifications

Item	Value	Unit	Percentage
1.2.1 Frame (beams, columns and slabs)	500,000	kgCO2e	15.72%
1.2.2 Upper Floors	450,000	kgCO2e	14.03%
1.3.1 Ground floor slab	220,000	kgCO2e	6.89%
1.3.2 Internal walls, partitions and doors	230,000	kgCO2e	7.12%
1.4.1 External wall systems, cladding and shading devices	250,000	kgCO2e	7.68%
2.1.5 Floor covering and finishes	210,000	kgCO2e	6.65%
2.3.1 Heating plant and distribution	310,000	kgCO2e	9.78%

2.3.3 Electricity generation and distribution	250,000	kgCO2e	7.93%
2.4 Ventilation system	230,000	kgCO2e	7.28%
Other classifications	540,000	kgCO2e	16.93%

Table 13 Case study 02 Scenario 01 Global warming kg CO2e - Classifications

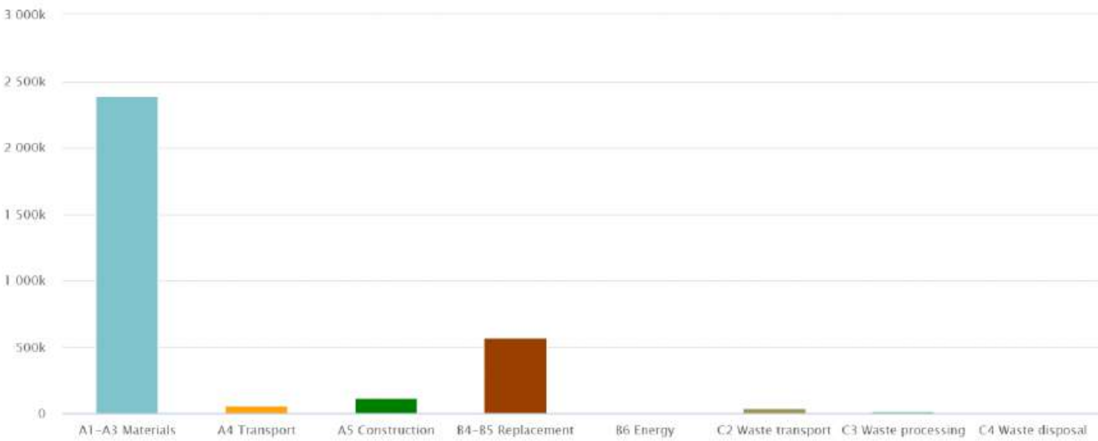
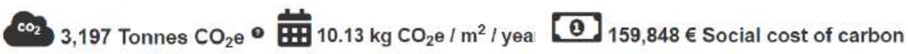


Figure 41 Case study 02 Scenario 01 Global warming kg CO2e – Life cycle stages

Item	Value	Unit	Percentage
A1-A3 Materials	2,400,000	kgCO2e	74.68%
A4 Transport	56,000	kgCO2e	1.76%
A5 Construction	120,000	kgCO2e	3.79%
B4-B5 Replacement	570,000	kgCO2e	17.81%
B6 Energy (Excluded)	0	kgCO2e	0.0%
C2 Waste transport	38,000	kgCO2e	1.19%
C3 Waste processing	18,000	kgCO2e	0.57%
C4 Waste disposal	6,300	kgCO2e	0.2%

Table 14 Case study 02 Scenario 01 Global warming kg CO2e – Life cycle stages



As shown in the analysis of scenario 01 for the second case study, the embodied carbon benchmark grade is (E) with 585 kg CO2e/m2, the highest amount of GWP is from (A1-A3 Materials) 2,400k kg CO2e

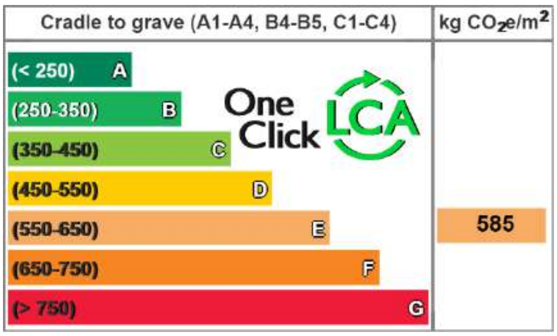


Figure 42 Scenario 01 Carbon benchmark

Scenario 02:

The area of the building was added on One Click LCA software, then the bill of quantities for the rehabilitation were added manually on the software.

