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ARCOM Doctoral Workshop on

BIM
Management and Interoperability

Thursday 20th June 2013

Birmingham School of the Built Environment
Birmingham City University,
Birmingham B4 7XG, United Kingdom

Workshop Chair:
Professor David Boyd

ARCOM ASSOCIATION OF RESEARCHERS IN CONSTRUCTION MANAGEMENT

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ARCOM Doctoral Workshop Programme
Birmingham City University, Birmingham UK
Thursday 20th June 2013

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Introduction

This is the first workshop hosted by ARCOM in this rapidly developing field. The focus is on the way we are changing the how we work as a result of BIM. ARCOM aims to develop excellent research in the construction management field and encourages critical and alternative perspectives. Such perspectives are required as the use of BIM is in flux and as such it makes it complex to research and the results are difficult to interpret. In addition, the idealised proposals for how work should be conducted and driven by data transfer protocols obscures how work is being undertaken. The workshop will provide an opportunity to share theoretical and empirical insights in order to advance what is a fragmented field of study.

ARCOM also seeks to encourage and advance early career researchers. It does this through such workshops in order to develop the research community not just academically but socially so that it is sustainable for the future.

Professor David Boyd
Workshop Convenor
Birmingham City University

THE BIM INFORMATION NEEDS FOR SUSTAINABILITY IN CONCEPTUAL DESIGN

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Sustainability in construction has attracted considerable attention from scholars as well as from regulatory bodies. However, early design stage sustainability analysis remains problematic because of the conflicting factors affecting sustainability, the limited and fragmented project data in hand at early design stage and deficiencies of existing sustainability analysis software for quick evaluation of conceptual design alternatives. BIM's building information management and integration capabilities present opportunities to support early design sustainability analysis. In this paper, early findings of an on-going BIM based early design sustainability analysis application development project are presented. Through literature review and in-depth interviews conducted with a sustainability professional, a categorization of the information needed for quick evaluation of different conceptual design alternatives from a sustainability point of view is developed. The categorization developed and presented in this paper aims to guide further stages of the project of the development of the application and also to support the writing of a BIM Execution Plan for projects where holistic early design sustainability analysis is intended.

Keywords: design, information management, information technology, sustainability.

INTRODUCTION

A widely accepted definition of sustainability is given by the Brundtland Commission as “Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987). The energy consumption of buildings contributes significantly to global CO2 emissions that cause global warming which threatens the future of our planet. This fact makes the energy performance of buildings an important issue for their sustainability. It is stated that 40% of global CO2 emissions results from building operations (Park et al. 2012). However, El-Alfy (2010) states that economical, functionality, durability, aesthetics, ecology, health and sociocultural aspects of a building design are all together the factors affecting a building’s sustainability. A building’s sustainability is dependent on several inter-related and inter-dependent factors and these factors are affected by the design decisions made by different players of a construction project can be in conflict (Anastas and Zimmermann 2003). The inter-relations and inter-dependencies that should be considered for a meaningful sustainability analysis require the collective evaluation of the design information created by different players of the project design team. Therefore, a collaborative and robust building information management system is desirable to support such analysis (Lam et al. 2004).

Building Information Modelling (BIM) can be defined as the process of development and use of a digital model of the facility intended to be built. The resulting product of BIM, the Building Information Model, has the ambition as being the central hub for all information about the facility from its inception onward. This information may take on many forms (e.g visual and numerical) and has many roles to play for the whole life cycle of the facility (BIM Industry Working Group 2011). The conceptualization and use of the Building Information Model as the central hub for all information requires all stakeholders of the project to contribute to and exploit this building information in an inter-disciplinary collaborative effort during its whole life cycle. Therefore, BIM is increasingly considered as an Information Technology (IT)-enabled approach that allows better management and representation of building information during its whole life cycle (Fischer 2004). Consequently, it is argued that information management capabilities of BIM, create new opportunities for sustainability evaluation and decision-making in building design (Bank et al. 2010; Nguyen et al. 2010).

This paper presents the early findings of a BIM application development project which aims to provide sustainability professionals a BIM based building sustainability analysis tool for the evaluation of different conceptual design options quickly. One of the authors took part in the initial stage of the project for one month as part of a European Union funded Pioneers into Practice placement program. The work, which will be reported here, focused on exploration of current challenges for quick evaluation of different conceptual design options from sustainability perspective as well as determination of what main categories of information are needed to conduct BIM based sustainability analysis at conceptual design stage in order to enable this evaluation. These challenges are explored through a literature review and in-depth interviews with a sustainable design professional. The main challenges are identified and a framework which categorizes the information needed by sustainability professionals for quick evaluation is developed and presented.

