LCM at the Urban Scale: BIM and Nature Based Solutions

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Abstract Access to data on built environment databases makes nowadays possible generating models of the urban spaces to facilitate visualization and analysis of information and synthesize it in sustainability indicators to support urban planning decisions. Life Cycle Assessment (LCA) can greatly benefit from this wealth of potentially available information. The use of LCA data in models developed in Building Information Modelling (BIM) platforms is likely to facilitate the implementation of quantitative environmental assessment in the construction field and their extension, from the building to the city level. Within sustainable urban planning and management, also Nature-Based Solutions (NBS) play a potentially important role, although benefits, co-benefits and costs associated with NBS projects still remain not sufficiently understood. All those aspects have been discussed via the presentation of case studies, proofs of concept and experts' visions within this session.

1 Introduction and Scope of the Session

An assessment of energy and environmental performances of building stocks at large spatial scales is increasingly needed for decision support in sustainable urban planning and policy making. While current bottom-up building stock models have mainly focused on the operational energy use up to the last decade, a more holistic environmental assessment of the different stages of buildings life cycle is now required. However, extending a Life Cycle Assessment (LCA) model from the

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building to the district or city scales entails a number of methodological and operational challenges.

LCA as inventory and environmental impact assessment tool can largely benefit from datasets and knowledge base frameworks based on Building Information Modelling (BIM) and Nature-Based Solutions (NBS). The use of BIM has the aim to help engineers to design digital models and share building information in an interoperable and reusable way [1]. However, firstly to apply BIM concepts designers create 3D models of buildings hinging upon built-in databases, which are not interoperable with the analysis tools used in LCAs of buildings. This hampers the quantification of the potential environmental impacts of buildings using those materials databases to support the decision-making process [2, 3]. Secondly, the modelling of a detailed BIM is time-consuming and especially in early design phases detailed information is usually not yet available. To this end, basic 3D models can be used to do simplified LCAs of buildings and neighbourhoods and compare variants in early design, when the optimization potential is high. Thirdly, a number of standards and data formats for 3D modelling and visualization of buildings and cities have been developed, e.g. CityGML [4, 5]; however, these models are often not used in planning and operation, partly because of problems with interoperability and partly due to the efforts to keep the models up to date [6].

Finally, BIM-based sustainability in the construction sector relates, at higher scales than single buildings, with the sustainability of urban planning and management, and therefore to the efficient use of resources and impact mitigation measures in cities. In this regard, it is worth observing that the improvement of cities' sustainability is nowadays supported through the explicit implementation of Nature-based Solutions (NBS) [7, 8] in urban planning. Those represent, among others, a means to activate impact mitigation measures in cities [7, 9]. How to harness NBS to promote well-being in urban areas does represent another challenging and timely research theme [10, 11], which is not explored in the LCA context. NBS strictly belong to the sustainable management of natural resources, urban spaces and technological know-how. Their introduction in urban contexts (at the spatial level of building, neighbourhood, or whole city) is recommended for several reasons, such as to reinforce the social cohesion and reduce poverty, and enhance the provision of urban ecosystem services and biodiversity. However, the impact of NBS projects, in terms of benefits, co-benefits and costs is still not sufficiently understood. Hence, the study of NBS related impacts, based on an LCA approach, could facilitate the interpretation of the sustainability dimensions underpinning NBS.

This LCM2017 conference session explored the challenges mentioned above via some case studies, proofs of concept and a discussion based on different experts' visions. The objective was to offer an overview on some methodological and applied advances that, from building to city scales, may open up concrete opportunities for: (i) a better exploitation of urban resources, data and know-how (i.e. integration between BIM and LCA), and (ii) a smooth transition towards sustainable and resilient cities (i.e. assessment/implementation planning of NBS with a life cycle thinking approach).

2 Summary of the Session's Presentations

2.1 *Building Information Modelling Applications*

Impacts embodied in the building components (materials, etc.) have a more and more important role in buildings, considering the transition process from traditional buildings to energy-efficient buildings. In order to trace these embodied impacts efficiently, tools like BIM help in keeping track of inventory data for building construction elements, as well as technical installations, such as ventilation systems.

This was the subject of the first presentation, **“Life Cycle Assessment of a Ventilation System in and Office Building in Trondheim”**, by **Alexander Borg**.

In this study, a BIM model was used to find inventory data on a ventilation system. A supplied dataset was used to create the inventory for the embodied impacts in the building components, and energy simulations allowed the calculation of the energy demand throughout the use phase of the building. A dynamic methodology was applied to better encompass the long lifetime of buildings. The results showed that energy use accounts for the majority of the impacts for most impact categories, but embodied impacts have a larger share of emissions than previously shown in literature, although total impacts coincide with literature data.

From the presented study emerges how BIM-LCA integration needs a collaborative process and data sharing. In order to benefit from BIM not only in the advanced stages of a project, but also in its early stages, there is a need for a simplified, design-integrated method based on early BIM models with limited information. The presentation of **Alexander Hollberg** (**“Design-integrated LCA using early BIM”**) dealt with the potential of BIM technology to facilitate the application of LCA in the early design stage of a building. Early design stages are in fact very important for building's environmental impacts mitigation. Building's life-cycle impact can be significantly reduced by choosing materials with low embodied impacts at early design stages [12, 13]. However, the number and complexity of the decisions to be taken in this phase and typically the lack of knowledge on which decisions have the highest impacts on a building's environmental performance, often lead designers to postpone decisions to later stages of the design process. A high potential to facilitate this early stage decision process is seen in the use of BIM [14–16]. However, while BIM is more and more applied in detailed design stages, simple 3D models are typically used to compare design variants in early stages. A simplified, design-integrated method based on these early BIM models with limited information was thus introduced, which uses simple 3D geometry and a parametric LCA model. The method was applied to the conception design of a residential neighbourhood.