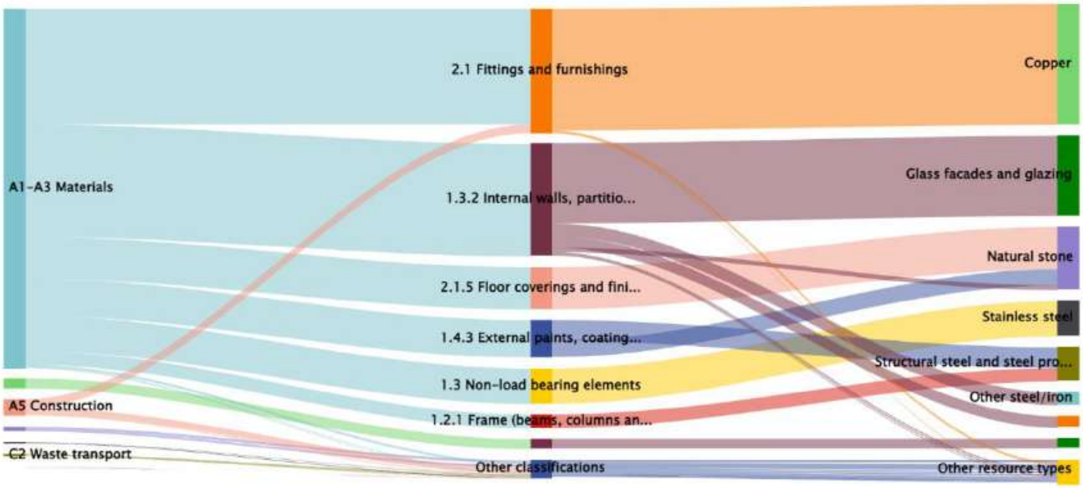


Figure 44 Case study 02 Scenario 02 Sankey diagram, Global warming

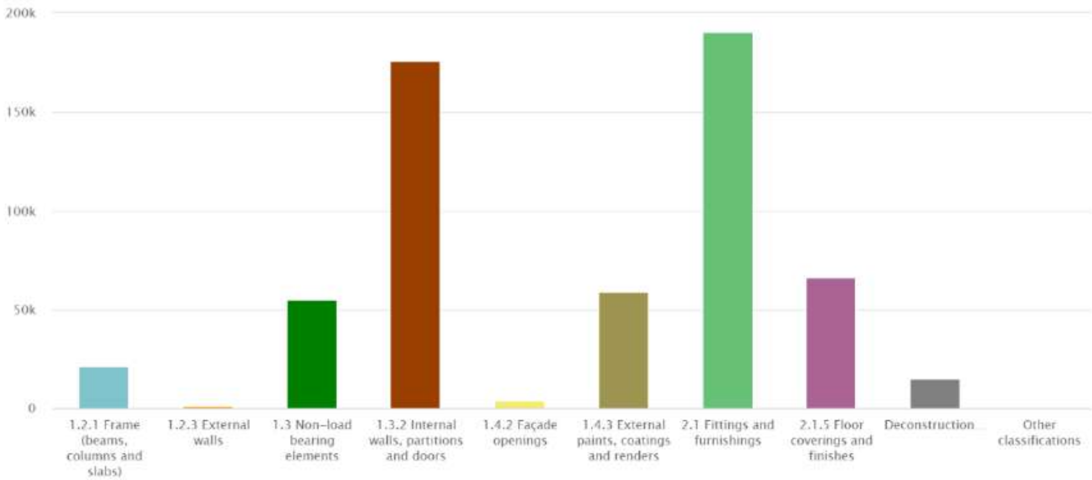


Figure 43 Case study 02 Scenario 02 Global warming kg CO2e – Classifications

Item	Value	Unit	Percentage
1.2.1 Frame (beams, columns and slabs)	21,000	kgCO2e	3.58%
1.2.3 External walls	1,100	kgCO2e	0.19%
1.3 Non-load bearing elements	55,000	kgCO2e	9.32%
1.3.2 Internal walls, partitions and doors	180,000	kgCO2e	29.94%
1.4.2 Façade openings	4,100	kgCO2e	0.7%
1.4.3 External paints, coatings and renders	59,000	kgCO2e	9.97%

2.1 Fittings and furnishing	190,000	kgCO2e	32.37%
2.1.5 Floor coverings and finishes	66,000	kgCO2e	11.26%
Deconstruction/ demolition scenarios	15,000	kgCO2e	2.54%
Other classifications	750	kgCO2e	0.13%

Table 15 Case study 02 Scenario 02 Global warming kg CO2e – Classifications

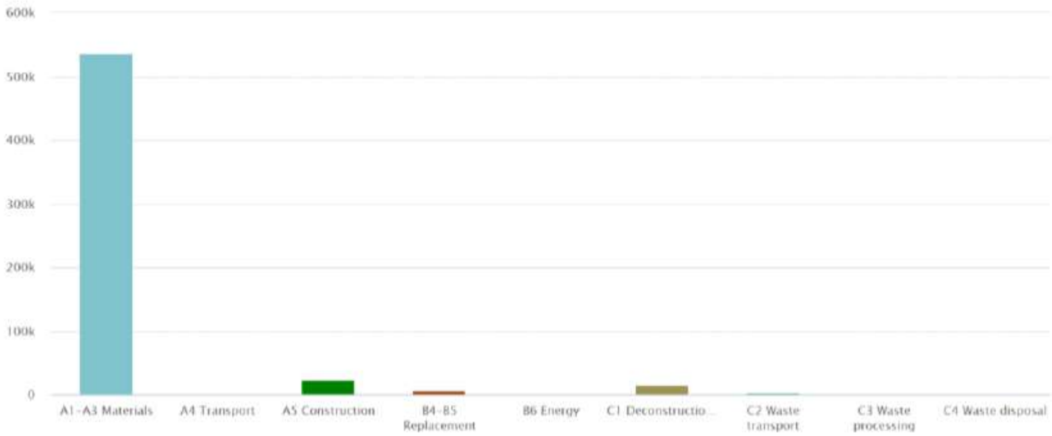


Figure 45 Global warming kg CO2e – Life cycle stages

Item	Value	Unit	Percentage
A1-A3 Materials	540,000	kgCO2e	91.26%
A4 Transport	1,900	kgCO2e	0.32%%
A5 Construction	24,000	kgCO2e	4.08%
B4-B5 Replacement	7,000	kgCO2e	1.19%
B6 Energy	0	kgCO2e	0.0%
C1 Deconstruction/demolition	15,000	kgCO2e	2.54%
C2 Waste transport	2,800	kgCO2e	0.48%
C3 Waste processing	120	kgCO2e	0.02%
C4 Waste disposal	650	kgCO2e	0.11%

Table 16 Case study 02 Scenario 02 Global warming kg CO2e – Life cycle stages

588 Tonnes CO_2e 1.86 kg CO_2e / m^2 / year 29,384 € Social cost of carbon

In scenario 02 for the second case study, the embodied carbon benchmark grade is (A) with 104 kg CO2e/m2, the highest amount of GWP is from (A1-A3 Materials) 540k kg CO2e