CHALLENGES OF BIM BASED SUSTAINABILITY ANALYSIS AT CONCEPTUAL DESIGN STAGE

A building's sustainability is dependent on several inter-related and inter-dependent factors and these factors are affected by the design decisions made by different players in a construction project (Anastas and Zimmermann 2003). In the traditional, non-BIM design workflow, performance assessments of the design are generally undertaken after the completion of architectural design when the design is almost completed (Soebarto and Williamson 2001; Schlueter and Thessling 2009). Such performance assessments consists of several independent (Bank et al. 2010) detailed analyses made by expert software using the detailed design information. Crucially, this detailed information is not available at the early design stages and also involves considerable interpretation by experts (Schlueter and Thessling 2009). These independent analyses hinder having a holistic understanding of sustainability issues and presenting a holistic sustainable design solution (Bank et al. 2010).

The performance assessments made at late stages of the design may lead to design of buildings that have only limited sustainability e.g. in terms of services but not in architectural aspects (Schlueter and Thessling 2009). The performance assessments that are undertaken at late stages of design also lead to adoption of bolt-on solutions rather than holistic solutions for the unsatisfied target criteria found out by analyses. This is due to the impossibility of making big design changes at late stages of design development because of the concerns about cost and time. Sustainability and environmental impact issues of a building really require to be considered before the conceptual design stage and these considerations should be reflected in the conceptual design alternatives to achieve the sustainability targets (Ding 2008). It is widely acknowledged that most of the key design decisions affecting the building's sustainability are made during early design stage and these decisions that are made at early design stage have the greatest impacts on the cost as well (Bank et al. 2010). Therefore, one of the challenges is to find a design evaluation method suitable for early design stage that provides enough understanding of the design for decision making (Brahme et al. 2001).

Sustainable building design is a matter of optimization of several different aspects of a building because of the conflicting nature of some of the factors affecting sustainability (Anastas and Zimmermann 2003). This creates several challenges for early design sustainability analysis. First, information from different players of the design team needs to be integrated, reachable and exploitable in order to conduct an inclusive automated sustainability analysis (Nguyen et al. 2010; Wong and Fan 2013).

Second, a sustainability professional is required for the translation of client needs and project specific constraints to determine the target sustainability performance criteria. These sustainability professionals knows about the different aspects of building sustainability and their relations at systems-level and so can interpret results to support decision making. Mutis and Issa (2012) stated that users from different backgrounds of an integrated and shared building model may have problems making sense of the information embedded into the model due to semantic gaps between the ways this information is presented to them and the way they need to use it to perform their tasks. This means that, in order to enable sustainability professional to benefit from the information embedded into the model for his/her analysis and interpretation; design information should be presented him/her in a way he/she makes sense of it. In a similar way, for sustainability analysis at conceptual design stage, analysis method and criteria should be configured in a way so that it does not rely on detailed design information before that has been generated by the designers (Ding 2008).

Third, building assessment schemes to guide sustainable building design such as Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM) were not designed to be used as design guidelines. The fact that they are increasingly being used as such (Cole 1999) is also an important deficiency in sustainability analysis. The credit-weighting approach of building assessment techniques is the heart of these approaches which compound to the final score of the building being assessed and there is no consensus for the weightings used (Cole 1998; Lee et al. 2002). Ding (2008) criticizes that “the overall performance score is obtained by a simple aggregation of all the points awarded to each criterion. All criteria are assumed to be of equal importance and there is no order of importance for criteria”. Mainly due to conflicting nature of some of the factors affecting sustainability, he adds that the criteria should be developed according to each project’s aims and conditions (Ding 2008). It can also be argued that, pre-defined criteria (i.e. criteria which are not project specific) of building assessment schemes may hinder some sustainable design avenues, making designers focus on high and relatively easily gained credits provided under some pre-defined headings of the scheme while disfavouring some others.

