Paper 118. Life Cycle Assessment (LCA) and its role in improving decision making for sustainable development

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Abstract

There is growing interest in life cycle thinking and the whole life sustainability of buildings. The 2011 UK Low Carbon Construction Action Plan identifies the need for clarity on the definition of life cycle "zero carbon" impact as there are various methods of assessment. How do we educate on the various methods? LCA is an established tool that is currently in use to assess this total life cycle impact; however there is no one LCA method that has universal acceptance. For the sustainable development professional this causes a problem as they are unsure as to which particular method they should use.

This paper explores the common methods used to examine the life cycle of a building, focusing on the practical stages to consider for first year through to postgraduate students. What journey should we take the students on to help them understand the importance of LCA and its applicability to sustainable development? Ultimately, we need to educate to enable students to begin work or postgraduate studies with the knowledge and confidence to enable them to improve decision making. Through this paper, an exploration of how we can align a degree program to include LCA is investigated; considering the key stages to be taught at the relevant level.

1 Introduction

Sustainability has steadily increased in focus and complexity over the last decade (Maragakis, 2013). As a result the number of quantitative methods used to assess sustainability has increased. To measure resources we use life cycle assessment (LCA), for consumption we use ecological footprint and for quality we use environmental performance indices. For students studying in the built environment this causes a problem as each method is different and not comprehensively taught on most degree programs in the UK. Students need a fundamental grounding in each these areas to help them make the right decisions. This paper focuses resources and the use of LCA as an assessment technique. This is because it is the most crucial and relevant to students of the built environment. Furthermore, the importance of considering the life cycle impact of a building has been recognised as a way to increase profitability and engender sustainability. As a result, the Royal Institution of Chartered Surveyors (RICS) have developed a method to calculate embodied carbon of buildings (RICS, 2013); the Building Research Establishment (BRE) have expanded their Green Guide to Specification to measure the environmental impacts of individual building materials (BRE, 2013) and the Higher Education Academy (HEA) BIM Academic Forum (BAF) reports that Building Information Modelling (BIM) needs to consider life cycle impacts (HEA, 2012).

With this growing need for consideration of life cycle impact, this study aims to develop the right pedagogy, identifying and explaining how Life Cycle Assessment (LCA) can be introduced into sustainable development teaching and used in practice for both undergraduate and postgraduate

students in the built environment[1]. It serves as a guide to highlight transition from LCA theory into industrial practice. Most importantly it focuses on the modern necessity of LCA in both academia and industry.

2 Why focus on Sustainability?

Since the introduction of the UN Millennium Development Goals, supported by the more business focused UN Global Compact, there is a growing need to focus and measure sustainability on a global and local scale using methods such as the Circles of Sustainability. Students in the built environment are taught about these initiatives and the feedback collated is that these global initiatives, although interesting, do not help students to improve their decision making at a local level. For example, a graduate employed by a construction company may be asked to highlight how sustainability may impact their business. The most importance issues for that company are (1) economic impact (2) future regulation/legislation and (3) competitive advantage.

(1) *economic impact:* Should the construction company focus on building more sustainable homes/offices? Will there be a growing demand for these types of buildings? A more sustainable home will have reduced operating costs over its lifetime and there is an emerging body of evidence highlights how sustainable buildings enhance the productivity and health of occupants, Kats *et al* (2003), Kozlowski (2003) and Lucuik (2005)

(2) *future regulation/legislation:* The building sector has a large global impact on the environment. The building sector accounts for around 25-30% of the total energy consumed in Organisation for Economic Co-operation and Development (OECD) countries (Pearce, 2012). How will this impact the future of the construction industry?

(3) *competitive advantage:* What are their competitors doing? Are they changing the way in which the company operates to meet a future demand and remain competitive?