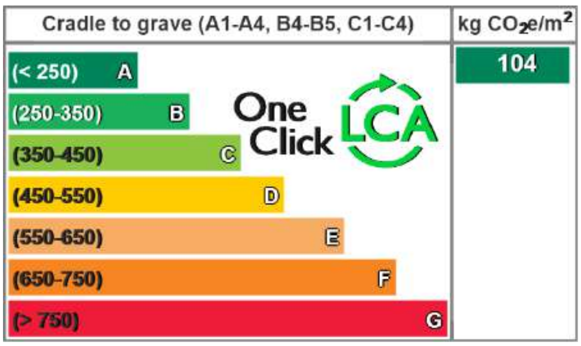


Figure 46 Scenario 02 Carbon benchmark

Attaba office Scenario 01 and scenario 02 comparison

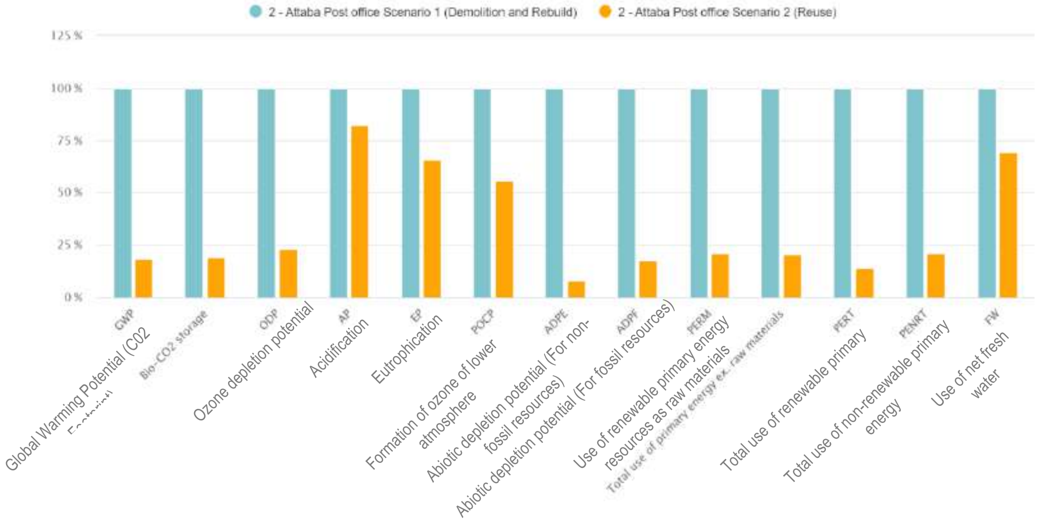


Figure 47 Case study 02 Environmental Impacts for Scenario 01 versus Scenario 02

Environmental Impact	Definition	Scenario 01	Scenario 02	Savings
Global Warming Potential (CO2 footprint)	How much heat a greenhouse gas traps in the atmosphere.	100%	19%	81%
Bio-CO2 storage	Processes in which CO2 originating from biomass is captured and stored.	100%	20%	80%
Ozone depletion potential	Represents a relative value that indicates the potential of a substance to destroy ozone gas	100%	23%	77%
Acidification	Refers to compounds' precursors to acid rain. These include sulfur dioxide (SO2), nitrogen oxides (NOx), nitrogen monoxide (NO), nitrogen dioxide (N2O), and other substances.	100%	80%	20%
Eutrophication	Eutrophication is the enrichment of nutrients in a certain place causing toxic bacteria. It can be aquatic or terrestrial.	100%	60%	40%
Formation of ozone of lower atmosphere	This is called Smog formation.	100%	55%	45%
Abiotic depletion potential (For non-fossil resources)	The over-extraction of minerals, fossil fuels and other non-living, non-renewable materials which can lead to exhaustion of natural resources	100%	10%	90%
Abiotic depletion potential (For fossil resources)	The removal of abiotic resources from the earth, or the depletion of non-living natural resources.	100%	20%	80%
Total use of non-renewable primary energy	Coal, petroleum, and natural gas. Carbon is the main element in fossil fuels	100%	20%	80%

Total use of renewable primary energy	Geothermal, solar, wind, tide and wave sources.	100%	18%	82%
Use of net fresh water	Achieving an overall reduction in water use	100%	70%	30%

Table 17 Case study 02 Environmental Impacts comparison between Scenario 01 and Scenario 02

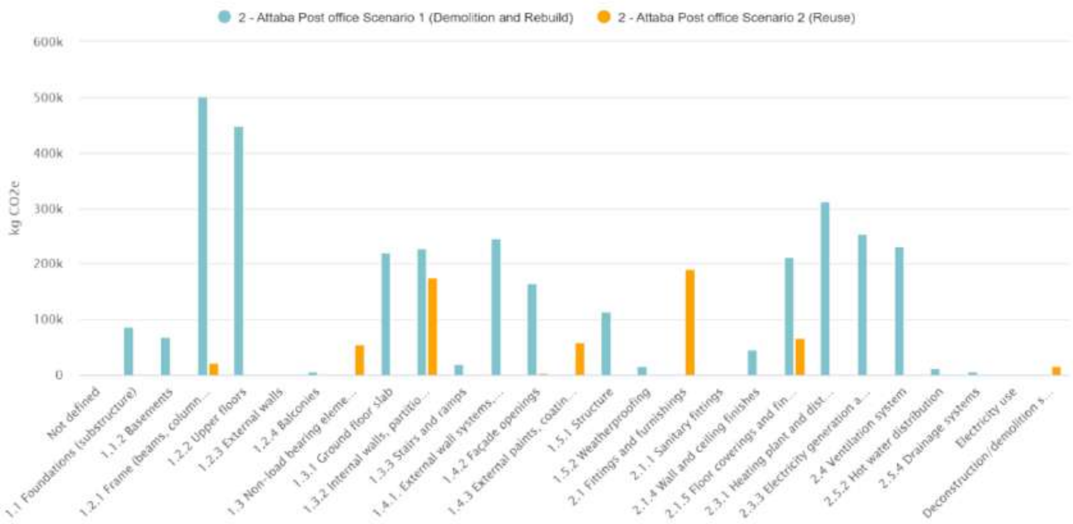


Figure 48 Case study 02 Classifications for Scenario 01 versus Scenario 02

Element	Scenario 01	Scenario 02	Savings	Unit
A1-A3 Materials	2,400,000	540,000	77.5%	kgCO2e
Total amount of carbon emissions	3,197	588	81.6%	Tonnes CO2e

Chapter 5: Results and Discussion

Results

It was shown from the analysis in both case studies CONSOLEYA and Attaba post office that Scenario 01 which is (Demolish and rebuild) consumes much more embodied carbon emissions than Scenario 02 which is (Rehabilitation)

In the first case study CONSOLEYA scenario 02 (Rehabilitation), the carbon footprint is 96% less than scenario 01 (Demolition and rebuild). Although the highest life cycle stage for both is (A1-A3), in scenario 01 it records 1,200,000 kg CO_2e while in scenario 02, it records 49,000 kg CO_2e

Case study 01 (CONSOLEYA)

Element	Scenario 01	Scenario 02	Savings	Unit
A1-A3 Materials	1,200,000	49,000	96%	kgCO_2e
Total amount of carbon emissions	1,578	80	95%	Tonnes CO_2e

Table 18 Case study 01 Results

While in the second case study Attaba post office scenario 02 (Rehabilitation), the carbon footprint is 77.5% less than scenario 01 (Demolish and rebuild). Although the highest life cycle stage for both is (A1-A3), in scenario 01 it records 2,400,000 kg CO_2e while in scenario 02, it records 540,000 kg CO_2e

Case study 02 (Attaba post office)

Element	Scenario 01	Scenario 02	Savings	Unit
A1-A3 Materials	2,400,000	540,000	77.5%	kgCO_2e
Total amount of carbon emissions	3,197	588	81.6%	Tonnes CO_2e

Table 19 Case study 02 Results

Average Results from the two case studies

	Element	Savings
Scenario 02 (Rehabilitation)	A1-A3 Materials	**86.75%**
	Total amount of carbon emissions	**88.3%**

Table 20 Average results from the Case studies

Average Environmental Impacts

Environmental Impact	Definition	Scenario 02		Average Savings
		Case Study 01	Case Study 02	
Global Warming Potential (CO_2 footprint)	How much heat a greenhouse gas traps in the atmosphere.	95%	81%	**88%**
Bio-CO_2 storage	Processes in which CO_2 originating from biomass is captured and stored.	87%	80%	**83.5%**
Ozone depletion potential	Represents a relative value that indicates the potential of a substance to destroy ozone gas	95%	77%	**86%**
Acidification	Refers to compounds' precursors to acid rain. These include sulfur dioxide (SO_2), nitrogen oxides (NO_x), nitrogen monoxide (NO), nitrogen dioxide (N_2O), and other substances.	96%	20%	**58%**
Eutrophication	Eutrophication is the enrichment of nutrients in a certain place causing toxic bacteria. It can be aquatic or terrestrial.	87%	40%	**63.5%**
Formation of ozone of lower atmosphere	This is called Smog formation.	95%	45%	**70%**
Abiotic depletion potential (For non-fossil resources)	The over-extraction of minerals, fossil fuels and other non-living, non-renewable materials which can lead to exhaustion of natural resources	97%	90%	**93.5%**
Abiotic depletion potential (For fossil resources)	The removal of abiotic resources from the earth, or the depletion of non-living natural resources.	95%	80%	**87.5%**
Total use of non-renewable primary energy	Coal, petroleum, and natural gas. Carbon is the main element in fossil fuels	95%	80%	**87.5%**
Total use of renewable primary energy	Geothermal, solar, wind, tide and wave sources.	30%	82%	**56%**
Use of net fresh water	Achieving an overall reduction in water use	98%	30%	**64%**