The integration between BIM and LCA should in any case hinge upon a mutual transfer of information: BIM data in the LCA framework and LCA results back into the BIM database. However, this full integration poses interoperability issues. The presentation by **Adélaïde Mailhac** (**“A proposition to extend CityGML and ADE Energy standards for exchanging information for LCA simulation at urban**

scale”) addressed the potential of BIM to reduce efforts during the data acquisition phase in order to facilitate the challenging task of extending LCA studies from single buildings to complex systems as districts, urban facilities and territories. To date, LCA data requirements have not been fully integrated into the CityGML format nor its Application Domain Extensions (ADE). The presenter proposed an extension of CityGML and Energy-ADE standards for exchanging information for LCA simulation at urban scale. The scope of the study was limited to the integration of information necessary for LCA of buildings’ construction and renovation.

2.2 *Nature-Based Solutions*

When looking at the whole scale from building to city, the application of an LCA perspective can help disclosing the real benefits of NBS for the renaturing and sustainability of urban systems. The study entitled “**Dynamic Assessment of Nature Based Solutions through Urban Level LCA**”) and presented by **Özge Yılmaz** anticipated the basis to obtain a comprehensive environmental assessment of NBS to address urban challenges. The H2020 project Nature4Cities [11] was introduced and its overarching approach for modelling urban ecosystems, which in one work package integrates LCA and urban metabolism (UM), was described. Performing a dynamic assessment with time series data was suggested as a way to promote the identification of hotspots within a determined time frame, allowing the assessor to categorise and mitigate extremes and make informed decisions on desired temporal patterns. In the authors’ view, data needs for the dynamic assessment is supported by two simulation methodologies: BIM for the built environment and Agent Based Modelling (ABM) for social behavioural patterns.

Finally, the last session’s presentation complemented the previous ones by exploring whether or not different spatial distributions of possible NBS implementations in the city (as a function of the topological structure of the urban system itself) can make a difference in terms of quantification of the desired beneficial effect (such as carbon uptake). This was the topic of **Marlène D.F. Boura** (“**How does the spatial distribution of green within cities impact carbon flows? A European scale analysis**”).

3 **Issues Discussed and Future Perspectives Identified**

The case study discussed by Alexander Borg has shown how the use of an external tool, like Excel, as an intermediate step for inventory modelling is very time consuming and not optimal to ensure a convenient use of a BIM-LCA model. There is potential for automation of this process, but it is important to first being able to ensure the reliability and transparency of the data used in an automatic data transfer

process. The automation of information transfer from external data sources to BIM is one of the current challenges that BIM-LCA integration has to face.

Ongoing research shows that ventilation systems can contribute significantly to increase GHGs emissions, especially considering that these systems do not always work properly from the start, and faulty equipment must be replaced, thus generating additional emissions through materials and labour. The presentation showed that, given the role they play in buildings performances, embodied impacts of ventilation systems should be reduced, via increased recycled and recyclable materials content, and taking into account also alternative ventilation methods like hybrid natural ventilation.

The “early BIM” approach presented by Alexander Hollberg raised a lot of interest in the audience. A question was asked about the comparison between the impacts of a building where environmentally sound decisions are taken at the early stage and one where these decisions are taken only at later stages of the design. The comparison has not been done so far by the authors, but the same systems boundaries were used in the early stages as they would apply to later stages. As pointed out by one of the attendees, the approach presented is similar to the one taken by other tools used for LCA in building design, especially TallyTM. However, as Alexander Hollberg highlighted, the main difference lays in the full integration into the design process. Their approach provides instant feedback while changing parameters, which is a unique feature in the current state of the art. Furthermore, they combine operational energy demand calculation and the embodied impact calculation in one method. This kind of approach appeared slightly different from a “conventional” BIM approach. The authors call it “early BIM”, because they link information to the geometric 3D model. Conventional BIM, such as Revit models, contain more detailed information stored in the 3D model. This results in a more complex model which cannot be adapted as quickly as simple 3D models. Therefore, they use the simple models in early stages, which can then ideally be enriched with detailed information throughout the design process.

The topics discussed by Adélaïde Mailhac gave an interesting overview of the potential of BIM use in an LCA framework, explaining that BIM can be used in every phase of the LCA, not just in the early conception stage. However, data availability in the right format (e.g. CityGML compliant data) still remains a problem, since data is not provided easily by every actor, public or private.

Finally, the approach presented by Özge Yılmaz intrigued the audience due to its modular structure, which integrates different approaches. It also raised concerns about the seamless incorporation of ABM, which is a dynamic simulation tool, with a rather static LCA approach. The presenter recognized that LCA provides a snap-shot of environmental impacts over a given period of time and a shift from static LCA to more dynamic LCA is certainly necessary for successful integration of ABM and LCA. A second observation concerned the suggestion to include not only the behavioural patterns, but also consumption patterns in the ABM simulations. This aspect will be taken into account in conjunction with an urban metabolism approach within the Nature4Cities project.

Another question was asked about the actual sustainability assessment of NBS. In other words, NBS are nowadays often sought because they are capable of improving a certain element of an urban system, improve its performances with respect to a specific aspect (e.g. green facades to improve the thermal comfort in buildings and reduce heating and cooling loads) or supposedly increase people well-being. But is the lifecycle sustainability of NBS systematically assessed? Are we ready to provide holistic assessments of NBS, or are we rather running the risk of swooping on NBS without evaluating any possible side effect? The answer to this question can be found in the consistent application of holistic (lifecycle based) assessment of NBS, as proposed in Nature4Cities.

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