Two approaches are identified in the literature for BIM based sustainability analysis applications. Some research concentrates on integration of existing and widely accepted sustainability performance analysis tools (e.g. Integrated Environmental Solutions-Virtual Environment) with other widely accepted collaborative BIM tools (e.g. Stumpf et al. 2009; Azhar et al. 2011) whereas some other research aim to develop new analysis tools which are able to communicate with widely accepted collaborative BIM tools (e.g. Schlueter and Thesseling 2009; Nguyen et al. 2010). Park et al. (2012) make the point that high development costs, usability and interoperability issues of adapting existing energy analysis software need to be considered when deciding between the two approaches.

BIM INFORMATION NEEDS FOR SUSTAINABILITY IN CONCEPTUAL DESIGN

The challenges identified in the previous section led the application development project team to create a new early design sustainability analysis application for quick evaluation of different conceptual design options. There were several reasons behind this decision. As stated in the previous section, although there is on-going research and development that aims to provide seamless interoperability between collaborative BIM tools (e.g. Autodesk NavisWorks) and widely used sustainability analysis software (e.g. Integrated Environmental Solutions-Virtual Environment), there are still interoperability problems. Transfer of the building model from collaborative BIM tools to proprietary sustainability analysis tools causes loss of information in many instances. Therefore, development of a new application using the Application Programming Interfaces (APIs) to communicate with dominant collaborative BIM tools in the market was preferred.

There are also some other important issues regarding the usability of existing applications. Firstly, from the interview with the sustainability professional, a wide range of factors is required to understand the outputs of the analyses conducted by existing, widely used sustainability analysis tools. This is seen as a deficiency considering the fact that at conceptual design stage the effects of different building sub-system configurations (e.g. type of external fabric, heat generation and distribution systems) and their advantages and disadvantages need to be shared with the client and other design team members in a way they can make sense of it. Thus, it is believed by the project team that development of a new early design stage sustainability analysis tool would allow them to present the outputs of analyses in a more meaningful way for client and other design team members.

Furthermore, from the interview with the sustainability professional, the existing sustainability analysis tools don't provide enough flexibility to easily change the architectural and functional building sub-systems' configurations (e.g. type of external fabric, glazing percentage, energy generation and distribution systems) at level required (i.e. systems level) for conceptual design evaluation. Many objects of the model in the sustainability analysis tool need to be selected individually and dropdown menus need to reconfigure the model to evaluate the effects of systems configuration alternatives. It is believed by the project team that development of a new early design stage sustainability analysis tool would be more convenient as it would allow the project team to group the information embedded in the collaborative building model according to their needs and therefore provide a more flexible and suitable working environment for evaluation of different building sub-system configurations.

Finally, because of the deficiencies in their credit-weighting approach and their pre-defined criteria that don't reflect project peculiarities; development of a new information framework that suits early design holistic sustainability analysis is preferred rather than following an existing building assessment scheme (e.g. LEED) for information categorization and sustainability evaluation.

CATEGORIZATION OF INFORMATION FOR EARLY DESIGN SUSTAINABILITY ANALYSIS

Sustainability and environmental impact issues of a building need to start to be considered even before the conceptual design stage and these considerations should be reflected in the conceptual design alternatives to effectively achieve the sustainability (Ding 2008). This view is supported by the interviewed sustainability professional who stated that building functionality, site conditions, target building performance criteria, budgetary and time limits should be understood and documented during RIBA (The Royal Institute of British Architects) Stages A (Project Appraisal Stage) and B (Design Brief Stage) to enable an efficient sustainable design starting from RIBA Stage C (Conceptual Design Stage).

Through the in-depth interviews conducted with the sustainability professional, RIBA Stage C is divided into three consecutive stages from sustainability point of view of RIBA Stage C. These stages and their aims are presented in Figure 1. The first stage is for selection of building system (e.g. timber frame, reinforced concrete frame, pre-fabric etc.). The interviewee stated that clients generally want to know about time and cost implications of different building systems before development of multiple conceptual design alternatives. This also helps development of more easily comparable conceptual design alternatives. Thus, high-level building functionality, site conditions and target building performance criteria of each building system alternative need to be presented to the client together with their budgetary and time implications before proceeding with multiple conceptual design alternatives. It is stated by the interviewee that this task can be performed using spread sheet applications because at this stage of the project, evaluation of each building system alternative mainly depends on experience as well as insight about the historical data and limited project specific information in hand.

Following the building system assessment, a sustainability pre-assessment meeting needs to be organized. This meeting is important to inform design team members about the sustainability criteria established during RIBA Stages A and B and therefore to enable development of comparable and satisfactory conceptual design alternatives.