Table 21 Average Environmental Impacts from the Case studies

Summary

The rehabilitation scenario (Scenario 02) in both cases (CONSOLEYA and Attaba Post Office) revealed to have a significant environmental benefit as an approach in the construction industry, where in case of rehabilitation, the demand of new materials is much lower than scenario 01 (demolish and rebuild). As seen from the analysis of the materials classifications and the Sankey diagrams (Pages 62, 64, 71 and 73) that the highest materials consuming carbon emissions are (Ready-mix concrete, Reinforcement for concrete (rebar) and HVAC components and equipment) which are mainly used in constructing the skeleton structure and floors of the building. While in Adaptive reuse these materials are saved as the structure is already there.

Lessons learned from Adaptive reuse case studies

The Adaptive reuse of heritage buildings can have many challenges during the project depending on the condition of the building, some of these challenges that were present in our case studies can be categorized as follows:

Infrastructural challenges: presented in basement water sedimentation resulted from the non-maintained condition of the building before rehabilitation.

Cost challenges: in some cases, the cost of rehabilitation in categories such as electricity connections can reach or exceed the same cost that is for new buildings.

Structural modifications challenges: the heritage buildings structure in most cases cannot be modified easily, since interior walls can be load bearing and not applicable to be removed. For that, in order to adapt the building for today's needs, structural modifications are necessary to redistribute the structural load.

Availability of specialized Knowledge to deal with rehabilitation challenges:

Due to the low demand on the rehabilitation projects, most of the professionals concentrate their potentials in dealing with new constructions, while only a very few deals with buildings with historical significance and knows the techniques used in dealing with these buildings.

Figure 49 Basement water sedimentation (Source: Ahmed Mady)

Figure 50 Replanning structure loads for the new purposes (Source: Ahmed Mady)

Reality Check

As shown previously in this research analysis and results, the amount of carbon emissions that can be saved in case of Adaptive reuse of heritage buildings is remarkably high compared to new constructions. However, there are many reasons why more heritage buildings are brought down to be demolished instead of reused in Egypt, these reasons are: 1- unsatisfied owners. 2- society and culture. 3-lack of awareness. 4- building adjustments limitations. 5- Low market demand. 6- stakeholders lack of interest. 7- political will. These factors require further investigations to be addressed in depth in order to reveal the challenges and limitations for the Adaptive reuse of Heritage Buildings in Egypt.

Figure 51 Factors hinder Adaptive reuse approach in Egypt. (Source: Author)

Chapter 6: Discussion and Conclusion

Discussion and Conclusion

This research focused on the Environmental aspects of the Adaptive reuse of heritage buildings in Egypt, through conducting a life cycle assessment on two heritage buildings in Downtown, Cairo. The results of the analysis conducted, confirms the potential of adaptive reuse to reduce the amount of embodied carbon emissions by 86% compared to demolition and rebuild. Other environmental impacts were also calculated such as (Acidification, Eutrophication, Ozone layer depletion, and so on). These impacts are mostly neglected in the decision-making process, so it was important to highlight the savings in these impacts in case of Adaptive reuse of heritage buildings and bring attention to them.

The decision whether to reuse a heritage building or not is in fact a complex decision as it depends on so many criteria. This research aimed to illustrate the environmental benefits that can be reached in case of adaptive reuse of heritage buildings to encourage decision makers and stake holders to put the environmental aspect in consideration, especially in this climate emergency time we are living in. Adaptive reuse of heritage buildings needs the support from both the private and the governmental sectors to be implemented in Egypt

To conclude, further research investigations are needed to address first: the limitation and challenges of adaptive reuse of heritage buildings in Egypt that hinder its application despite the fact of having unique cultural value and environmental savings. Second: The impact of Adaptive reuse of heritage buildings on the economic and social aspects in Egypt. Third: The role of governmental bodies in Adaptive reuse of heritage buildings in Egypt. Fourth: The role of Adaptive reuse in fulfilling today's environmental challenges. Fifth: A methodology to estimate the percentage of heritage buildings in real estate stock market. Lastly, what construction techniques can benefit in reducing the embodied carbon emissions from the construction industry for a more sustainable future?

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Appendices

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives	
1.	Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 10% (typical) recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3) ?	301 tonnes CO_2e	26.4 %	Show sustainable alternatives	Add to compare
2.	Reinforcement steel (rebar), generic, 90% recycled content, A615 ?	189 tonnes CO_2e	16.5 %	Show sustainable alternatives	Add to compare
3.	Bricks, 226x104x60, 226x85x60 mm ?	91 tonnes CO_2e	8.0 %	Show sustainable alternatives	Add to compare
4.	Water circulation radiator, per 1kW / unit ?	71 tonnes CO_2e	6.2 %	Show sustainable alternatives	Add to compare
5.	Electricity distribution system, cabling and central, for all building types, per m2 GFA ?	61 tonnes CO_2e	5.3 %	Show sustainable alternatives	Add to compare
6.	Concrete masonry units, 200 mm ?	54 tonnes CO_2e	4.8 %	Show sustainable alternatives	Add to compare
7.	Masonry mortar, light, 1000 kg/m3 ?	48 tonnes CO_2e	4.2 %	Show sustainable alternatives	Add to compare
8.	Self levelling mortar, for floors, walls and overhead appl., 3-50 mm, 1400 kg/m3 ?	42 tonnes CO_2e	3.7 %	Show sustainable alternatives	Add to compare
9.	Air handling unit, with heat recovery through plate heat exchanger, 10 000 m3/h (5885.8 ft3/min), 1256 kg/unit (2769 lbs/unit) ?	28 tonnes CO_2e	2.5 %	Show sustainable alternatives	Add to compare
10.	Ventilation ducting, per m linear, D: 500 mm (19.69 in) ?	29 tonnes CO_2e	2.5 %	Show sustainable alternatives	Add to compare
11.	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3 (1.56 lbs/ft3), (applicable for densities: 0-25 kg/m3 (0-1.56 lbs/ft3)), Lambda=0.031 W/(m.K) ?	24 tonnes CO_2e	2.1 %	Show sustainable alternatives	Add to compare
12.	Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 0% recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3) ?	20 tonnes CO_2e	1.8 %	Show sustainable alternatives	Add to compare
13.	Float glass, single pane, generic, 3-12 mm (0.12-0.47 in), 10 kg/m2 (2.05 lbs/ft2) (for 4 mm/0.16 in), 2500 kg/m3 (156 lbs/ft3) ?	20 tonnes CO_2e	1.7 %	Show sustainable alternatives	Add to compare
14.	Woven wall-to-wall carpet, PA 6, textile fabric backing, 0.5-0.6 kg/m2 pile weight ?	20 tonnes CO_2e	1.7 %	Show sustainable alternatives	Add to compare
15.	Finishing wall mortars, French average, 3 mm, 4.2 kg/m2 ?	18 tonnes CO_2e	1.6 %	Show sustainable alternatives	Add to compare
16.	EPS insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 ?	16 tonnes CO_2e	1.4 %	Show sustainable alternatives	Add to compare
17.	Mineral mortar, ?	16 tonnes CO_2e	1.4 %	Show sustainable alternatives	Add to compare
18.	Mortar for masonry use, 1500 kg/m3 ?	13 tonnes CO_2e	1.1 %	Show sustainable alternatives	Add to compare
19.	Glass wool, acoustic ceiling panel, 20 mm, 4.0 kg/m2 ?	10 tonnes CO_2e	0.9 %	Show sustainable alternatives	Add to compare
20.	Wooden entrance door, per m2, 809x2053 mm, 42x92 mm frame, 52 mm door leaf ?	9.3 tonnes CO_2e	0.8 %	Show sustainable alternatives	Add to compare
21.	Gypsum board, 12.5 mm, 9.3 kg/m2, 744 kg/m3 ?	9.2 tonnes CO_2e	0.8 %	Show sustainable alternatives	Add to compare
22.	Concrete roof tiles, Avg. thickness per m2: 22.4 mm, 334x420 mm, 2100 kg/m3 ?	6.6 tonnes CO_2e	0.6 %	Show sustainable alternatives	Add to compare
23.	Ready-mix concrete, low-strength, generic, C12/15 (1700/2200 PSI), 0% recycled binders in cement (220 kg/m3 / 13.73 lbs/ft3) ?	6 tonnes CO_2e	0.5 %	Show sustainable alternatives	Add to compare
24.	Aluminum profile for windows and doors, 2600 kg/m3 ?	6.1 tonnes CO_2e	0.5 %	Show sustainable alternatives	Add to compare
25.	Gypsum plaster board, regular, generic, 6.5-25 mm (0.25-0.98 in), 10.725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3) ?	5.1 tonnes CO_2e	0.4 %	Show sustainable alternatives	Add to compare

