Environmental Impact Assessment Review 57 (2016) 63–77

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

A model for the sustainable selection of building envelope assemblies

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ARTICLE INFO

Article history:
Received 30 January 2015
Received in revised form 12 November 2015
Accepted 12 November 2015
Available online xxxx

Keywords:
Buildings sustainability
Sustainability indicators
Envelope assemblies

ABSTRACT

The aim of this article is to define an evaluation model for the environmental impacts of building envelopes to support planners in the early phases of materials selection. The model is intended to estimate environmental impacts for different combinations of building envelope assemblies based on scientifically recognised sustainability indicators. These indicators will increase the amount of information that existing catalogues show to support planners in the selection of building assemblies.

To define the model, first the environmental indicators were selected based on the specific aims of the intended sustainability assessment. Then, a simplified LCA methodology was developed to estimate the impacts applicable to three types of dwellings considering different envelope assemblies, building orientations and climate zones. This methodology takes into account the manufacturing, installation, maintenance and use phases of the building. Finally, the model was validated and a matrix in Excel was created as implementation of the model.

1. Introduction

Construction is responsible for an indiscriminate use of non-renewable resources and is an important source of waste and pollution for the air, soil and water. According to UNEP (United Nations Environment Programme) and OECD (Organisation for Economic Cooperation and Development) data, the built-up environment accounts for between 25% and 40% of energy consumption, between 30% and 40% of the solid waste burden, and between 30% and 40% of the greenhouse gas emissions generated worldwide (Oteiza and Alonso, 2008).

It is important to stress the importance of studying the potential environmental impacts produced by the use of certain building materials, but it is also important to highlight the impact represented by the combination of these materials when used in a certain constructive assembly (Casado, 1996). Likewise, it is necessary to be able to establish relationships between these impacts and those produced throughout the lifespan of the building, due to both the actual materials used and the energy consumption linked to the building assemblies employed in the building envelope. As the person responsible for developing the core of the building around which the rest will later be constructed, the designer or planner must be able to control the selection of suitable materials and building assemblies used in their project (López-Mesa et al., 2007). In order to make their decisions they therefore need to have access not only to valid technological alternatives but also to relevant objective information about them, as well as instruments that allow them to be evaluated in a comprehensive manner (Ruá, 2011).

Thus, to increase the sustainability of construction it is necessary to consider reducing both the energy consumption and the CO_2 emissions of buildings by improving the building assemblies that make up the building envelope. This envelope has to guarantee the quality of the environment inside the building, since the exchange between the inner and outer environment takes place through it. It is also the point where illumination, ventilation or heat flow act as fundamental design parameters (Haapio and Viitaniemi, 2008).

Obviously the environmental assessment of the building assemblies used for the envelope requires a scientifically rigorous methodology. Among the leading methodologies accepted by the scientific community for environmental impact assessment, the Life Cycle Analysis (LCA) is the most suitable because it is an analytical procedure focused on evaluating the whole life cycle. LCA, however, is an exhaustive, very laborious and complex process that must be carried out by highly skilled professionals and the time needed to apply it is often incompatible with the time available for producing designs. As a result, few life cycle analyses of buildings have been carried out in some countries. In the international context, a wide variety of tools based on the LCA methodology have been developed with the specific aim of aiding the planner in the sustainable selection of building assemblies. These tools allow the components of the building to be evaluated and cover all the different phases of the life cycle (Huedo and López-Mesa, 2012; Zabalza et al., 2009). These tools hardly apply outside the countries where they were developed since the environmental impact level caused by building materials and assemblies varies from one territory to another, due to the geographic placement of raw materials extraction and transformation plants in relation to the building location as well as

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http://dx.doi.org/10.1016/j.eiar.2015.11.005
0195-9255/

to the possible differences in construction techniques (Mateus and Bragança, 2011).

In Spain, there are environmental assessment tools such as TCQ2000 and its module TCQGMA, which only assess the impacts generated during the manufacturing process and installation of the materials, i.e. the embodied impacts, without taking into account the use phase of the building, i.e. the operating impacts. On the other hand, there are building energy simulation tools such as LIDER and CALENER which offer data about consumption and CO_2 emissions of buildings (Zabalza et al., 2009; Rúa et al., 2012; Alonso et al., 2010); they do not, however, take into account the embodied impacts of the manufacturing and installation stages or the impacts generated by the maintenance of the building.

At an international context, there are several studies that propose different methods to evaluate the environmental impact of buildings which consider both embodied and operating energy (Mithraratne and Vale, 2004; Alías and Jacobo, 2008; Argüello and Cuchí, 2008; Verbeeck and Hens, 2009; Ortiz et al., 2010; Ruá et al., 2010). One of them deserves special mention because it synthesises all collected data in the form of indicators to assign scores to each design alternative, considering the different impacts along the whole building life cycle, which is of application to New Zealand houses (Mithraratne and Vale, 2004). The evaluation in this model is made for the whole building, whereas in this paper we focus on the building envelope in order to support the early phases of building envelope materials selection. Our aim is to increase the amount of information that existing catalogues show to support planners in the selection of building assemblies.

