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Integration of life cycle assessment in a BIM environment

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Abstract

Currently, the construction industry is turning towards sustainability. Nevertheless, in order to achieve a sustainable performance, a balance between environmental, social and economic criteria has to be created. There are already different tools available which have the potential to reach this goal. It is necessary to identify them as such and find out how they can be integrated to obtain synergies and contribute to sustainable construction. These tools have to be implemented in early design phases so as to add value to the project. In the present paper, two powerful methods, namely BIM and LCA, will be highlighted. Such methods can be of great assistance in the context of sustainability. On the one hand, BIM supports integrated design and improves information management and cooperation between the different stakeholders throughout the different project life-cycle phases. On the other hand, LCA is a suitable method for assessing environmental performance. Both LCA and BIM should be integrated in the decision-making process at an early stage with a view to achieving a holistic overview of the project, including environmental criteria, from the beginning.

Keywords: Building Information Modeling (BIM); Construction Industry; Design Phase; Integration; Life Cycle Assessment (LCA); Sustainability.

1. Introduction

The construction industry is moving towards sustainability. At the same time, the sector is facing new challenges. Costs need to be reduced, while quality has to be improved. In addition, further demands, such as reducing energy and resources consumption, must be met (Sjøgren, 2011).

Sustainability is generally described as being based on environmental, social and economic aspects. Ideally, there should be a balance between these three pillars. In other words, sustainable construction may be characterized as having the lowest environmental impact while enjoying a high level of social and economic development (Hakkinen, 2008).

At present, the construction industry is inefficient, and there is a need of change. Such inefficiency is mainly caused by industry-specific features, such as lack of cooperation and wasted resources (Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2013).

One of the aims of the construction industry is to profit from the knowledge and technology currently available for achieving a sustainable performance (Chong et al., 2009). There are already a number of assessment tools in use with regard to construction, but they do not provide universal evaluation. Such a tool must be able to evaluate construction performance based on various criteria and, at the same time, integrate the information in the design framework. In this way, it becomes possible to compare different alternatives (Hakkinen, 2008). Among the already existing tools and methodologies that can be applied in the construction industry are Building Information Modeling (BIM) and Life-Cycle Assessment (LCA). However, in most cases, these tools are not being used beneficially.

This paper will assess the properties of both methodologies, showing how and in which project phases they should be implemented so as to improve performance in the construction industry.

2. Change in the Construction Industry. Integration of LCA and BIM in the early design phases

The construction industry is turning towards sustainability. In order to achieve this aim, a balance between environmental, economic and social aspects has to be reached. Consequently, these criteria have to be taken into account during the design phase.
2.1. Project’s phases with higher capacity to influence the project (design phase)

This section highlights the project phases which can have the greatest influence in terms of achieving sustainable construction.

The early design phases are the ones which have the greatest influence on the project as a whole due to the fact that project planning is more flexible at this stage. As the project evolves, flexibility is reduced, and the chance of making changes is smaller, or making changes involves higher costs. During the early phases, there is more potential for studying different alternatives, reducing costs, implementing changes and improving performance (Burke, 2001). The design phase can thus be considered as one of the key phases in achieving sustainability, as has been highlighted by the British government: “Good design is synonymous with sustainable construction” (HM Government, 2008).

Sustainable design has to be meticulous, with increased effort in the early phases due to the fact that decisions made during this time will significantly influence the project as a whole. At the same time, the entire construction life cycle has to be considered. It is important to view sustainable construction not as a complicated or expensive trend, but as a form of integrated design, where all components of a given project are seen holistically rather than individually (C-SanD, 2001). It can be said that integrated design is a key factor in achieving sustainability (McGraw Hill Construction, 2010).

Various alternatives have to be compared in the early design phases with a view to selecting the most suitable one, based on the three pillars of sustainability. For this purpose, a huge amount of information has to be dealt with. This is one of the main reasons why, at present, sustainable methods are often implemented in the later project phases, when the final solution has already been developed. However, at the point, the potential and capacity for influencing the project are greatly reduced (Hakkinen, 2008).

Thus it follows that sustainable methods such as BIM and LCA should be applied in the early phases so as to be fully integrated in the decision-making process.

2.2. Information management (BIM)

The use of Building Information Modelling (BIM) has the potential to improve the overall information flow, thereby achieving better project performance and quality. Moreover, this tool enhances transparency and collaborative work between the stakeholders. The resulting improvement in communication leads to waste reduction and helps to avoid future errors (HM Government, 2012).

BIM greatly supports integrated design due to improved collaboration between the stakeholders and a better overview of the project as a whole (McGraw Hill Construction, 2010).

