Sustainable Construction Approach through Integration of LCA and BIM Tools

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ABSTRACT

The construction industry is turning more and more towards sustainability. To achieve sustainability, a balance between environmental, economic and social aspects has to be reached. Therefore these criteria have to be taken into account during the building design phases. LCA is a suitable tool for assessing a building's environmental performance. Nevertheless, it has some issues that need to be resolved for its integration in the design process and use as an assessing design tool. By integrating LCA with other tools, such as BIM, a more holistic approach to sustainable construction could be achieved. Thus already existing tools can create synergies for attaining higher efficiency and sustainable construction. Furthermore, these tools should be implemented from the early project phases onwards, since the capacity to influence the project is greater in these phases. Finally, two different approaches for integrating LCA and BIM are presented in order to highlight future research fields.

INTRODUCTION

The construction industry is facing new challenges. The society demands new infrastructure, reduction in the consumption of energy and resources, and implementation of sustainable construction. There is a need for more cost reduction, quality increase and focus on services, thereby changing the focus of the industry from a cost-driven philosophy into a value-driven one (Sjøgren, 2011).

Due to current concerns about sustainability and environmental impacts of the construction industry, different methods are being introduced to assess environmental performance. One of the tools developed for this purpose is Life Cycle Assessment (LCA), which is currently being fostered as a decision-making support tool for reducing a building's impacts and achieving sustainable design (American Institute of Architects, 2010).

LCA implementation could really contribute to the achievement of sustainability along the project's life cycle (Ortiz et al., 2009). It is a well-known fact that sustainability has three pillars (economic, social and environmental aspects).

LCA methodology is environmentally oriented; therefore it should be combined with other tools for achieving an overall sustainable project (ISO, 2006).

SUSTAINABILITY IN CONSTRUCTION INDUSTRY. BUILDING'S ENVIRONMENTAL IMPACTS ASSESSMENT (LCA)

The development of LCA has been slower in the construction industry than in other sectors, despite the fact that it was first implemented in 1990 and is an important tool for achieving sustainability in the building process (Khasreen et al., 2009). While the instructions given in the various LCA standards fit well to industrialized processes, they do not fit so well when dealing with buildings due to a number of special features. The long life cycle of a building and the fact that each product is unique greatly influence the implementation of LCA in this field. Therefore, some special considerations have to be taken into account when applying LCA guidelines to buildings (Arena & De Rosa, 2003), since such guidelines do not create a specific methodology for performing the assessment, but only constitute guidelines and requirements (The World Bank Group, 2012).

As a starting point, in order to obtain the greatest benefit from LCA performance, the following question should be answered: When must LCA be implemented so as to achieve the most efficient results for the project? To find the answer to this question, it is necessary to identify those phases which have the highest potential for influencing the project.

The design phase, for example, has a high potential for adding value to the project. At this point, the project is really flexible. In the construction phase, on the other hand, the project has already lost flexibility and only small changes can be made. The capacity to influence the project becomes smaller as the project progresses. The initial phases have great potential for implementing changes, studying different alternatives, improving performance, and reducing costs (Burke, 2001). Therefore, the design phase should be considered as the first stage for achieving sustainability, as has been accepted by the British government: "Good design is synonymous with sustainable construction" (HM Government, 2008).

From this it follows that the implementation of LCA as a decision-making tool in the early phases contributes in a more efficient way to sustainable project development.

Main advantages of LCA as a decision-making tool. As previously mentioned, LCA has a high potential for assessing decision-making in the early project phases. It can guide material selection, help to compare alternatives, support the planning of the procedure for residues management, aid the development of the construction plan, etc. It also highlights the main opportunities for improving environmental performance along the whole life cycle. LCA methodology makes it possible to compare the environmental performance of different buildings and to learn from this experience (ENSLIC, 2007). Furthermore, a wide variety of environmental aspects can be analyzed in addition to energy consumption (Buyle et al., 2012).