In order to reduce the environmental, social and economic impact of the building sector, the UK government has announced targets for all new housing to be "zero carbon" by 2016, with new commercial buildings following suit by 2019 (Pearce, 2012). The introduction of this legislation is in advance of the legal requirements of the Energy Performance in Buildings Directive (EPBD) recast for all new buildings in Europe to be 'nearly zero-energy' by 2020 (EU, 2010). As a result should the graduate be advising the construction company to shift its focus and concentrate on the production of zero carbon building materials? But what does zero carbon actual mean? For a building to be "zero carbon" or "nearly zero-energy" there is a need to accurately measure the life cycle impact of the building and at present this causes a problem as data to make informed decisions is scarce. Furthermore, a universal method of measuring embodied carbon does not exist as identified in the UK Low Carbon Construction Action Plan (BIS, 2011) and (Malmqvist *et al.*, 2011) noted additional problems regarding interpretation of results and the high costs of performing a LCA. These are the challenges we face and why knowledge of LCA is essential to help improve decision making.

3 Life Cycle Assessment (LCA) in theory and practice

Life Cycle Assessment (LCA) is the technique used for carrying out quantitative analysis of the environmental aspects of a product or service over its entire life cycle. It is a tool that allows for

[1] This would include students studying in Architectural Technology, Building Services Engineering, Building Surveying, Civil Engineering, Construction Management, Quantity Surveying and Real Estate Management.

analysis of environmental aspects of a product and provides an assessment of the potential impacts on the environment. It has been used sparingly in the buildings sector since 1990 (Fava, 2006) and is based on the International Standards Organisation (ISO) 14040 methodology, (ISO, 2006). From which additional standards have been developed such as the Publicly Available Specification (PAS) 2050. The assessment, as defined by ISO 14040, typically includes an assessment of production, use and disposal of a product. This list is not exhaustive and it is common to develop additional stages for use in different applications, (Finnegan, 2004), (CEN/TC 350, 2008).

If one uses the ISO14040 methodology and applies it to the building sector to compare the life cycle contribution of carbon for a typical commercial building. The results show that around 84% of the total carbon output is derived from the operational phase of the building over its lifetime use (Hue, 2010). Therefore one can use LCA to inform decision making and in this case focus efforts on reducing carbon in the operational stage. If the UK government achieves its aim of zero carbon commercial buildings in 2019, will the total life cycle contribution at operation still be 84%? The answer is no as when buildings become more energy efficient, so the relative importance of the embodied carbon will grow and in a low energy building the carbon associated with materials and construction can be as high as 40% of the total lifetime impacts, (Battle, 2009). In order to achieve a zero carbon commercial building in 2019, a "fabric first" hierarchy is proposed. This entails reducing the demand for heating and cooling; seeking low carbon energy supply and offsetting by generating renewable energy off site. All of which will result in increased carbon emissions through the supply chain and LCA can be used to calculate and evaluate these changes.

Most LCA users will use the ISO14040 or PAS2050 methodology to develop their own basic model in Microsoft Excel with simple inputs/outputs at each stage, as used by (Hue, 2010). Experienced users will use one of the industry standard LCA tools of which there are three main types. A more extensive list of LCA tools is provided by (Khasreen *et al.,* 2009).

(1) Basic: Basic calculations in Excel sheets with simple input and output only covering one or a few environmental impacts. Little or no experience is needed to develop a tool of this type.

(2) Medium: LCA calculations can be made with help of building tools such as Ecosoft, EcoEffect, Equer, Legep, Envest and Beat (ENSLIC Building, 2010). These specific applications have been developed to facilitate the use of LCA in the building sector. Some experience and training beyond that of the basic assessment are required to use these tools.

(3) Advanced: Those users with a detailed understanding of how to build an LCA model can use a more comprehensive LCA tool such as SimaPro or Gabi. Users will be training before they can use these types of tool and they must be able to handle these software applications on a building level (ENSLIC Building, 2010).

With knowledge of why we need to focus on sustainability and how LCA can be used, the next step is to design a framework for teaching in the built environment.

4 Teaching LCA in the Built Environment

Due to market demand, LCA is already incorporated into teaching in the built environment in a number of Universities across the US and Europe. If one considers an undergraduate in the UK starting a degree in the built environment in September 2013, they will graduate with a degree in 2016 and/or masters in 2017. By 2016 all new housing is anticipated to be "zero carbon" and the built

environment will be looking for life cycle experts and people with an understanding of the fundamentals.