With the help of BIM, both time and resources can be saved. In fact, it has been estimated that in the construction industry the same data may be entered up to seven times (Sjøgren, 2011). This could be avoided by using BIM models as an information source.

The particular features of BIM make it into an appropriate method for achieving sustainable construction. It has a positive impact on the three pillars of sustainability. Firstly, with regard to economic aspects, the better quality of information leads to cost reduction. Various alternatives can be analyzed in the early design phases of a project, which improves efficiency and decision-making. Secondly, with regard to social aspects, BIM-based analysis and simulation make it possible to assess different parameters, such as daylight, which leads to an improvement in working and living conditions. Such assessments are more complex without the use of BIM-based tools. Thirdly, with regard to environmental aspects, BIM software can be applied in different ways, e.g. energy analysis (Autodesk, 2005). It should be pointed out, however, that its capacity for evaluating environmental issues will be enhanced if it is integrated with LCA tools.

Generally, it can be said that BIM has a huge potential for achieving sustainability in the construction industry. However, it is currently underused mainly due to a lack of interoperability (Nisbet & Dinesen, 2010). By creating synergies with other methodologies, such as LCA, the overall scope of BIM could be increased.

2.3. Environmental criteria in the early design phases (LCA)

At the present time, there is growing concern about the environmental impacts of the construction industry. Life-cycle assessment (LCA) can be seen as one of the most suitable methods for assessing such impacts as a whole (American Institute of Architects, 2010).

LCA may be used as an assessment tool for decision-making in terms of sustainable construction (Ortiz, et al., 2009). However, it has some drawbacks that need to be solved before it is integrated in the design process.
One of the main drawbacks of LCA is that it depends on the quality and availability of the data. It is frequently the case that there are simply not enough data or the available data are not up to date or below standard. This will lead to assumptions which, in turn, make the assessment inaccurate (American Institute of Architects, 2010).

The lack of project information is an obstacle for LCA performance during the early project phases and, as such, one of the reasons why, in the majority of cases, LCA is performed after the design phase. As a matter of fact, in Europe, LCA is often only done for certification purposes after the building has been completed (Tritthart, et al., 2010). As mentioned above, the phases with the highest potential for influencing a project are at the beginning. Therefore, in order to improve overall environmental performance, LCA tools have to be implemented in these early design phases. Indeed, manual re-entry of project information into LCA tools constitutes a major problem as it is a redundant, failure-ridden and time-consuming task. As a rule, the data are already contained in the building model, so there is really no need to enter them again. If the building information has to be re-entered, the risk of mistakes and misunderstandings increases. By integrating BIM and LCA, this problem could be solved, since the LCA tools would have direct access to the BIM information (Eastman, et al., 2011).

As a matter of fact, there is a general lack of standardization concerning LCA procedures. The existing ISO standard provides a general framework, but does not indicate individual methodology (American Institute of Architects, 2010).

Environmental assessment of the entire building is a complex procedure due to the multifaceted constructions, which, in themselves, are made up of a wide variety of products. Each of these products has its own features and life span, which means that they have varying relevance with regard to environmental impacts. There is also uncertainty concerning the use phase of the building (Tritthart et al., 2010) and therefore assumptions have to be made, which, in turn, increases the inaccuracy of the assessment (Buyle et al., 2012).

The construction industry is well known for its complicated nature, which makes the implementation of LCA methodology more difficult. Each of the projects has its own characteristics, specific location, features, etc. Therefore an individual assessment for each project is required considering its different conditions. An automatic LCA calculation in the mean time is not accurate because of several reasons; one of these reasons could be the difficulty of considering transportation issues, which have a noticeable impact on the environment.

It would be possible to solve some of the main drawbacks by integrating LCA and BIM tools. The three main pillars of sustainability (i.e. environmental, economic and social aspects) could be taken into account in the early design phases and thus approached more effectively.

### 3. Integration of LCA and BIM

The advantages of integrating LCA and BIM in the early design phases with the purpose of achieving a wider approach to sustainable construction are clear. Nevertheless, the integration of LCA in the BIM framework could be approached from different perspectives. Two different proposals for this integration are going to be presented below.

#### 3.1. First approach: Direct access to the BIM model information to calculate the LCA performance

The information required for performing an assessment of the complete construction project during its entire life cycle can be obtained directly from the BIM model, since this model is created during the early design phases and contains the main features characterizing the construction. By drawing on this information, manual data re-entry into the LCA software, which is one of the main drawbacks of the LCA performance, will be avoided.
Figure 1. First suggested approach for LCA and BIM integration.

