4-2012

Data sharing for sustainable assessments

Tajin Biswas
Carnegie Mellon University

Tsung-Hsien Wang
Carnegie Mellon University

Ramesh Krishnamurti
Carnegie Mellon University, ramesh@cmu.edu

Published In

Proceedings of the International Conference on Computer Aided Architectural Design Research in Asia (CAADRIA), 2012, 193-202.

T. Fischer, K. De Biswas, J.J. Ham, R. Naka, W.X. Huang, *Beyond Codes and Pixels: Proceedings of the 17th International Conference on Computer-Aided Architectural Design Research in Asia,* 193–202.

DATA SHARING FOR SUSTAINABLE ASSESSMENTS

Using functional databases for interoperating multiple building information structures

TAJIN BISWAS, TSUNG-HSIEN WANG
Carnegie Mellon University, Pittsburgh, USA
tajin@cmu.edu

and

RAMESH KRISHNAMURTI
ramesh@cmu.edu

Abstract. This paper presents the development and implementation of an automatic sustainable assessment prototype using functional databases. For the practical purpose, we use Leadership in Energy and Environmental Design (LEED) as the exemplar standard to demonstrate the integrative process from building information aggregation to final evaluation. We start with a Building Information model, and use Construction Operations Building Information Exchange (COBie) as a bridge to integrate LEED requirements. At present, the process of sustainable building assessment requires information exchange from various building professionals. However, there is no procedure to manage, or use, information pertaining to sustainability. In our research, we translate rules from LEED into computable formulas and develop a prototype application to produce templates for LEED submission.

Keywords. Building information databases; sustainable assessment.

1. Introduction

In the building industry, assessment schemas are increasingly being used to objectively measure sustainability achievements. These are also known as ‘green/sustainability’ rating systems. A green/sustainable building rating system is defined as a tool that examines the performance or expected performance of a ‘whole building’ and translates that into an overall assessment that allows for comparison against other buildings (Fowler and Rauch 2006). In the US, a commercial green building is generally considered to be one certified by a sustainable building rating system; for example Leadership in Energy and Environmental Design (LEED), which is developed by US Green Building Council (USGBC) to establish a common standard of measurement and evaluation (Yudelson 2008). Green building evaluation is a multi-person and multi-phase process (Turkaslan-Bulbul 2006); therefore, sharing building design information among different building domains and professionals is essential. The current process of sustainable building evaluation is highly disparate. Even with the use of conventional Computer-Aided Design (CAD) tools, this requires a great deal of human intervention and interpretation. This makes the process of sustainability assessment costly and time consuming. (Nguyen et al. 2010)

Keysar and Pearce (2007) have identified 275 tools in 14 categories, which are required, at various times, in evaluating sustainable buildings. To enhance cooperation and use of building information for assessment, we focus our research on current building information interoperability tools and standards in the Architecture Engineering, and Construction (AEC) domain coupled with functional databases.

2. Sustainability assessment and tools

Green/Sustainable architecture is no longer a current phenomenon. It is increasingly being addressed in the building industry by different sustainability assessment standards (Solomon 2005). Krygiel and Bradley (2008) state that “many tools used to measure the impact of sustainable design strategies are not directly accessible within a Building Information Model (BIM) itself; therefore, data needs to be exported to another application or imported from a external data source.” A “Building Information Model is a digital representation of physical and functional characteristics of a facility; a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle.” (Smith and Edgar 2008)

2.1. SUSTAINABILITY ASSESSMENT STANDARDS

There are many different assessment systems used around the world. Fowler’s study (2006) shortens the list first, by combining several rating systems used in multiple countries, and second, by subsuming those that are derived from other rating systems. A summary of two such representative assessments standards are given below.

The British Research Establishment (BRE) was the first to develop an environmental impact assessment method, BREEAM, British Research Establishment's Environmental Assessment Method. Subsequently, other countries adopted the BRE approach in developing their own assessment method (Reed 2010). BREEAM has become the de facto measure of building environmental performance in Europe "BREEAM" (2011). There are versions specific to the UK; other versions are tailored to countries or regions to address specific environmental issues and weightings; construction methods and materials and reference to local standards. In assessing a building, points are awarded for each criterion. The points are then summed for a total score. The overall building performance is awarded a "Pass", "Good", "Very Good" or "Excellent" rating based on the score. BREEAM major categories of criteria for Design and Procurement include the following: Management, Health and Wellbeing, Energy, Transport, Water, Materials, Land use, Ecology and Pollution.