When teaching LCA in the built environment it is best to integrate LCA design into existing programs. There is no need to develop new specific modules. There are a number of universally accepted techniques and a number of academics have already integrated LCA into their teaching. Assistant Professor Erin Moore has added LCA as a topic to her undergraduate program at the University of Oregon's Architecture Department. She begins with lifecycle thinking which is first introduced to undergraduates as a means to get students thinking about the ecological connection of the products and processes used during the assembly and life of a building. They are encouraged to "re-think the lifecycle of construction materials to account for the embodied energy, embodied water, and ecological and human health impacts of their production, use, and disposal (or re-use)". Moore teaches hands on practice using LCA tools (in this case SimaPro) and believes that LCA is an important concept for architecture students to understand for two main reasons; so that in the future they can easily evaluate and make better design decisions as well as be able to competently work and discuss analyses with LCA consultants, (Moore, 2010). At Arizona State University (Brundiers *et al.*, 2010) introduces sustainability teaching in years 1 and 2 around simulating the real world and evaluating how sustainability impacts a real world problem. In the later years of the degree program he engages with the real world focusing on case studies linking theory to practice. (Sullivan and Walters, 2013) teach LCA, life cycle costing, Building Information Modelling and Leadership in Energy and Environmental Design (LEED) as part of their construction management degree at the University of Florida. This is in response to a growing industry demand for skills and knowledge in this area from the US Green Buildings Council (USGBC). Not only is there industry demand, students are also beginning to recognise the importance of developing such skills to equip them ready for industry. A report by the Higher Education Academy (Drayson *et al.*, 2012) demonstrates this with 80% of first-year students surveyed reporting they believe sustainability skills are going to be important to their future employers with the majority believing that it is the role of universities and courses to prepare them for graduate employment.

4.1 Framework for teaching

In order to prepare students correctly it is necessary to consider the approached from other academics and the industry need. Year 1 in Table 1 refers to the first year of an undergraduate program and Year 4 refers to a postgraduate masters degree level student. For each year, through a typical degree program in a school of the built environment, an explanation of the key themes that should be taught is highlighted together with an explanation.

Table 1: Framework for including LCA teaching in the built environment

Year 1	Year 2	Year 3	Year 4
Learning	**Methodologies**	**Applications**	**Innovation**
Sustainability in the built environment	Methods of Sustainability assessment	Real work application of sustainability	Future direction and innovation
LCA theory, thinking and	LCA tools, methodologies	Use of LCA tools in the	Future of LCA tools

use	and types	real world	and BIM

4.2 Year 1

The first year of an undergraduate program is about learning and in order to improve decision making in sustainable development it is important to start with the right foundation. Sustainability in the built environment should be focused on a number of key themes as follows:

- *Environmental and impact* – applied learning linked to resources, consumption and quality focusing on why LCA is important in assessing the impact the built environment has in relation to other sectors. The inputs (energy use) and resultant outputs (emissions) and how they impact society. Understanding the true life cycle environmental impact of particular building materials and choices made at the design stage. The BRE Green Guide should be covered along with the basics of BREEAM and LEED.

- *Regulation and legislation* – what is the current regulation and legislation? how robust are they and how will they change in the future? Focusing on issues such as the Carbon Reduction Commitments (CRCs), Carbon Floor Price, EUETS, Climate Change Agreements (CCAs) amongst others.

- *LCA theory* – lecture materials should cover what is a LCA and how does it work? What are the fundamental building blocks? Why is it important to the built environment and how is it used? How is LCA used in the BRE Green Guide?

The type of assessment and examination should be focused on the level of knowledge attained. A typical exam question could be: What the main materials used in the construction of a commercial building and what is the resultant carbon impact? If we change the type of material, what is the resultant carbon and financial impact? What other options are available to provide a more sustainable solution? Another question could focus on future regulation where the student could be asked if new legislation would change the way construction industry assesses sustainability. Finally, a series of tutorials should be used to help students build a simplistic LCA model, starting with mindmaps and moving into more detailed analysis.

