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Towards an integrated approach for evaluating both the life cycle environmental and financial performance of a building: A review

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Abstract

A building is responsible for the emission of a significant amount of greenhouse gas (GHG) emissions over the various stages of its life cycle. Industry and government have been primarily focused on assessing and implementing mitigation measures related to the operational GHG emissions of buildings, leaving the emissions related to other life cycle stages, such as raw material extraction and maintenance, largely ignored. However, the uptake of assessments, such as life cycle assessment (LCA), and mitigation measures that consider buildings' emissions from a life cycle perspective has been slow due to various barriers. One such barrier that has not been as widely documented yet is the uncertainty towards the financial cost of life cycle GHG emission reduction. There has been an increase in studies that have included both the environmental and financial assessment of a building or building systems over its expected lifetime. These studies often use the economic methodology called life cycle costing (LCC), that complements the life cycle approach of LCA, to help quantify the financial impact of a project. However most of these studies either base their results on exemplary low energy buildings, not traditional buildings that dominate the built fabric. In addition there is a trend to primarily focus on residential buildings, leaving other building typologies neglected. Other aspects to notice from these studies include the fact that most present findings of the life cycle energy impact, not life cycle GHG impact. There is also a need to use more comprehensive life cycle inventory data, such as hybrid, not just process data, to provide more comprehensive results. And lastly, most studies consider at new buildings, not refurbished or existing buildings. LCA and LCC support each other from a life cycle perspective however there is still a need to further develop an approach to concurrently balance both economic and environmental performance to create a more sustainable built environment.

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Nomenclature

GHG	Greenhouse gas
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
NPV	Net Present Value
IRR	Internal Rate of Return
LCCf	Life Cycle Carbon footprint

1. Introduction

A building is responsible for the emission of a significant amount of greenhouse gas (GHG) over the various stages of its life cycle. These life cycle stage emissions can be broadly classified as operational emissions (emissions relating to the running of the building such as heating and cooling) and embodied emissions (those emissions relating to the manufacture, construction and maintenance of the building). Embodied emissions include both the initial emissions (released during extraction, manufacture, transport and construction) and recurrent emissions (released during the maintenance and repair of the building over its lifetime).

With the growing awareness towards the effect GHG emissions have on climate change [1], building environmental assessments have increased. These assessments help quantify the environmental performance of a building. The buildings' operational stage has been the main focus of these assessments and consequent mitigation strategies, leaving the other strategies largely ignored. However the embodied emissions from materials and manufacturing, transport, maintenance and disposal have been estimated to be as high as 70% for certain building typologies over their lifecycle [2]. Thus it has become paramount to assess buildings based on their life cycle performance. Life cycle assessment (LCA) has been demonstrated to provide an appropriate framework for assessing a building or a building systems environmental performance over its expected lifespan.

However there has been a slow uptake of building strategies that consider the life cycle performance of a building. Several barriers are hindering the uptake of LCA, from consistency of method, availability of comparable data and government policy. These barriers have been well documented in the literature. However one of the remaining barriers, uncertainty towards cost, has not been as widely explored. Building owners and project developers are unsure of what the cost implications might be to include both operational and embodied emission reduction strategies into their projects and design team members do not have sufficient knowledge or appropriate tools to answer their cost concerns. Building design decisions are commonly based on issues pertaining to construction cost [3] with capital cost remaining the primary criterion for building procurement decisions. Financial cost plays a large role especially when it comes to low carbon construction with the consideration of 'green' designs always prefaced with the question 'How much more will this cost?' [4].

There has been an increase in studies that have included both the environmental and financial assessment of a building or building systems over their expected lifetime. These studies often use the economic methodology called life cycle costing (LCC), that complements the life cycle approach of LCA, to help quantify the financial performance of a project. The objective of this study is to first provide a brief overview of these recent studies, secondly to determine the relevant key elements of these studies and then thirdly highlight any aspects that have been neglected in these studies that need to be developed further in future research regarding the quantification of environmental and financial performance of buildings. The structure of the paper will first include a brief introduction of the LCA and LCC methodology and then provide an overview of relevant recent studies concluding with areas for future research.

2. Background

Traditionally a life cycle assessment and a life cycle costing for a built project are carried out independently of each other, as described in the sections below.