In the US, from the onset of the United Green Building Council in 1993, there have been releases of different versions of its rating tool LEED for various building types, the most current being LEED 2009 (this applies to five building types-new construction, core and shell, schools, existing building and commercial interiors). This assessment system has six main categories; Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Air Quality and Regional Priority and Innovations in Design, each addressing specific environmental concerns "USGBC" (2009). Within each category there are specific design goals that have to be met for any particular LEED certification, namely, silver, gold or platinum. Each goal is worth one point; the final certification is based on evaluation of the goals documented.

2.2. ASSESSMENT METHODS

Sustainability assessment criteria are evaluated by quantitative and/or qualitative measures. Quantitative measures reflect numerical values for instance, annual energy use, water consumption, greenhouse gas emissions, volume of reused material and so on.

On the other hand, qualitative measures use comparable measurements such as the impact on ecological value, or rely on user testimony, for example, that certain procedures have been followed. Qualitative criteria of assessments are difficult to encode as they are subject to evaluation from unbiased third parties (Nguyen et al. 2010). It takes time and effort to input data, and varies in interpretation by the different professionals (AlWaer et al. 2009).

An assessment criterion can be evaluated whenever the relevant information is available in the building model. Although this seems straightforward, in reality this involves transformations, which may entail subjective judgement. A simple example is ‘floor area’. In different building information models it can be named as as ‘NetFloorArea’, ‘NetArea’ and ‘GSA BIM Area’- all referring to the same value of the ‘floor area’. There are other similar interpretations for the numerous building elements that are involved in the exchange throughout the AEC domain, Some of these confusions can be avoided if the information is stored in a standard building information model.

2.3. BIM AND INTEROPERABILITY

According to buildingSMART (2010) “BIM standards will integrate standards used in the AEC industry”. Current standards include the Industry Foundation Classes (IFC), ISO standards, BIM templates and Construction Operations Building Information Exchange (COBie) (East 2011, buildingSmart 2012). According to the National BIM Standard Project Committee, “A Building Information Model is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward.” (Smith and Edgar 2008)

There are commercial software, which provide BIM solutions, for instance, Autodesk Revit Architecture, Bentley Microstation Triforma, and ArchiCAD by Graphisoft, Inc. These BIM tools employ their own proprietary data structures for representing a building and other design information (containing graphical and non-graphical information). Figure 1 depicts a typical data exchange set up.

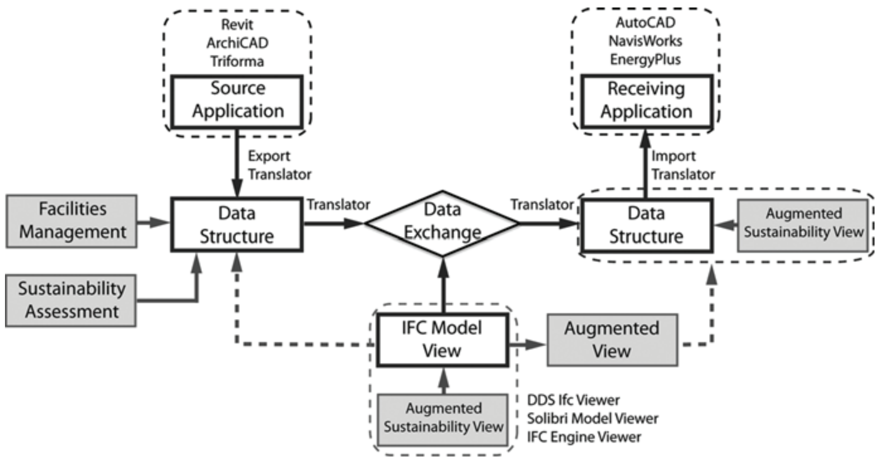

Figure 1. Current Data Exchange from software to another via IFC translation.

The ideal exchange, highlighted in blue in the figure, involves just IFC, which is an extensible ‘framework model’ to cater to a large set of consistent data representations in the AEC domains (Eastman et al. 2008). It is built using the ISO-STEP EXPRESS language. In practice, IFC can have multiple implementations. Consequently, BIM tools with good IFC import/export translators may still only be able to exchange very little useful data.

For this reason IFC translations from source applications have to be enhanced, perhaps, in stages. Such enhancements need to be considered carefully when used by exchanging applications. For example, there are viewers for IFC model geometry and property, which display attributes of selected objects and provide means to view data in different sets of entities (Eastman et al. 2008). Despite variations in object representation, efforts are being made to define IFC more uniformly and precisely. IFC models are non-proprietary, and as such are increasingly being adopted by governments and agencies (Eastman et al. 2008). However, generally, IFC models do not contain information sufficient for sustainability evaluations. In order to share design information from a software tool, and sustainability related information, we found COBie to serve as a suitable data structure to integrate the necessary building information and evaluation requirements.