LCA facilitates cost minimization, since it reduces environmental costs and contributes to a reduction in energy and resources consumption (ENSLIC, 2007). It also contributes to an increase in social awareness concerning environmental impacts. Currently, the costs of environmental impacts are not included in the final budgets; thus the chance to show the environmental costs and effects of a specific construction helps to achieve sustainability. The society must be conscious of the real costs that environmental impacts have (Buyle et al., 2012).

Main limitations of LCA. Despite the clear advantages of LCA for the construction industry, it also has some inherent limitations. There is still a need for development and improvement, and special care should be taken when analyzing results (Buyle et al., 2012).

Before LCA can be applied, some particular requirements have to be fulfilled. An expertise is needed for its execution and specific software for its performance. Furthermore, a complete database must be available, since the quality of the analysis depends on the quality of the data. In addition, LCA could be a very time-consuming task (The World Bank Group, 2012).

Data availability can be highlighted as one of the main difficulties involved in developing an LCA assessment. Sometimes there are simply not enough data or the available data are of limited value because they are not up to date or do not fit the standard requirements (Jensen et al., 1997). All this leads to assumptions, which increases the inaccuracy of the assessment (American Institute of Architects, 2010).

There is a lack of standardization and fixed methodology with regard to LCA performance (American Institute of Architects, 2010). The valid ISO standards concerning LCA provide a general framework, but do not give a unique methodology (ISO, 2006).

The building itself is made up of a wide variety of products, each with its own characteristics, life span and varying relevance concerning environmental impacts. Moreover, there is uncertainty concerning the building's future use, maintenance or refurbishment. All these reasons make it very difficult to assess the whole building as a single product (Tritthart et al., 2010). Different assumptions have to be made concerning the different stages of the life cycle, thus increasing the uncertainty of the assessment (Buyle et al., 2012).

Another problem is the misuse of LCA due to its implementation in the late phases of the project. In Europe many LCAs are developed for certification purposes instead of being used in the early design phases as a decision-making tool (Tritthart et al., 2010). For the implementation of LCA as a decision-making support tool a large amount of data is required during the early project phases. However, fewer project data are available in these phases. Currently, the required data are collected from the 2D drawings and have to be entered manually in the LCA software, but this process is laborious, time-consuming and cost-intensive. Hence LCA assessments are frequently undertaken during the late project phases or when the building is already finished. This situation could be improved if LCA was combined with BIM, since the data required for performing an LCA during the design phase could be obtained directly from the BIM software (Eastman et al., 2011).

All the above mentioned limitations relate to the complexity and costs of the procedure, a lack of accuracy and the difficulty of data access and interpretation (ENSLIC, 2007). Further development is needed if LCA is to be implemented effectively as a decision-making tool. LCA methodology has several drawbacks which could be solved by integrating it with BIM.

APPROACH TO SUSTAINABLE CONSTRUCTION: INTEGRATION OF LCA AND BIM

Sustainability in the construction industry depends on achieving the lowest possible environmental impact while encouraging social and economic development. Currently, the industry is inefficient due to a lack of cooperation and subsequent waste of resources. Therefore some form of change is needed (Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2013).

Integrated design should be seen as a key factor in achieving sustainability, since it focuses efforts in the early design phases (McGraw Hill Construction, 2010), which means a higher capacity for influencing the project and adding value.

The construction industry is aiming to use the knowledge and technology available to achieve sustainability in all its activities (Chong et al., 2009). Currently, the industry has powerful tools such as BIM and LCA, which hold great potential for sustainable construction.

BIM can be highlighted as an important contributor to sustainability, since it supports the implementation of integrated design. It has a great capacity for information management and supports collaboration of the different stakeholders involved in the project from the early design phases onwards. This provides an overview of the project, and the construction industry can perform more effectively (McGraw Hill Construction, 2010).