	The Core - Ground Floor and Mezzanine				
A. Civil Works					
A.1	Supply and install block and mortar works for the new interior walls as per the approved design (12 cm thick) (Cement blocks)	m2	406		
A.2	Supply and install block and mortar works for the new interior walls as per the approved design (25 cm thick) (Cement blocks)	m2	60		
A.4	Supply and install gypsum interior walls as per the approved design (10 cm thick - Rockwool Infill - white type - manufacturer KNAUF)	m2	103		
A.5	Demolishing works (old block works) (Refer to demolishing plan)	LS			
TOTAL					

	The Factory - First Floor				
D. Container					
D.1 Container					
D.1.1	Customized 20 ft. Container. (Refer to ID-33 & ID-52)	LS	1		
TOTAL					

C.3 LVT Tiles					
C.3.1	supply and install **LVT Tiles** Supplier: Tarekett, Model: LVT tiles, Vintage Zinc, 50 x 50 cm, Ref. 24207096	m^2	520	Local	Imported
TOTAL					

	La Belle Epoque - Second Floor				
C. Floor Finishes					
C.1 Hardwood floors					
C.1.1	Restore existing parquet flooring	m^2	340		
TOTAL					
	Main Stairs				
D. Stairs & Railings					
D.1 Stairs					
D.1.1	Restore existing main stairs	LS	1		
TOTAL					
D.2 Railings					
D.2.1	Restore existing railings	LS	1		
	TOTAL				

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives	
1.	Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 10% (typical) recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3) ?	665 tonnes CO_2e	27.8 %	Show sustainable alternatives	Add to compare
2.	Reinforcement steel (rebar), generic, 90% recycled content, A615 ?	445 tonnes CO_2e	18.6 %	Show sustainable alternatives	Add to compare
3.	Aluminium frame window, 24.27 kg/m2, 2.3 m2/unit ?	160 tonnes CO_2e	6.7 %	Show sustainable alternatives	Add to compare
4.	Water circulation radiator, per 1kW / unit ?	145 tonnes CO_2e	6.1 %	Show sustainable alternatives	Add to compare
5.	Electricity distribution system, cabling and central, for all building types, per m2 GFA ?	124 tonnes CO_2e	5.2 %	Show sustainable alternatives	Add to compare
6.	Bricks, 226x104x60, 226x85x60 mm ?	116 tonnes CO_2e	4.9 %	Show sustainable alternatives	Add to compare
7.	Autoclaved aerated concrete masonry blocks, 150 mm, 70.9 kg/m2 ?	113 tonnes CO_2e	4.7 %	Show sustainable alternatives	Add to compare
8.	Self levelling mortar, for floors, walls and overhead appl., 3-50 mm, 1400 kg/m3 ?	86 tonnes CO_2e	3.6 %	Show sustainable alternatives	Add to compare
9.	Masonry mortar, light, 1000 kg/m3 ?	62 tonnes CO_2e	2.6 %	Show sustainable alternatives	Add to compare
10.	Ventilation ducting, per m linear, D: 500 mm (19.69 in) ?	59 tonnes CO_2e	2.5 %	Show sustainable alternatives	Add to compare
11.	Air handling unit, with heat recovery through plate heat exchanger, 10 000 m3/h (5885.8 ft3/min), 1256 kg/unit (2769 lbs/unit) ?	57 tonnes CO_2e	2.4 %	Show sustainable alternatives	Add to compare
12.	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3 (1.56 lbs/ft3), (applicable for densities: 0-25 kg/m3 (0-1.56 lbs/ft3)), Lambda=0.031 W/(m.K) ?	39 tonnes CO_2e	1.7 %	Show sustainable alternatives	Add to compare
12.	Glass wool insulation panels, unfaced, generic, L = 0.031 W/mK, R = 3.23 m2K/W (18 ft2°Fh/BTU), 25 kg/m3 (1.56 lbs/ft3), (applicable for densities: 0-25 kg/m3 (0-1.56 lbs/ft3)), Lambda=0.031 W/(m.K) ?	39 tonnes CO_2e	1.7 %	Show sustainable alternatives	Add to compare
13.	Ready-mix concrete, normal-strength, generic, C30/37 (4400/5400 PSI), 0% recycled binders in cement (300 kg/m3 / 18.72 lbs/ft3) ?	38 tonnes CO_2e	1.6 %	Show sustainable alternatives	Add to compare
14.	Woven wall-to-wall carpet, PA 6, textile fabric backing, 0.5-0.6 kg/m2 pile weight ?	39 tonnes CO_2e	1.6 %	Show sustainable alternatives	Add to compare
15.	EPS Insulation, T: 10-2400 mm, 600 x 1200 mm, 0.031 W/m2K, 16 kg/m3 ?	36 tonnes CO_2e	1.5 %	Show sustainable alternatives	Add to compare
16.	Finishing wall mortars, French average, 3 mm, 4.2 kg/m2 ?	23 tonnes CO_2e	1.0 %	Show sustainable alternatives	Add to compare
17.	Mineral mortar, ?	23 tonnes CO_2e	1.0 %	Show sustainable alternatives	Add to compare
18.	Glass wool, acoustic ceiling panel, 20 mm, 4.0 kg/m2 ?	21 tonnes CO_2e	0.9 %	Show sustainable alternatives	Add to compare
19.	Mortar for masonry use, 1500 kg/m3 ?	19 tonnes CO_2e	0.8 %	Show sustainable alternatives	Add to compare
20.	Concrete roof tiles, Avg. thickness per m2: 22.4 mm, 334x420 mm, 2100 kg/m3 ?	16 tonnes CO_2e	0.7 %	Show sustainable alternatives	Add to compare
21.	Ready-mix concrete, low-strength, generic, C12/15 (1700/2200 PSI), 0% recycled binders in cement (220 kg/m3 / 13.73 lbs/ft3) ?	15 tonnes CO_2e	0.6 %	Show sustainable alternatives	Add to compare
22.	Wooden entrance door, per m2, 809x2053 mm, 42x92 mm frame, 52 mm door leaf ?	14 tonnes CO_2e	0.6 %	Show sustainable alternatives	Add to compare
23.	Gypsum board, 12.5 mm, 9.3 kg/m2, 744 kg/m3 ?	14 tonnes CO_2e	0.6 %	Show sustainable alternatives	Add to compare
24.	Gypsum plaster board, regular, generic, 6.5-25 mm (0.25-0.98 in), 10.725 kg/m2 (2.20 lbs/ft2) (for 12.5 mm/0.49 in), 858 kg/m3 (53.6 lbs/ft3) ?	10 tonnes CO_2e	0.4 %	Show sustainable alternatives	Add to compare
25.	Massive wooden flooring/parquet, 22-450 x 44-7000 x 8-35 mm, 11.71 kg/m2 ?	6.8 tonnes CO_2e	0.3 %	Show sustainable alternatives	Add to compare