2.4. COBIE AS A DATA STRUCTURE

COBie is a format primarily intended for use of managed assets. In this data structure, information is cumulatively provided during the design, construction, commissioning and handover phases of a building. The information includes room lists and area measurements, material and product schedules, construction submittal requirements, construction submittals, equipment lists, warranty guarantors, and replacement part providers, which are normally included in several different places within current contracts (East 2011). The objective of COBie is not to alter the type of information that is required, just to standardise the format of that information to save building owners and occupants, having to rekey the information multiple times. We adopted COBie data structure because the format offers a structure that could be used, extended and augmented to drive sustainability assessments with a functional database prototype.

3. From BIM to assessment

For sustainability assessment, we used a LEED NC 2.1 silver-certified building as the case study. The model was prepared in a commercial BIM tool. This was exported first as an IFC model, and then translated to a COBie model.

During translation from BIM to COBie we had to address a number of issues. First, dealing with loss of information during translation. Second, adding information required for LEED assessments; these are external to the model, such as occupant number, area of buildings surrounding the project for site density, type of ground cover and their corresponding their runoff values etc. Third, converting LEED rules into computable form. Lastly, creating a functional database to aggregate, evaluate, and propagate information into LEED submission ready templates. Figure 2 indicates where data is augmented in COBie database. As shown, LEEDDensity is a new sheet that is added to the database. Sheets such as Attributes, Facility, Type, Space, Zone, Systems, and Job have added columns with new fields and rows of data. The sheets Floor, Contacts, Component and Documents retain their original columns but have rows with additional data.

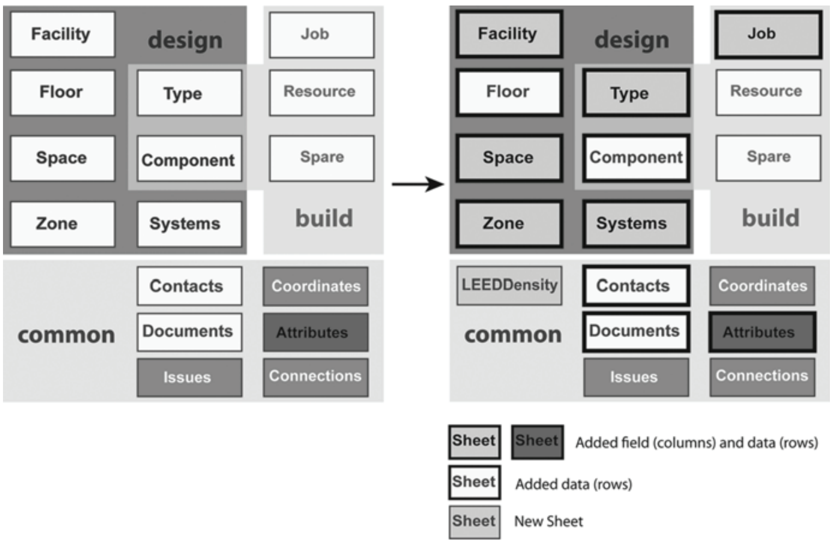

Figure 2. Illustrating the augmentation of COBie for LEED (COBie diagram source: http://www.wbdg.org/resources/cobie.php: Figure 5).

3.1. FUNCTIONAL DATABASE APPROACH

Current research using commercial BIM and LEED requirements have demonstrated the feasibility for semi-automated evaluation (Barnes and Castro-Lacouture 2009, Nguyen et al. 2010, Krishnamurti et al. 2010). In each study, information for sustainability evaluation was added, either by providing external databases or by augmenting the model using the capability of the software to store additional information. Figure 3 shows the process of sharing information from a BIM to fill LEED templates for evaluation.

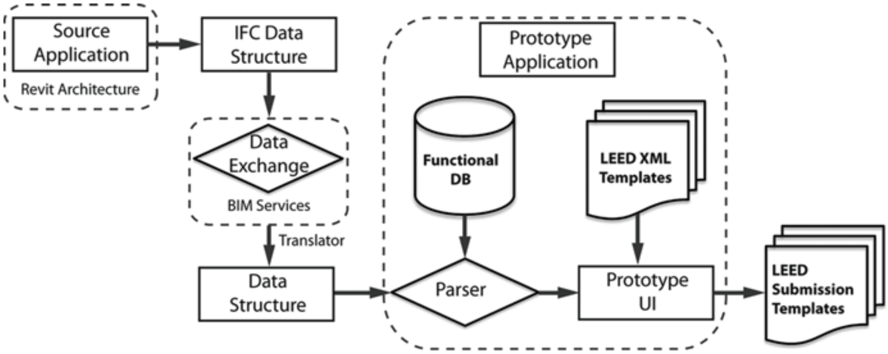

Figure 3. Data sharing for sustainability assessment using prototype.