Moreover, by eliminating the need to reenter the same data, the use of BIM helps to avoid unnecessary waste of time and resources caused by inefficient data management. It has been estimated that, at present, in the construction industry, the same data may be entered up to seven times (Sjøgren, 2011). Indeed, manual reentry of the project data into the LCA tool is one of the main drawbacks that have to be overcome (Eastman et al., 2011). By successfully integrating LCA and BIM, these issues could be resolved, since the LCA tool could directly access the data of the BIM model.

BIM can be used to enhance sustainability with positive impacts on the respective three pillars. BIM models contain information on the cost of the project and facilitate cost reduction in sustainable design, since they provide the necessary information and analyze it. BIM implementation also improves a project's efficiency and increases coordination, so that any waste of energy and materials is reduced. With regard to the social dimension, the analysis and simulation of different parameters would be really complicated if BIM-based tools were not used due to the hard task of entering data. Thanks to BIM implementation, complex analysis, such as daylight, can be performed in order to create better working or living conditions. Nevertheless, its capacity for improving environmental performance could be enhanced through integration with LCA tools.

BIM is a tool with great potential for achieving sustainable design, but currently this potential is still underused. One of the main reasons for this is the lack of interoperability (Nisbet & Dinesen, 2010). BIM's potential for sustainability could be enhanced by creating synergies with other existing tools, such as LCA.

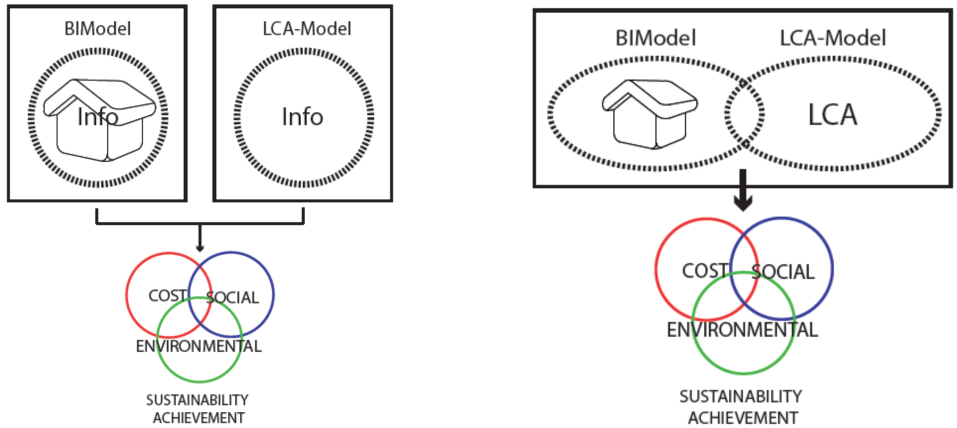

Figure 1. Comparison between non-integrated and integrated approach to sustainability.

Different approaches to BIM and LCA integration in decision-making. Two different approaches for integrating BIM and LCA will be presented:

On the one hand, automatic extraction of the building data directly from the BIM model supports the performance of LCA. The results of the assessment can be used for comparing alternatives in the early design phases. Some of the main characteristics of an efficient decision-making tool are given in the following.

It is important to avoid manual data reentry. The data should be taken directly from the BIM model. Moreover, the integrated tool has to be easy to use for non-experts. If the tool is to be implemented in the early design stages by engineers and architects, its use should be easy enough to encourage them to integrate it into their normal skill set.

Real-time assessment is also desirable. One of the main problems of conventional LCA tools is that they are very time-consuming. If the integrated tool is to be used for decision-making, the assessment procedure must be quick. It has to provide a real-time assessment and facilitate the evaluation of different alternatives within the framework of the integrated design process. Moreover, there should be a comparison between different alternatives for selecting the solution with the best performance.

It must be possible to assess the whole building. At the same time, the integrated tool should allow the user to select particular elements to be evaluated for materials selection or solution definition purposes. Moreover, users need to have the possibility of selecting different environmental indicators to be calculated for adapting the assessment to the needs of the client or designer.