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البند	بنود الأعمال	الوحدة	الكمية	المدة باليوم	ملاحظات
37	بالعدد أعمال توريد وتركيب باب خشب بيش بابن للفتحات عرض 100 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	1		
38	بالعدد أعمال توريد وتركيب باب خشب منزلق ظاهري من أخشاب البيتش بابن للفتحات عرض 90 سم وبارتفاع 2.5 متر والتثبيت من أعلى والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	1		
39	بالعدد أعمال توريد وتركيب أبواب زجاجية من زجاج السيكوريت سمك 8 مم للفتحات عرض 90 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	4		
40	بالعدد أعمال توريد وتركيب باب خشب بيش بابن من ضلفتين للفتحات عرض 120 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	2		
41	بالعدد أعمال توريد وتركيب باب خشب بيش بابن من ضلفتين للفتحات عرض 140 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	5		
42	بالعدد أعمال توريد وتركيب باب خشب بيش بابن من ضلفتين للفتحات عرض 160 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	8		
43	بالعدد أعمال توريد وتركيب باب ضلفتين من الحديد المشغول والزجاج السيكوريت سمك 8 مم للفتحات عرض 160 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	5		
44	بالعدد أعمال توريد وتركيب باب خشب بيش بابن من ضلفتين للفتحات عرض 200 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	1		
45	بالمتر المسطح أعمال توريد وتركيب حديد مشغول لزوم شبابيك داخلية والبند يشمل زجاج سيكوريت سمك 8 مم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	92		
46	بالعدد أعمال صيانة وتجديد الشبابيك الخشبية بأبعاد 3.2 * 2.4 متر والبند يشمل كل ما يلزم من تثبيت والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	24		
47	بالعدد أعمال توريد وتركيب زجاج سيكوريت سمك 8 مم عازل الصوت لشبابيك الدور الأول بأبعاد 3.2 * 2.4 متر والبند يشمل كل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	24		
48	بالعدد أعمال توريد وتركيب Curtain wall لشبابيك الدور الأول بأبعاد 3.2 * 2.4 متر والبند يشمل كل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	24		
49	بالعدد أعمال صيانة وتجديد حديد مشغول أعلى الأبواب بمسطح حوالي 2 م2 والبند يشمل تنظيف وصنفرة ورش المواد المزيلة للصدأ كالبيوتك أو ما يماثلها ويشمل أيضاً دهان طبقة من المواد الإيبوكسية المانعة للصدأ والتشطيب بالدهانات المطلوبة والتثبيت وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	10		
	أعمال الإكسسوارات للأبواب والشبابيك				
50	بالعدد أعمال توريد وتركيب ماكينة غلق الباب طبقاً للعينات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	60		
	أعمال الديكورات والإكسسوارات				
51	بالمتر الطولي توريد وتركيب جرانيت روزا أسواني نص لمعة سمك 3 سم لزوم جلسات الإنتظار بعرض 50 سم طبقاً للعينة المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	39		
52	بالمتر الطولي أعمال ترميم وإصلاح ومعالجة أعمدة من الحديد بمحيط مقطع حوالي 0.5م والبند يشمل كل ما يلزم لنهو البند من صنفرة ورش بمادة البيوتك لإزالة الصدأ ودهان مواد إيبوكسية لمنع الصدأ وكل مايلزم لنهو البند طبقاً لأصول الصناعة وتعليمات الإستشاري	م.ط	150		