Since LEED requirements are periodically revised, we can bypass hardwiring the requirements by developing a computable set of LEED rules stored in a database format. Taking the evaluation rules as input, these are then interpreted for real-time evaluation. By providing this additional functionality to an otherwise static database, it allows the application to easily accommodate future rating requirement updates. It enables the multi-disciplinary cooperation from sustainable assessment rule mapping to corresponding building data (and vice versa). The output generates LEED submittals in XML format, which contain aggregated results ready for evaluation. This demonstrates a process where design information can be embedded and retrieved by different software and professionals—from design to sustainable assessment.

3.2. ASSUMPTIONS AND CHALLENGES

We made certain assumptions when preparing COBie sheets for evaluation. These are: (i) building data comes from the translated BIM; (ii) data required for LEED evaluation is augmented, either by adding new data sets to the original COBie format or by augmenting the structure; and (iii) preprocessed data, typically requiring simulation, such as energy usage, or lighting qualities of a space, e.g., whether 75% of spaces are naturally lit, require the COBie structure to be augmented.

The challenges we faced were in identifying the kinds of information that would readily translate to COBie, and determining how and where to store the requisite information for LEED evaluation. From a data storage perspective the original data structure requires extension, without altering its basic premise and purpose. From a LEED perspective, both qualitative and quantitative measures need to be assessed through the LEED queries. Qualitative measures are verified by the presence or absence of certain documents as required by LEED—these are stored in the spreadsheet named ‘Documents’. Quantitative measures are processed by queries to mapped entities in COBie, for example, building area, volume of recycled material used, etc.

Data is extracted and collected from the given database by invoking the assessment rules codified in the mapping database. The mapping database maintains the underlying interoperation mechanisms for various data structures. Figure 4 illustrates the integrative process of our prototype application, which takes a COBie database as input, automates data exchange by executing mapping rules in the functional database, and populates the XML LEED templates.

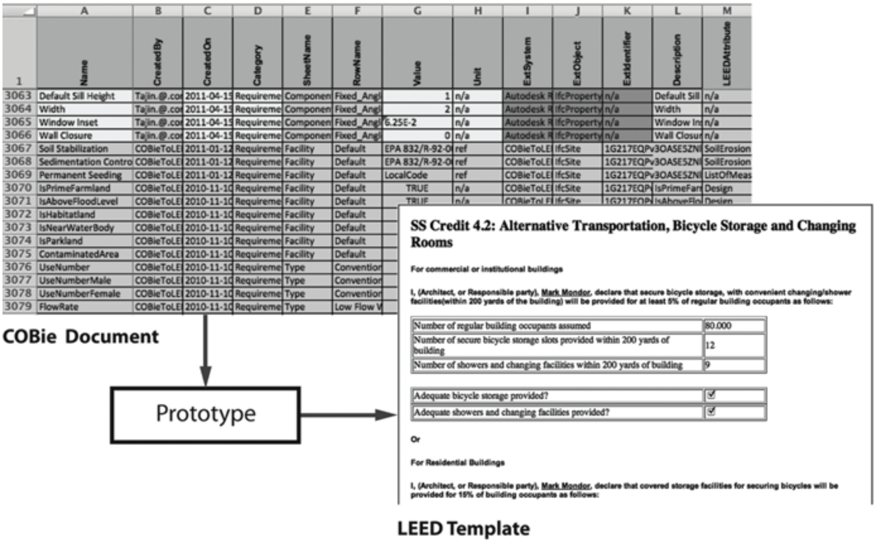

Figure 4. Data sharing for sustainability assessment using prototype.

4. Conclusion

This study shows an approach to sharing BIM information through a series of inter-operation between various standard data structures, namely, IFC and COBie. We use a database approach to manage the data exchange rules required for sustainability assessments. The prototype application demonstrates automation of LEED NC 2.1 template generation within an integrative process. The expected contribution is the acceleration of the integration and cooperation between various building professions to pursue improved sustainable environments.

We analysed the nature of the data required to fill LEED NC 2.1 templates. Our analysis show that approximately, on average, 45% of the data is retrieved from the COBie model without augmentation, the remaining 55% is retrieved from data that is added to COBie. Of the added data (55%), 35% of the data can be identified as attributes of the building elements. This includes the data that has to be post processed from simulation results, for example, for energy and lighting. The remaining 20% mainly pertain to queries for support documents that are required for submission.