Despite the fact that some research and software are already available in relation to achieving effective integration of LCA and BIM, further development is required in this field. LCADesign can be highlighted as an example of current achievements. It is an automatic take-off tool that extracts information directly from the BIM model, using IFC as a data-sharing format. LCA is performed by combining the quantity building data obtained from the BIM model with the life-cycle inventory data in order to obtain different environmental indicators. LCADesign also makes it possible to compare different alternatives (Tucker et al., 2003). Ecquate Pty Ltd, which is the company in charge of managing the software, has temporarily withdrawn it from the market for improvements with a view to assessing bigger structures and civil projects.

Advantages of this approach:

- Avoids manual data re-entry
- Different alternatives can be compared. The results will highlight the hotspots where intervention is required and thus enhance environmental performance.
- Evaluates the entire life cycle of the building, thus achieving a more accurate approach to LCA evaluation. Makes it possible at an early stage to calculate the environmental performance of the complete building from beginning to end.
- Different environmental indicators may be used for assessment.
- Real-time assessment, which means that it can be employed as a decision-making tool.

Disadvantages of this approach:

- As the performance of the LCA is not developed in the BIM software itself, any changes in the BIM model can only be made by going back to the BIM software and then re-importing the model into the LCA platform.
- Interoperability between BIM models and LCA tools has not been fully developed yet. Up to now, this problem has been solved by transferring the model information via IFC format into a common database, where it can be combined with the LCA inventory database. Therefore one of the challenges now is how to extract the BIM model information effectively and import it into the software for LCA performance.
- There are also some difficulties involved in performing the LCA of the complete building during its entire life cycle.

3.2. Second approach: Environmental properties included in the BIM objects

This second approach seeks to find an automatic and efficient link between BIM models and environmental information included in the life cycle assessment databases.
Figure 2. Seeking an automatic and efficient link between BIM models and environmental information.

With this approach, the features of the various BIM objects (information) include environmental properties based on LCA calculations. There are already a number of libraries which describe the different characteristics of BIM objects. One could thus incorporate the relevant environmental information pertaining to these objects (which were previously calculated with LCA methodology) with the other properties. In this way, it would be possible in the pre-design and design phases to include environmental criteria in the decision-making process regarding the selection of materials and building elements. Consequently, when the designer is selecting the different elements to be included in the model, the planner can also take into account the environmental performance of these elements, as shown in Figure 3.

Figure 3. Second suggested approach for LCA and BIM integration.

Once the model is ready, a list can be made of the different components and their properties. It is then possible to take information from this list for the LCA of the building. For example, a spreadsheet can be used for relating building quantities to LCA database information. The resulting assessment will be mainly material-oriented, since it is based on information referring to different materials and components. Moreover, it is just an estimation for use up to the construction phase, because it is too difficult to evaluate the entire life cycle with such simple tools.

Nevertheless, this procedure might constitute an initial step in integrating and relating information from the building model and the LCA databases.

Moreover, for achieving an efficient use of the environmental information included in the smart-objects, designers have to be trained. It is important that designers are able to understand the environmental information given and its meaning in order to be able to compare between different alternatives. Therefore, this information has to be presented in a clear way.

Advantages of this approach:

- Environmental information is included in the properties of the BIM objects, which means that environmental properties are on the same level as other properties regarding the construction elements and may be used as
decision-making criteria. Moreover, designers and engineers will get used to including environmental criteria in the regular decision-making procedure.

Disadvantages of this approach:

- It is less accurate in terms of calculating the LCA of the whole construction.
- Although it may be considered as an initial step in integrating the model information with the information included in the LCA databases, further developments are needed to improve the efficiency of this approach.
- It is still unresolved the issue of calculating and automatically including the information related to transportation of the different materials and elements to the construction site, considering the different characteristics, location, and features of each project.

4. Conclusion

One of the main aims of integrating LCA and BIM is to obtain a convenient decision-making method. Obviously, it must be easy for the designers to apply such tools on a day-to-day basis without being LCA experts. If greater effort is required, they will not use the tools adequately. Indeed, a lack of information must be seen as a general obstacle irrespective of which tools are used for life-cycle assessment.

With regard to the two approaches which have been presented for integrating LCA and BIM, it can be concluded that the first one, which is based on the assessment of the entire construction life cycle, is more accurate despite the fact that it is more complex, and further development is required in this field. The second approach, which is mainly material-oriented, may be seen as a way of including environmental criteria on the same level as other features in the early design phases in terms of selecting materials, products and elements. In other words, it highlights the importance of environmental criteria during the decision-making process.

Ongoing research shows that the second approach is not as suitable as the first approach with reference to the LCA of the whole construction because it is generally less accurate. Nevertheless, it could be viewed as a starting point for the inclusion of environmental criteria in the early design phases.

References