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البند	بنود الأعمال	الوحدة	الكمية	المدة باليوم	ملاحظات
53	بالمتر الطولي أعمال ترميم وإصلاح ومعالجة كمرات من الحديد بمحيط مقطع حوالي 2م والبند يشمل كل ما يلزم لنهو البند من صنفرة ورش بمادة البيوتك لإزالة الصدأ ودهان مواد إيبوكسية لمنع الصدأ وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	82		
54	بالمتر المسطح أعمال توريد وتنفيذ تكسيات حوائط من الطوب الزجاجي أبيض مصنفر مقاس 6*12*25 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	40		
55	بالمتر المسطح أعمال تجاليد خشبية من خشب الأرو المصمت تخانة 10 مم للحوائط بارتفاع حوالي 1.5 متر والبند يشمل كل ما يلزم من دهانات وتشطيب وتثبيت وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	350		
56	بالمتر المسطح أعمال تجاليد من ألواح من الحديد الصاج سمك 5 مم للحوائط بارتفاع حوالي 1.5 متر والبند يشمل كل ما يلزم من دهانات وتشطيب وتثبيت وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	97		
57	بالعدد توريد سلة مهملات مع طفاية سجائر من الإستانلس ستيل إسطوانية الشكل بارتفاع 70 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	97		
	أعمال الجمالون الحديد للبهو الرئيسي				
58	بالطن أعمدة حديد دائرية المقطع طبقاً للرسومات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	طن	5		
59	بالطن أعمال سقف من قطاعات الحديد طبقاً للرسومات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	طن	12		
60	بالمتر المسطح أعمال سقف من زجاج السيكوريت المزدوج سمك 8 مم طبقاً للرسومات وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	517		
	أعمال الصحي				
61	بالعدد توريد وتركيب واختبار مرحاض الرتبي من الصيني بصندوق طرد واطي مقاس لا يقل عن 68سم * 35 سم من الصيني باللون المطلوب من اجود الانواع ايديال استاندرد او ديورافيت وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	8		
62	بالعدد توريد وتركيب مرحاض الرتبي من الصيني خاص لذوي الإحتياجات الخاصة بصندوق طرد واطي مقاس لا يقل عن 68سم * 35 سم من الصيني باللون المطلوب من اجود الانواع ايديال استاندرد او ديورافيت وكافة الإكسسوارات اللازمة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	2		
63	بالعدد توريد وتركيب حوض غسيل ايدي من الرخام تريستا رمادي سمك 3 سم حسب الشكل واللون المطلوب وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	6		
64	بالعدد توريد وتركيب حوض غسيل ايدي من الرخام تريستا رمادي سمك 3 سم لذوي الإحتياجات الخاصة حسب الشكل واللون المطلوب وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	2		
	أعمال متنوعة				
65	بالمتر الطولي توريد تركيب جلسة تنجيد من الجلد من الجلد المطلوب وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	115		
66	بالمتر الطولي توريد وتركيب شريط من النحاس الأصفر للكونتر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	58		
67	بالمتر المسطح أعمال توريد وتركيب زجاج سيكوريت مزدوج سمك 8 مم مع عمل تشكيلات من حديد الكريتال طبقاً للرسومات وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	250		
68	بالمتر المسطح توريد وتركيب جرانيت روزا أسواني نص لمعة سمك 3 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	59		
69	بالمتر المسطح توريد وتركيب جرانيت أسواني أخضر غامق سمك 3 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	25		
70	بالمتر الطولي توريد وتركيب تجاليد من الخشب الموسكي الأبيض المصمت ماسيف تخانة لا تقل عن 10 مم لزوم ستارات التكييف والبند يشمل التشطيب بالورنيش والأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	58		

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	يتم تنفيذ الأعمال طبقاً للرسومات التفصيلية المرفقة لبنود الأعمال الموضحة بالمقايسة التقديرية.				
	يتم تقديم عينات لكل بنود الأعمال ولا يجوز العمل بها بدون موافقة الشئون الهندسية.				
	أعمال التكسير والإزالة				
1	بالمتر المسطح أعمال تكسير وإزالة حوائط من الطوب بسمك متوسط 15 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	782		
2	بالمتر المكعب أعمال تكسير وإزالة قواطع من الخرسانة المسلحة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م3	12		
3	بالمتر الطولي أعمال فك وإزالة فواصل من الزجاج بارتفاع حوالي 2 متر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	63		
4	بالعدد أعمال فك وإزالة شبابيك حديد بأبعاد تقريبية 2*3 متر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	21		
5	بالمتر المسطح أعمال فك رخام وجرانيت وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	365		
6	بالمتر المسطح أعمال تكسير أرضيات بلاط وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	810		
	أعمال أحواض الزهور والزراعة				
7	بالعدد توريد وعمل أحواض زهور خشبية سويدي مقاس 50 سم * 90 سم بارتفاع 80 سم والبند يشمل الفيبر بلاستيكية من الداخل وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	35		
8	بالمتر المسطح توريد وعمل مباني من الطوب الطفلي المصمت سمك 12 سم (مقاس 6*12*25 سم) لزوم أحواض الزراعة والبند يشمل عزل مائي APDM للأحواض من الداخل وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	77		
9	بالمتر الطولي توريد وعمل تجاليد خشبية من خشب الأرو المصمت تخانة لا تقل عن 10 مم لأحواض الزراعة بارتفاع حوالي 90 سم والبند يشمل جلسة خشبية من خشب موسكي سمك 10 سم بعرض حوالي 50 سم لزوم جلسات الإنتظار والتشطيب بالأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	77		
10	بالمكعب توريد وفرد تربة صالحة للزراعة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م3	52		
11	بالمتر المسطح توريد وزراعة نجيل بيسبم 10 وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	10		
12	بالعدد توريد وزراعة [illegible] بارتفاع أوراق 50 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	100		
13	بالعدد توريد وزراعة زهور [illegible] بارتفاع 30 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	400		
14	بالعدد توريد وزراعة نخيل سيكس بارتفاع خشب 25 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	12		
15	بالعدد توريد وزراعة نخيل [illegible] بارتفاع لا يقل 120 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	23		
16	بالعدد توريد وزراعة شجرة [illegible] بارتفاع 150 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	4		
17	بالعدد توريد وزراعة شجرة فيكس [illegible] بارتفاع 150 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	10		
18	بالعدد توريد وزراعة شجرة فيكس لارتا بارتفاع 150 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	10		
19	بالعدد توريد وزراعة نخيل [illegible] بارتفاع خشب 8 م وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	5		
	أعمال الأرضيات				