There ought to be link between the information in the BIM model and that in the LCA databases. As a first approach, some of the information on the main environmental parameters could be included among the features of the BIM objects. Therefore, if this information is presented together with the remaining features of the

BIM objects (e.g. length, weight), the designer will be able to consider environmental criteria when selecting materials. Indeed, relating information could be seen as the first step towards achieving a link between BIM and LCA.

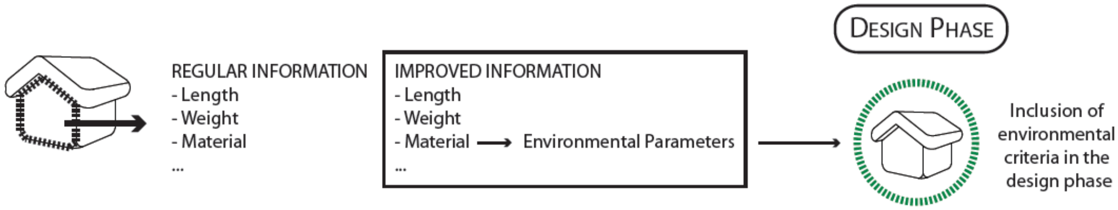

Figure 2. Environmental information included in the BIM model.

Moreover, a list of the different components of the BIM model and their properties (including environmental information) can be generated in order to estimate the LCA of the whole building. This assessment will be material-oriented due to the fact that it is based on combining information on the different materials and components, instead of considering the whole construction process. It is less accurate and complete than the assessment of the building as a whole, but it could be used as an easier first approach for including environmental criteria during the decision-making process in the early design phases.

CONCLUSIONS

The aim of this research is to highlight the importance of the early design phases and the integration of LCA and BIM with the purpose of achieving an assessment that covers the three main pillars of sustainability. There needs to be a link between BIM models and LCA information. Currently, the costs of the proposed design can be estimated in the early design phases. This should likewise be possible with regard to the environmental performance of the building.

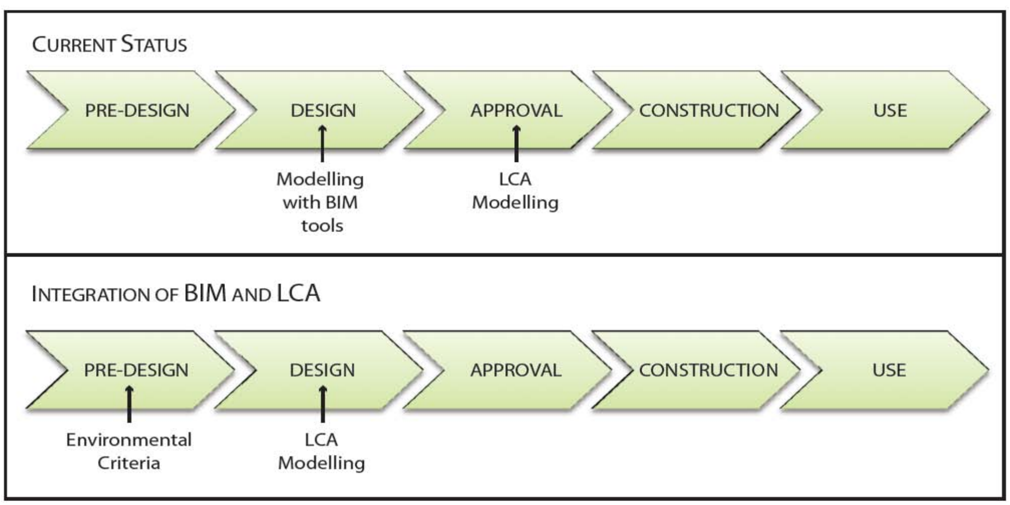

Figure 3. Comparison between current procedure and integration of BIM and LCA.

Of the two approaches presented here for integrating BIM and LCA, the first one, which is based on the assessment of the whole building along its life cycle, is more accurate, but it has not yet been completely achieved. The second approach, which is based on including LCA information in the BIM objects, could be used as an initial step towards achieving integration. At the same time, it may also be the first measure towards including environmental information in the early design phases.

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