INFORMATION MODELING AND SIMULATION TO SUPPORT SUSTAINABLE CONSTRUCTION

Souheil Soubra, PhD / Head of division, souheil.soubra@cstb.fr
Julien Hans, PhD / Head of division, julien.hans@cstb.fr
Guillaume Picinbono, PhD / Senior engineer, guillaume.picinbono@cstb.fr
Centre Scientifique et Technique du Bâtiment (CSTB), France

ABSTRACT

The transformation process towards sustainable construction will be greatly improved by the adoption of Information Modelling combined with simulation capabilities. Indeed, the impacts of the built environment upon global climate change as well as associated economic and political issues represent complex and multidisciplinary challenges to which the construction industry must respond through the implementation of innovative business processes as well as systems integration both facilitated by information technologies.

In particular, the coupling of BIM (Building Information Model) with information about environmental dimensions of building materials and components (e.g. carbon footprint, energy performance …) allows simulation packages to predict the effects of using different materials / components in various conditions. This will produce significant advantages to the designer by allowing to take into account the environmental impact of the building over its lifecycle. Many factors can then be considered such as the use of potentially lower carbon footprint materials and their energy performances along with trade off's associated with the cost implication and the use of renewable energies.

In that context, the paper will address R&D conducted by CSTB and aiming to develop a BIM based prescription tool coupled with environmental assessment functionalities. This tool allows to import a BIM / IFC coming from the architect and then, depending on the performances to achieve (e.g. the annual energy consumption), will search the industrial catalogues and then propose to the user relevant systems adapted to his project and the performances he wants to achieve. The quantity take off for materials and building products used for the construction are then automatically calculated and used to evaluate the environmental impacts of the building using Elodie, the building LCA tool developed by CSTB.

Keywords:, Life Cycle Assessment, Environmental (LCA), Product Declaration, Building Information Modeling (BIM), Industry Foundation Classes (IFC), eveBIM, Elodie

1. INTRODUCTION

Society is facing an overwhelming number of urgent issues related to global warming, carbon footprint and energy consumption reductions. The building sector is particularly under pressure as it is one of the biggest consumers of energy, either directly for lighting and thermal comfort (heating and air conditioning) or indirectly from the production of building materials. It also largely contributes to the massive use of critical resources (such as energy, water, materials and space) and is responsible for a large portion of greenhouse gas emissions. For example, in Europe, the construction sector generates up to 25% of the greenhouse gases and uses up to 45% of energy overall. Therefore, any serious strategy aiming to reduce greenhouse gas emissions and deliver energy savings will have to include the construction sector. Thus, the architecture, engineering, and construction (AEC) sector is under significant pressure to reduce its ecological footprint but at the same time, to provide better living and working conditions. Current business models and working methods are clearly not resulting in sustainable systems and so, new solutions are needed to address these complex and multidisciplinary issues. Improvements needed in the AEC processes relate to:

- Improved architectural and technical design.
- Building components coherent with the design.
- High-performance construction processes.
- Management of the overall lifecycle process i.e. design, construction, operation, maintenance, refurbishment, and destruction with a feedback loop of learned best practice to future projects.
- An operation process that ensures maintenance activities adapted to use and transparent to occupants.

The paper will focus on the design phase adapted both for new and existing buildings (in case of refurbishment). It will underline the importance of automatic generation of execution details compliant with assembly rules defined by the manufacturer without burdening the designer with the tedious task of explicitly describing these details. The result is a BIM / IFC enriched with execution details that can then be fed to environmental assessment tools.

2. RESEARCH CONTEXT

This context is greatly influenced by interoperability issues. Indeed virtually all surveys carried out in the construction industry place interoperability as a key issue for the use of Information and Communication Technologies (ICT) [WIX2009]. The evidence for available cost benefit comes from a study conducted by the US National Institute for Standards Technology (NIST) in which the lack of interoperability was estimated in 2004 to cost US industry more than US$15 billion per year [NIST2004]. However, estimates that are more recent suggest that this figure might be too low.

The key to interoperability is that there must be a common understanding of the building processes and of the information that is needed for and results from their execution. This is where Building Information Modeling (BIM) plays a key role since it is the term applied to the creation and use of coordinated, consistent, computable information about a building project in design, in construction and in building operation and management.