وزارة الاتصالات
الهيئة القومية للبريد
الادارة العامة لتخطيط وتنفيذ المشروعات

مقايسة تقديرية للأعمال الخاصة بتجديد وصيانة المركز الرئيسي لحركة البريد بالعتبة

البند	بنود الأعمال	الوحدة	الكمية	المدة باليوم	ملاحظات
20	بالمتر المسطح توريد وتركيب أرضيات من الحجر الطبيعي المحلي (80 متنا) سمك 4 سم بمقاس 80*100 سم طبقاً للعينات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	460		
21	بالمتر المسطح توريد وتركيب أرضيات من الرخام المحلي الأبيض سالكوتا سوهاجي سمك 4 سم مقاس 80*100 سم طبقاً للعينات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	58		
22	بالمتر المسطح توريد وتركيب أرضيات من الرخام تريستا رمادي سمك 3 سم طبقاً للعينات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	85		
23	بالمتر المسطح توريد وتركيب أرضيات من الجرانيت روزا أسواني سمك 3 سم طبقاً للعينات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	690		
24	بالمتر الطولي توريد وتركيب وزرة من الرخام المحلي الأبيض سالكوتا سوهاجي سمك 4 سم بارتفاع 15 سم طبقاً للعينات المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	52		
25	بالمتر الطولي توريد وتركيب خوص من النحاس مط مصمت (سمك 5 مم * عرض 10 مم) كفواصل جرانيت الأرضيات حسب العينة المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	1838		
26	بالمتر الطولي توريد وتركيب خوص من النحاس مط مصمت (سمك 5 مم * عرض 15 مم) كفواصل جرانيت الأرضيات حسب العينة المعتمدة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م.ط	260		
	أعمال الحوائط				
27	بالمتر المسطح أعمال توريد وتنفيذ مباني سمك 12 سم من الطوب الطفلي المصمت مقاس 6*12*25 سم وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	288		
28	بالمتر المسطح أعمال توريد وتنفيذ جرانيت روزا أسواني سمك 3 سم للحوائط وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	761		
29	بالمتر المسطح أعمال كشط وتكسير وإزالة بياض المحارة على الحوائط والبند يشمل صنفرة الحوائط وتنظيفها وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	274		
30	بالمتر المسطح أعمال كشط وتكسير وإزالة بياض أبيض للدهان على الحوائط والبند يشمل صنفرة الحوائط وتنظيفها وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	1550		
31	بالمتر المسطح أعمال صيانة حوائط من الحجر القديم والبند يشمل ملء الفواصل الفارغة إن وجدت ودهان سيلر (غلاف صديق للبيئة) عند الحاجة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	1277		
32	بالمتر المسطح أعمال صيانة حوائط من الطوب الأحمر والبند يشمل عقد الطوب فوق الفتحات والأبواب والبند يشمل ملء الفواصل الفارغة إن وجدت ودهان سيلر (غلاف صديق للبيئة) عند الحاجة وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	183		
	أعمال الأسقف				
33	بالمتر المسطح أعمال كشط وتكسير وإزالة بياض المحارة والمصيص على الأسقف وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	610		
34	بالمتر المسطح صيانة وتجديد السقف الخشبي واستبدال التالف ودهان السقف الخشبي بمادة العزل المعتمدة ودهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	610		
35	بالمتر المسطح أعمال تجاليد خشبية من خشب الموسكي الأبيض سمك 10 مم للأسقف (بروز الأسقف الخشبية) والبند يشمل كل ما يلزم من تثبيت والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	م2	156		
	أعمال الأبواب والشبابيك				
36	بالعدد أعمال توريد وتركيب باب خشب بيش بابن للفتحات عرض 90 سم وبارتفاع 2.5 متر والبند يشمل الحلق وكافة الإكسسوارات والمفصلات والمقابض والكوالين اللازمة والتشطيب بدهان الأستر وكل مايلزم لنهو البند طبقاً لأصول الصناعة والرسومات المعتمدة وتعليمات الإستشاري	عدد	15		

مستخلص البحث

المباني التراثية في مصر تواجه تحديات كثيرة بسبب عوامل كثيرة. من ضمن هذه العوامل عجز الميزانية, و القيود المالية, قلة الصيانة, و عدم وجود القوانين الكافية (عثمان 2018) هذه المباني, و التي منها الكثير ذو قيمة ثقافية و تاريخية, في خطر الزوال الي الأبد, ان لم يتم اتخاذ خطوات للحفاظ عليها.

اعادة استخدام المباني في واحدة من المفاتيح للحفاظ علي هذا النوع من المباني. و مشاركة هويتها الثقافية و التذكارية مع الأجيال القادمة. اعادة استخدام المباني هي استراتيجية ليس فقط للحفاظ علي المباني و لكن أيضا, قد تكون خطوة نحو الاستدامة الحضارية (بالين& لوف,2016) لها ايضا فوائد بيئية ملحوظة عن طريق تقليل البصمة الكربونية للمواد المطلوبة للانشاءات الجديدة و ايضا تقليل الهوادر الناتجة من عمليات الهدم. فانه مع اعادة استخدام المنشئات الموجودة بالفعل, يمكن تقليل الطاقة المستخدمة و الطلب علي المواد الجديدة للبناء. و بالتالي تقليل التأثير البيئي. (فيشر-جويتزمان 2016)

الأعمال البحثية مؤخرا في هذا المجال متمركزة حول تقليل الطاقة المشغلة للمباني التراثية من اجل الوصول الي الكفاءة في الطاقة. مع ذلك, هناك فجوة في مناقشة إشكال انبعاثات الكربون الكامنة من خلال دورة الحياة الكاملة للمباني, التي تركز علي الطاقة الكامنة للخامات, الطاقة المستخدمة اثناء مراحل البناء, و بعد هذا الطاقة التشغيلية للمبني.

هذه الدراسة تؤكد ان اعادة استخدام المباني التراثية, و بالأخص التي تم بناؤها بين القرن التاسع عشر و القرن العشرين, هي استراتيجية من اجل الوصول الي أهداف تقليل انبعاثات الكربون الموضوعة لقطاع المباني, من خلال تقليل مواد البناء, في حين الحفاظ علي القيم التراثية و التذكارية لهذه المباني.

المنهجية المستخدمة في هذه الدراسة تستخدم تقييم دورة الحياة الكاملة مقارنة بين اثر الكربون الذي ينتج من ترميم المبني التراثي, و اثر الكربون الذي ينتج عن هدم المبني و إعادة بناء مبني اخر في القاهرة, و ذلك باستخدام ادوات تقييم دورة الحياة التي تأخذ في الأعتبار, الاثار البيئية مثل الانبعاثات الناتجة عن الأحتباس الحراري, و كمية انبعاثات الكربون الكامنة و أكثر المواد المساهمة في تلك الاثار. و من المتوقع ان تقدم هذه الدراسة طريقة لتقدير الطاقة الكامنة لإعادة استخدام المباني التراثية و ذلك من خلال دراسة عدد من الحالات المحلية في القاهرة الخديوية.

الكلمات الرئيسية:

المباني التراثية، إزالة الكربون، إعادة استخدام متكيف، الاستدامة، إعادة الاستخدام.

إقرار

هذه الرسالة مقدمة في جامعة عين شمس للحصول على درجة العمران المتكامل والتصميم المستدام. إن العمل الذي تحويه هذه الرسالة قد تم إنجازه بمعرفة الباحث سنة...

هذا ويقر الباحث أن العمل المقدم هو خلاصة بحثه الشخصي وأنه قد اتبع الإسلوب العلمي السليم في الإشارة إلى المواد المؤخوذه من المراجع العلمية كل في مكانه في مختلف أجزاء الرسالة.

وهذا إقرار مني بذلك،،،

التوقيع

الباحث: ماركو يسري مراد زكي

التاريخ: سبتمبر 2023

استكشاف إمكانية تقليل انبعاثات الكربون المتجسدة من خلال إعادة استخدام المباني التراثية في مصر: حالة القاهرة الخديوية.

مقدمة للحصول على درجة الماجستير في العمران المتكامل والتصميم المستدام

اعداد: ماركو يسري مراد زكي

لجنة اشراف

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أستاذ التخطيط المتكامل و التصميم
رئيس قسم العمران المتكامل و المستدام - القاهرة

د/ خالد طرابية

معمارى الجامعة و أستاذ مساعد التصميم المستدام
بالجامعة الأمريكية في القاهرة

لجنة الحكم

أ.د ....
أستاذ ....
جامعة ....

أ.د ....
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جامعة ....

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الدراسات العليا

موافقة مجلس الكلية ..../..../....

موافقة مجلس الجامعة ..../..../....

ختم الإجازة

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تاريخ المناقشة ..../..../....

سبتمبر 2023

جامعة عين شمس