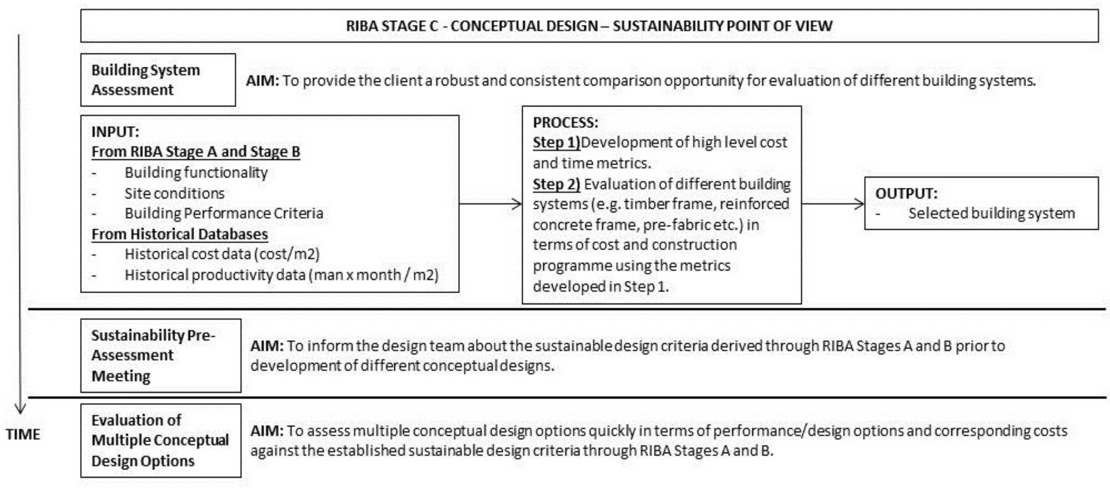

Figure 1: RIBA Stage C (Conceptual Design Stage) from sustainability point of view

The third stage is the evaluation of the multiple conceptual-design options. It was decided that it is this stage that can be leveraged by the computer application to be developed. As stated in the previous section, it was decided that the new application would use the information embedded in the building information model created by different contributing parties and merged under a collaborative BIM tool. This means that the model doesn't need to be transferred into the application to conduct sustainability analysis with the application extracting the information needed for sustainability analysis from the collaborative building model. This requires the robust structuring of the information to be entered into the model for later use by the sustainability professional and other analysis applications to enable quick evaluation of multiple conceptual design alternatives.

Analysis of how the structuring (i.e. identification of parameters and attributes to be assigned to objects and/or sub-systems in the model) of the information should be is not in the scope of this paper and will be undertaken at later stages of the application development project. Moreover, the structuring of the information to be entered into the model will change according to the collaborative BIM software that the application would be integrated with. However, a general framework which categorizes the information required for quick evaluation of multiple conceptual design alternatives from sustainability perspective has been developed to guide future BIM tool development in order to support sustainability professional's and analysis application's needs. This framework is presented in Figure 2.