IFC (Industry Foundation Classes) emerged as the major standard for BIM implementation in the scope of construction industry information exchange. Its development is the result of an industry consensus building process over several years and across many countries. IFC contains common agreements on the content, structure and constraints of information to be used and exchanged by several participants in construction and FM projects using different software applications. The result is a single, integrated information model representing the common exchange requirements among software applications used in construction and FM specific processes. It is currently registered with ISO as a Publicly Accessible Specification [ISO16739] with work now proceeding to make it into a full ISO standard.

Now that mainstream CAD applications such as Revit, Bentley, ArchiCAD and similar implement BIM / IFC import and export functions, the question is how to bridge the gap between these CAD packages and information coming from manufacturers about the technical characteristics of their components / systems and the assembly rules that need to be applied.

To address this question, a series of more focused objectives have been adopted, namely:

- To design a back office application allowing the manufacturers to describe the construction guidelines of their systems ;
- To research and develop on a lean expression of the geometry and position of manufactured products within a BIM / IFC model
- To experiment the use of this enriched BIM / IFC model by a calculation tool.

3. CONGIGURATION TOOL

In order to make BIM a central element for the entire building lifecycle including the process of construction and facility operation, it is of paramount importance to include in the model relevant information about the industrial components and systems used. This will allow to show information about systems, assemblies and their sequences and also to extract information about quantities and materials in order to assess various dimensions of the project such as sustainability analyses including building assessment (such as HQE, LEED, BREEAM, …), energy performance and life cycle costing.

In most cases, the BIM-IFC yielded in early design phases does not contain information about all the industrial components and systems used. Indeed, BIM is these phases is usually based on a 1/100 scale and contains only rough information about the thickness of the walls and insulation and some generic description of components. This is obviously a problem:

- for the precision and completion of the model,
- for the accuracy of the simulations and assessments done using this model

In collaboration with major manufacturers, CSTB is developing a configuration tool aimed to ease the task of the designer by automatically generating execution details of the systems used in coherence with construction guidelines provided by the manufacturers. The process of use of this tool is the following: a simple BIM comes from the architect who exports it in IFC format using the export function of his CAD tool. Depending on the performances to achieve (e.g. the annual energy consumption), the application will search the industrial catalogues (in fact in a database describing these catalogues) and then propose to the user relevant systems adapted to his project and the performances he wants to achieve. No choices are made automatically by the application, which simply suppresses from the list the systems that are not relevant depending on the context thus facilitating the task of the user who ultimately makes the decisions.

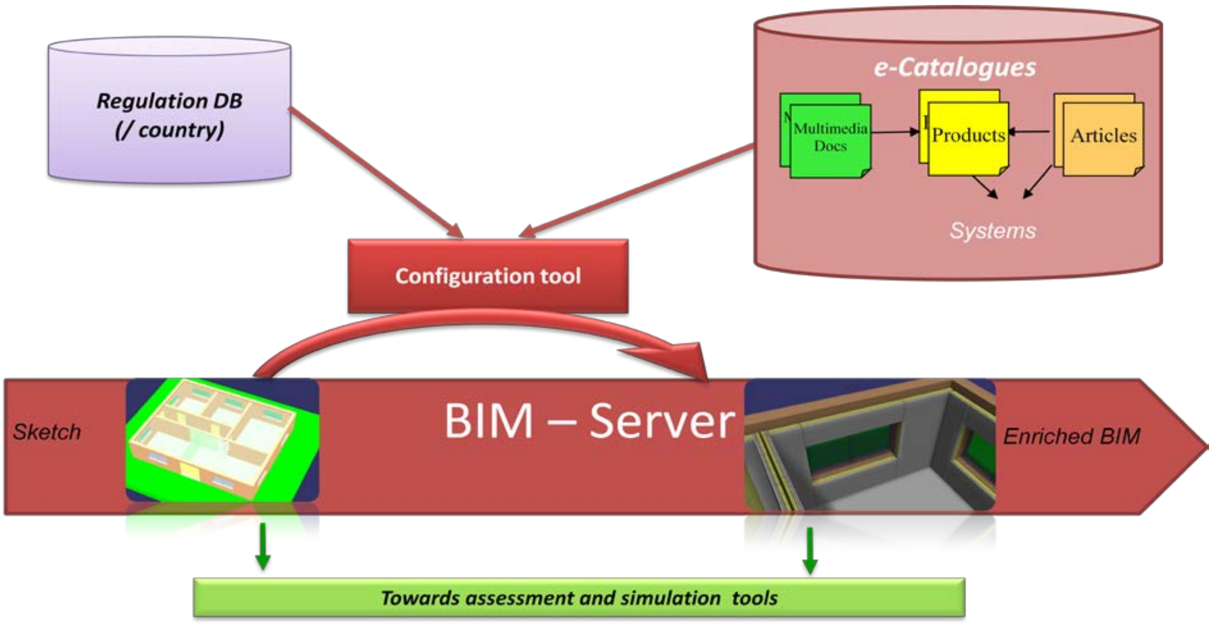

Figure 1: Configuration tool architecture

Then, once, the user selects the systems in the list proposed by the application, the latter will automatically propose the layout plan taking into account:

- the geometry of the project
- the assembly guidelines defined by the manufacturer.