We are currently exploring this approach to automatically create LEED 2009 templates. This flexible approach will allow for easy update of assessment standard rules as they evolve and change. It also has the potential to be scaled to consider multiple buildings (Krishnamurti et al. 2012). Other assessment standards such as Green Star of Australia or BREEAM could potentially be mapped and assessed. Any limitations observed are due to information loss from the translation from BIM to COBie and its unidirectional flow. The augmented COBie data structure and data cannot be fed back to the initial BIM due to the internal COBie to IFC mapping structure. Identifying, formalising and mapping of LEED required data to possible IFC entities and/or 'psets' is ongoing work.

Acknowledgements

The work done for this project, Automated LEED datasheets from lightweight IFC models was funded by Construction Engineering Research Laboratory (CERL), which aims at integrating building information with sustainability assessments using COBie as an intermediary platform. However, any opinions, findings, conclusions or recommendations presented in this paper are those of the authors and do not necessarily reflect the views of CERL.

References

AlWaer, H., Sibley, M. and Lewis, J.: 2009, Different stakeholder perceptions of sustainability assessment, *Architectural Science Review*, **51**(1), 48–59.

Barnes, S. and Castro-Lacouture, D.: 2009, BIM-enabled integrated optimization tool for LEED decisions, *in* Caldas, C. H. and O'Brien, W. J. (eds.), *Proc. ASCE International Workshop on Computing in Civil Engineering*, Austin, 258–268.

"BREEAM": The Environmental Assessment Method for Buildings Around The World. Available from: <http://www.breeam.org/page.jsp?id=135> (accessed 21 April 2011).

"buildingSMART": 2010. Available from: < http://www.bsame.org/index.php?option=com_content&view=article&id=123&Itemid=106 > (accessed 21 April 2011).

"buildingSMART": 2012. Available from: <http://buildingsmart.com/standards/ifc/model-industry-foundation-classes-ifc/?searchterm=None> (accessed 01 February 2012).

East, B.: 2011, "Construction Operations Building Information Exchange". Available from: <http://www.wbdg.org/resources/cobie.php> (accessed 21 October 2011).

Eastman, C., Teicholz, P., Sacks, R. and Liston, K.: 2008, *BIM Handbook: A Guide to Building Information Modelling*, John Wiley and Sons, Hoboken.

Fowler, K. R. and Rauch E. M.: 2006, *Sustainable Building Rating Systems Summary*, Technical Report PNNL-15858, Pacific Northwest National Laboratory, Richland, WA. Available from < http://www.wbdg.org/ccb/GSAMAN/sustainable_bldg_ rating_systems. pdf > *(accessed 21 February 2012)*.

Keysar, E. and Pearce. A. R.: 2007, Decision support tools for green building: facilitating selection among new adopters on public sector projects, *Journal of Green Building*, **2**(3), 153–171.

Krishnamurti, R., Biswas, T. and Wang, T. H.: 2010, Soft tools for sustainability, *in* Russell P. and Schoch, O. (eds.), *From Napkin to BIM*, publication pending.

Krishnamurti, R., Biswas, T. and Wang, T. H.: 2012, Modeling water use for sustainable urban design, *in* Müller Arisona, S. et al. (eds.), *Digital Urban Modeling and Simulation*, CCIS **242**, Springer, Berlin, 144–161.

Krygiel, E. and Bradley, N.: 2008, *Green BIM*, Wiley Publishing Inc., Indianapolis.

Nguyen, T. H., Shehab, T. and Gao, Z.: 2010, Evaluating sustainability of architectural designs using building information modelling. *The Open Construction and Building Technology Journal*, **4**, 1–8.

Reed, T. C.: 2010, An analysis of LEED and BREEAM assessment methods for educational institutions, *Journal of Green Building*, **5** (1), 132–154.

Smith, D. K. and Edgar, A.: 2008. "Building Information Modeling". Available from: <http://www.wbdg.org/bim/bim.php> (accessed 21 April 2011).

Solomon, N.: 2005, How is LEED faring after five years in use? *Architectural Record*, **193**(6), 135–142.

Turkaslan-Bulbul, M.: 2006, *Process and Product Modelling for Computational Support of Building Commissioning*, PhD thesis, Carnegie Mellon University, Pittsburgh.

"USGBC": 2009, Technical Advancements to the LEED Rating System. Available from: <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1971> (accessed 29 April 2011).