Scoring by means of indicators allows to compare data about different buildings using a reference to which the inputs and outputs can be related, the functional unit. It also allows checking the fulfilment of environmental prerequisites, in the initial phases of design, even before the actual design starts.

It would therefore be very interesting to have an evaluation model based on environmental indicators that assigns buildings envelope impact scores in a simple way, considering the whole life cycle. This model that would specifically be developed for building envelopes, would not only evaluate the embodied impacts of the manufacturing, installation and maintenance stages, but would also take into account the impacts generated by the installations due to the contribution of the envelope to energy efficiency during the use phase of the building (operating impacts). The interest in linking both types of impact stems from the fact that certain building assemblies might not substantially improve the energy efficiency of the building or that some high energy efficiency building assemblies include materials with a high impact in their manufacturing process, installation or maintenance. Planners require both embodied and operating energy-related information about building envelope solutions in order to select the building assemblies that ensure good environmental behaviour of the building throughout the whole of its life cycle.

An indicator is an environmental variable or estimation that provides aggregated summarised information about a phenomenon (MIMAM, 2000). Its function is therefore to provide information both clearly and efficiently. It is necessary to establish a minimum essential content for presenting indicators, both for processes involving the selection of the indicators themselves and for the analysis and validation of the information they contain, with the aim of having access to specific concise information so as to avoid ambiguities that may arise during their interpretation, as well as to be able to take them as the basis on which to make correct decisions. The system used to obtain the values that allow the development of the formulas for the indicators would be based on a simplified LCA methodology.

2. Aim

The main aim of this article is to define a model for assessing the environmental impact, based on a simplified LCA methodology, produced by different building assemblies used in the envelope of buildings so that they can be assigned a score by means of known sustainability indicators that take into account the manufacturing, installation, use and maintenance phases of building construction.

With this assessment model the intention is to contribute to the development of a tool, to be applied in Spain in the early phases of building materials selection, that allows obtaining estimated live data about the embodied and operating environmental impacts of building envelope assemblies, to aid the design planner in the selection of solutions of low environmental impact before the actual design starts. The main contribution of the model is proposing a method to estimate how to score the envelope impacts at an earlier phase than the existing methods in a simple way.

3. Research methodology

The methodology that was followed to develop this model is summarised in the diagram below (Fig. 1).

The adopted methodology is based on the generation of data regarding materials and assemblies of regular use in building construction in Spain, required to develop mathematical equations for a set of sustainability indicators previously selected for each of the building life cycle phases.

3.1. Selection of indicators and impacts rating

From a methodological point of view it must be underlined that the framework of analysis chosen to structure the system of indicators is the so-called "Pressure-State-Response (PSR)", adopted by the OECD (1994) and based on a causality model.

According to the general principles established in the norm ISO 15392, when evaluating buildings sustainability, the three dimensions of the sustainable development (environmental, social and economic) should be considered. However, this norm also establishes that the evaluation of sustainability can also be undertaken separately, depending on the scope of the evaluation. This work focuses on the environmental and economic evaluation of buildings envelope.

As the number of indicators that can be proposed is quite large, before going on it is necessary to select certain indicators, to clearly establish the sustainability goals and to determine what selection criteria are to be used. Hence, the grouping proposed by Standard UNE EN 15643-2 was considered, in the following areas:

- Indicators that describe environmental emissions,
- Indicators that describe use of resources,
- Indicators that provide complementary environmental information about waste.

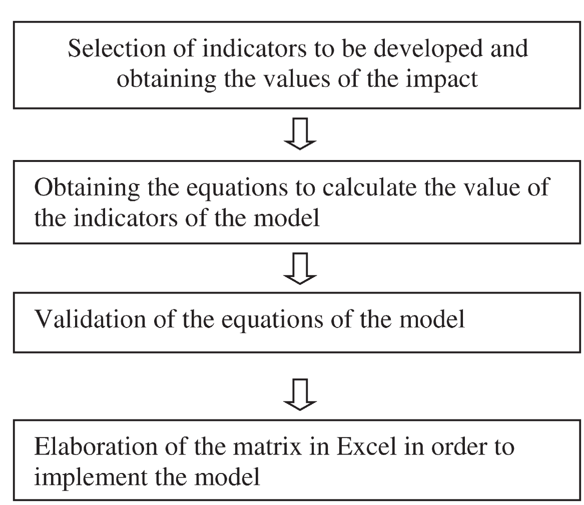

Fig. 1. Methodological overview of the research.