The result, which is the BIM IFC enriched with the systems in place, contains therefore all the information needed about quantity take offs and products used in order to be fed to various simulators and assessment tools.

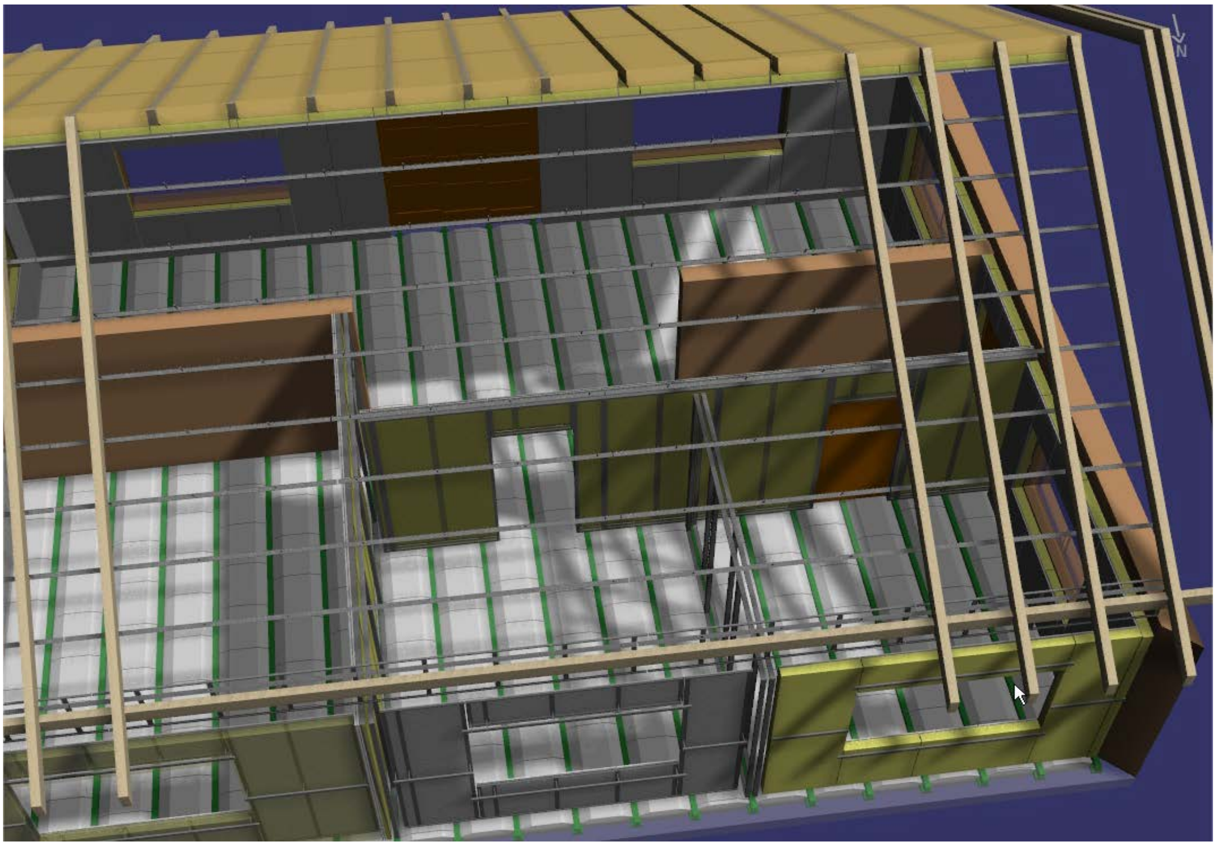

Figure 1: Example of an enriched BIM including execution details for roof and attic, slabs, internal separations and external walls.