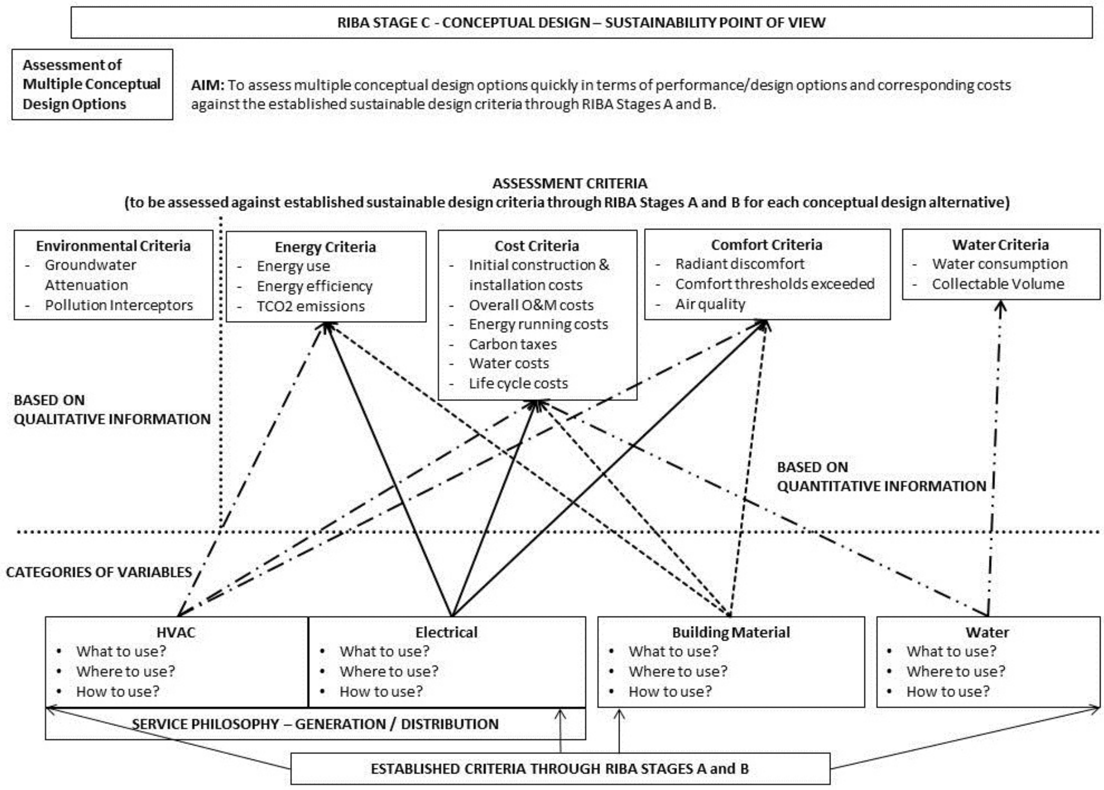

Figure 2: Categorization of the required information for sustainability analysis

The assessment criteria categories identified through the interviews represent the different aspects of sustainable building design which are needed to be evaluated for each conceptual design alternative at RIBA Stage C. Among them, the "Environmental Criteria" category is mainly based on qualitative information at RIBA Stage C; therefore, it was decided that this would be kept out of the analysis application. The arrows drawn between variable categories and assessment criteria categories show the contributions of each variable category to different criteria categories.

The answers to the questions under each variable category determines the required level of detail (i.e. what question) and contextual information (i.e. where and how questions) for each variable category in order to satisfy application's computational needs and sustainability professional's application usability needs. The sustainability professional, as the application user, would be able to quickly and easily reconfigure different sub-systems of conceptual designs to see the effects of different sub-systems' implications on sustainability. Thus, through understanding sustainability professional's needs and point of view allows them to satisfy user requirements. The interviews revealed that sustainability professional wants to be able to evaluate different sub-systems under four categories: HVAC, electrical, building material and water fittings at conceptual design stage. The level of information needs to be identified to address "what, where, and how" questions for each variable category. For example in the HVAC category, the "what" question should distinguish whether the whole system or distribution system and heat generation systems should be addressed? Again for HVAC category, the "where" question would answer whether the different heating/cooling zones in the building should be addressed or the positions of the spaces identified according to building orientation? Again for the HVAC category, the "how" question should identify the performance information needed for each element identified under the "what" question? It is argued that, answers to these questions would give a clear understanding of expectations of sustainability professionals from the application to be developed.

CONCLUSIONS

Sustainability in construction has attracted considerable attention from scholars as well as from regulatory bodies. However, early design stage sustainability analysis remains problematic because of the conflicting factors affecting sustainability, the limited and fragmented project data in hand at early design stage and deficiencies of existing sustainability analysis software for quick evaluation of conceptual design alternatives from sustainability perspective. BIM's building information management and integration capabilities present opportunities to support early design sustainability analysis. However, in order to benefit from BIM's capabilities, the requirements of early design sustainability analysis need to be well understood.

This paper, reporting on the early findings of an on-going BIM based application development project, outlined these requirements to enable sustainability professionals to quickly evaluate multiple conceptual design alternatives. The challenges of early design sustainability analysis stated in the literature and the findings of in-depth interviews conducted with a sustainability professional, were considered to develop a categorization of information needed for this application. This categorization was developed to guide the future stages of the application development project when the detailed information needs will be refined. Furthermore, this categorization can also be used as a support tool for creating a BIM Execution Plan for the projects where a holistic early design sustainability analysis is intended to be conducted. The limited results used in the paper may mean that the conclusions are not generalizable and so will be validated further through more interviews and workshops. Furthermore, such future research to validate the categorization presented in this paper will lead to a better understanding of early design sustainability analysis and better applications supporting it.

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