4.3 Year 2

Following the first year learning, the undergraduate should focus more on the methodologies and be presented with a clearer understanding of how and why sustainability assessments are carried out. This will begin with lectures and discussions on the various and numerous methods of sustainability assessment. There is then a requirement to link these methods to LCA thinking and start to discuss typical LCA tools that can be used to assess a full life cycle of a product.

In this second year, there are a number of key themes as follows:

- *Sustainability assessment* – methodologies for carrying out sustainability assessment should be followed using examples such as BREEAM and LEED together with an explanation of why they are important, what are their shortcomings and how can they be improved. A review of other methods will also be necessary.

- *LCA tools and methodologies* – linked to the sustainability assessment above, LCA tools such as those identified by (ENSLIC Building, 2010) and (Khasreen *et al.*, 2009)

should be introduced. A review of each tool, its main features and pros and cons should be covered. On completion this will enable the undergraduate to have a clearer understanding of the methodologies and which ones are of particular application to their studies. At this stage it is not the intention for the students to be able to use the models.

Assessment and examination should focus on methodologies. Which method is best and why? What are the shortcomings of current methods? What stage in the construction of a typical building do we introduce LCA thinking and design? Tutorials should again be used to allowing the students to build their own models and test their own theories and ideas.

4.4 Year 3

The final year of an undergraduate degree program in the built environment is about application of knowledge and should cover both sustainability and the use of tools in the real world. The students should be able to use the applied learning from year one and their knowledge of methodologies in year two to understand how they can be used in real world applications.

This final year and should be focused on a number of key themes as follows:

- *Sustainability in the real world* – as early as possible the students should be exposed to particular case studies and/or site visits to existing or new construction projects that assess sustainability. This should follow with further detail and explanation of how sustainability and LCA fits within the design and build of construction projects. Particular focus on the contribution and importance sustainability makes in the design, construction, use and demolition phases.

- *LCA tools in the real world* – One of the most common types of LCA tool used in the industry is GaBi. At this final year level the students should understand why this is the case. How is it used in practice, what data is required and what does it provide as output. Further understanding of its interaction with BIM. Finally it will be necessary to review costs and applications in industry.

Year 3 examination and testing should be focused on the real world and if possible the final year dissertation should be undertaken on a real world case study. At this stage the students should be able to link the applied learning and tutorial work of year 1 and 2 to the production of a professionally written dissertation and completion of an end of year examination. The examination questions should be focused on practical application of LCA in industry.

4.5 Year 4

At masters level, the students should be leading on innovation. They should have a sound knowledge of the principles behind LCA, the methodologies that are commonly used and most importantly how each tool is used in industry. The next step, innovation, should be examining the future direction of LCA and its integration with other processes.

This Year 4 should be focused on a number of key themes as follows:

- *Future direction* – How will LCA be used in the future and what is the best platform for its use in the built environment? The postgraduate students at this level should be designing new methods to integrate LCA with BIM. Researching new techniques to

assess whole life sustainability at the design stage and assessing the impact that zero carbon buildings face.

- *Market drivers* – Future regulation and legislation is key and the students should be lectured and undertake research on the impact of the market drivers. Will LCA become a part of planning law or a legal requirement for new developers? How will the Government use LCA in providing guidance on construction projects?

At masters level, innovation is key and the students should be tested on the future direction of LCA. Focusing on the major changes forecast for the industry and how LCA will be introduced.

5 Conclusion

As the construction industry begins to shift towards a more sustainable business model and government legislation becomes more stringent for industry in terms of sustainable practices, it is imperative that those educated within built environment professions are able to enter industry with the skills, knowledge and awareness of not just their chosen profession but how they can apply sustainability into their everyday working to align with an ever changing business climate. Past curriculum design has focused on educating students in their given professions without thinking how industry is moving forward and changing in light of climate change. The need to broaden students mindset in terms of these issues so they are placed to make real world decisions once in industry is paramount. Building LCA into undergraduate and postgraduate built environment courses will ensure that upon entering industry the professionals of the future are up to speed with a method that can enhance the sustainability of buildings and are ready to hit the ground running. As more and more employers are demanding graduates with these skills those trained on aspects such as LCA will undoubtedly gain an advantage in the jobs market.

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