4. ENVIRONMENTAL IMPACT ASSESSEMENT

To experiment the use and relevance of this enriched BIM / IFC model, this paper will focus on its exploitation by an environmental impact assessment tool developed by CSTB. Indeed, in order to meet the need of the construction sector in quantifying the environmental building performances and to use the environmental data produced by manufacturers, CSTB started in 2007 to develop a tool named Elodie. Based on a Life Cycle Assessment approach it is particularly adapted to the use of a methodology based on the product scale data included such as the one included in EPD's (Environmental Product Declaration).

Elodie provides assistance for the design of environmentally friendly constructive solutions. It allows comparing several alternatives for the same building or for the same part of work realized with different components, different materials, and even different constructive modes. Within few years, it will become a complete environmental assessment tool (with environment, but also health and comfort dimensions) and will be developed in coherence with sustainability assessment tools. It will be consistent with standardization basis and SBA (Sustainable Building Alliance - http://www.sballiance.org/) work about a core set of indicators shared by number of countries and the French HQE approach. Based on a life cycle approach and on the standard XP P01-020-3, the software can be used to set up models of new buildings or existing ones.

The calculation model of Elodie is based on the quantification of the flow's balance. At the building scale, these flows are named contributory elements. The model (illustrated by the following figure) considers the sum of the impacts of various flows as material and products, as energy and water consumptions.

Figure 5: The building environmental performance calculation model.

The quantification of the contributory element "product and material" is based on the FDES (French EPDs). This decision led to the development of a standard, (i.e. NF P01-010) issued in 2004. The adopted methodology for the EPDs establishment is based on Life Cycle Assessment (LCA) approach and includes also the health and comfort aspects. In order to improve the dissemination and the accessibility to these declarations, the EPDs, a public free access data base, has been created in 2004 (see INIES database at www.inies.fr). At present, there are about 500 EPDs. The LCA is based on a cradle to grave analysis including packaging, and complementary products. French EPDs contain 16 environmental indicators to evaluate the environmental impact of one product. French EPDs contain 16 environmental indicators to evaluate the environmental impact of one product.

	Environmental Impact		Unit
1	Energy consumption	Total primary energy	MJ
		Renewable energy	MJ
		non renewable energy	MJ
2	Ressource depletion (ADP)		kg Sb eq.
3	Water consumption		L
4	Recovered waste		kg
	Eliminated solid waste	hasardous waste	kg
		non hasardous waste	kg
		inert waste	kg
		radioactive waste	kg
5	Climate change		kg CO2 eq.
6	Atmospheric acidification		kg SO2 eq.
7	Air pollution		m3 of air
8	Water pollution		m3 of water
9	Destruction of the stratospheric ozone layer		kg CFC eq.
10	Formation of photochemical ozone		kg ethylene eq.

Table 1: The environmental indicators of French EPDs according to NF P 01-010.

The exchange process between BIM / IFC and Elodie is based on the application of FDES to building entities and then on the export the model to Elodie format. A specific perspective has been developed (to work only with the data that are of interest). The idea is to explore the model, and then sort the building elements by type, by materials or/and by spatial structure (e.g by storey…). The FDES can then be attributed to a group of selected elements. For example we can store all the elements by type and materials and thus select all the PVC windows and apply an FDES. This information is then stored in the BIM / IFC model in order to ease future use.

A specific action has been taken with BuildingSmart in order to include environmental properties in future versions of IFCs. By leaning initially on the French environmental standard, an agreement has been found in the definition of the environmental impact indicators. The new release of the IFC (IFC 2x4), will contain new environmental impact properties. These are:

• Total Primary Energy Consumption	• Renewable Energy Consumption
• Water Consumption	• Non Renewable Energy Consumption
• Hasardous Waste	• Resource Depletion
• Non Hasardous Waste	• Inert Waste
• Climate Change	• Radioactive Waste
• Atmospheric Acidification	• Stratospheric Ozone Layer Destruction
• Photochemical Ozone Formation	• Eutrophication

The primary result of Elodie is an environmental profile of the building, which compiles all the contributions of the various products, the site energy consumption and the water supply. This profile corresponds to the environmental indicators of the NF P01-010 standard, preserving all of them for a better transparency of the results. ELODIE allows considering distinctively the contributories impacts: building products, energy and water supply.

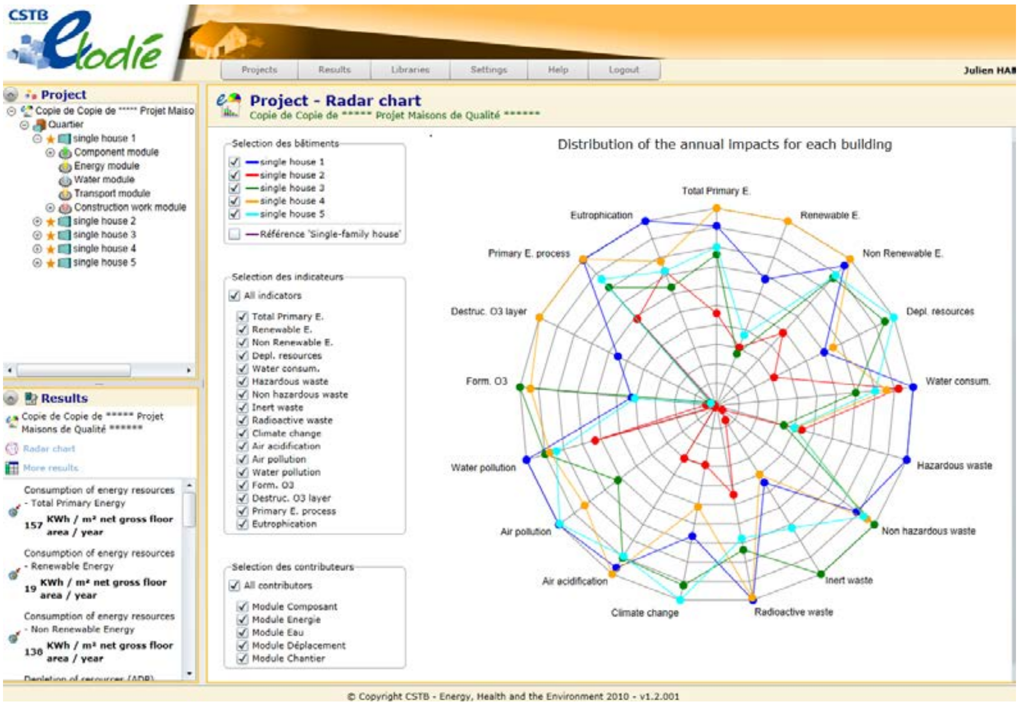

Figure 5: Comparison of various constructive solutions for a single house, on the environmental impacts of the building.

The calculation of the contribution of the construction products to the environmental impact of the building allows designers to compare several alternatives for the same building or for the same part of the building realized with different components, different materials, and even different constructive methods.

5. CONCLUSION AND FUTURE RESEARCH

Pressure to study energy conservation is increasing rapidly due to questions about fossil resources availability and concerns about climate modifications. In the construction sector, the first step to reduce energy consumption and limit environmental impact is to simulate the behavior of buildings. Many models have been developed over the years but these models tend to use partial information about the building and its components thus raising questions about the confidence one can have in the results.

New technology allowing to enrich BIM-IFC with detailed information about the industrial components and systems used without this being a tedious task for the user will permit to make relevant and complete information about the project available to various assessment tools. This will raise confidence in the results and allow to compare various constructive solutions from different points of view (energy consumption, environmental impact, cost …). We are convinced that over the next 5 years, this usage will grow to become a core method within the construction sector.

Finally, future research will focus on the improvement of the environmental assessment tool, in order to go towards a decision-making tool. One of the next steps will be to propose an evaluation model adapted to every typology and every design and construction stage.

REFERENCES

KUNZ, J., FISCHER, M. (2009). VIRTUAL DESIGN AND CONSTRUCTION: THEMES, CASE STUDIES AND IMPLEMENTATION SUGGESTIONS, CIFE WORKING PAPER #097, VERSION 9: JANUARY 2009.

NIST (2004). WWW.BFRL.NIST.GOV/OAE/PUBLICATIONS/GCRS/04867.PDF. [LAST VISITED JULY 2010]

SOUBRA, S.: THE NEED FOR CREATIVITY ENHANCING DESIGN TOOLS. IN: VIRTUAL FUTURES FOR DESIGN, CONSTRUCTION & PROCUREMENT. PETER BRANDON (EDS). BLACKWELL PUBLISHING (2008).

SOUBRA, S.: COMBINING 3D MODELS AND SIMULATIONS TO MEET THE DESIGN CHALLENGES OF THE TWENTY-ﬁRST CENTURY. IN COLLABORATIVE CONSTRUCTION INFORMATION MANAGEMENT. ISBN 13: 978–0–415–48422–0. TAYLOR & FRANCIS. 2009

WIX, J. (2009). IMPROVING INFORMATION DELIVERY IN COLLABORATIVE CONSTRUCTION INFORMATION MANAGEMENT. TAYLOR AND FRANCIS. PP. 156-165.