Creative Construction Conference 2013
July 6 – 9, 2013, Budapest, Hungary

INTERDISCIPLINARY, BIM-SUPPORTED PLANNING PROCESS

Lars Oberwinter
Vienna University of Technology, E234 - Institute of Interdisciplinary Construction Process Management, Vienna, Austria, Vienna, Austria, Oberwinter@industriebau.tuwien.ac.at

Iva Kovacic
Vienna University of Technology, E234 - Institute of Interdisciplinary Construction Process Management, Vienna, Austria, ikovacic@industriebau.tuwien.ac.at

Christoph Müller
Vienna University of Technology, E234 - Institute of Interdisciplinary Construction Process Management, Vienna, Austria, Vienna, Austria, cmueller@industriebau.tuwien.ac.at

Kristina Kiesel
Vienna University of Technology, E259 - Institute of Architectural Sciences, Vienna, Austria, kristina.kiesel@tuwien.ac.at

Linda Skoruppa
Vienna University of Technology, E259 - Institute of Architectural Sciences, Vienna, Austria, linda.skoruppa@tuwien.ac.at

Ardeshir Mahdavi
Vienna University of Technology, E259 - Institute of Architectural Sciences, Vienna, Austria, ardeshir.mahdavi@tuwien.ac.at

Abstract

Along with the rising technical capabilities of modern BIM applications, the performance requirements on interdisciplinary data and information exchange interfaces increase drastically. The planning practice reality demonstrates a number of problems with BIM implementation on technical (heterogeneous data, interfaces, large data volumes) but even more so on process level (question of responsibilities and work-load distribution, lacking standards or conventions on building-representation).

This paper will present the first results of an ongoing research carried out at Vienna University of Technology in cooperation with seven BIM software developers. The aim of the project is to evaluate the practical suitability of interdisciplinary data exchange interfaces and -methods offered by the current BIM tools and to point out preferable BIM software combinations at the current state of development to potential users. Also, insights are gained on an optimal way of modeling building elements within an interdisciplinary context.

Simulating a BIM supported planning process with students of architecture, structural engineering and building physics, the students were assigned to design a sustainable office building in interdisciplinary teamwork. Architectural, structural and ventilation models had to be created as well as an energy certificate and thermal and structural simulations. Each student group was assigned to work in a different, pre-defined software constellation and thus forced to handle interdisciplinary data exchange with the given interfaces. Thereby, data on technical issues (interoperability, usability) and process-related issues (efficiency, communication and coordination effort) were collected by the means of protocols and time-sheets.

Evaluating both, the primary BIM data and the according process documentation produced by the student groups, first findings show that an integrated, BIM-supported planning process in a heterogeneous software environment remains a big challenge due to interface limitations, regardless of which software constellation is chosen. Anyhow, first improvement solutions concerning both modeling conventions and technical interfaces have been identified.

Keywords: Open BIM, Collaboration, Integrated Planning, Exploratory Research, Experiment

1. INTRODUCTION

With upcoming requirements for sustainable buildings, the need for more integrated planning practice, which would enable simultaneous collaboration of various disciplines in order to share and create new common knowledge, arises. BIM is largely understood as object-oriented digital representation of a building or built environment that enables interoperability and data-exchange in digital form (Kiviniemi et al. 2008). In this context BIM addresses primarily the process of model-building and information exchange (Succar 2010). BIM (Building Information Modeling) has often been recognized by research and practice as a suitable tool to support collaborative planning and to facilitate communication and information exchange between participating planners. Eventually it can lead to higher efficiency and quality (Rizal and van Berlo 2010). BIM seems especially promising in terms of life-cycle oriented planning and optimization. Furthermore, time efforts can be reduced. BIM is believed to bear large potential towards integrated design (Prins and Owen 2010) inducing a shift from AEC (Architecture, Engineering, and Construction) fragmented practice that still largely dominates this industry (Fellows and Liu 2010). Rekkola et al. (2010) argue that "integrated design" is still handled rather loosely in the practice – often the creation of BIM model is sufficient for the project to be referred to as "integrated project", regardless of actual interdisciplinary data sharing and model use. BIM, in our understanding, is much more about how (design process), than about what (building model and its properties).

Since the AEC industry is project-oriented, the small markets are characterized by high fluctuation of the employees and related know-how loss. Owen et al. (2010) point out the need for BIM related trainings to enhance skills of project members. So far, they are often highly specialized in their own fields of expertise, but seldom trained to work in integrated project environment. The organizations also support this kind of professional development rarely. In most cases, the introduction of new BIM-tools means more than simple CAD-tool shift. The adoption is mostly related to the reorganization of the processes and the project related management strategy.

In the practical BIM operation and use a number of problems on different levels can be met. On the technological level the question of interfaces in the data transfer of the interdisciplinary models arises. Additionally, one has to cope with the heterogeneous data-structures from different software, the art of model building, and the management of ever larger data-volumes. On the semantic level, it can be noticed that each discipline needs individual information; the professional languages differ strongly as well as the means and methods to represent a building (Bazjanac and Kiviniemi 2007). The spectrum reaches from diverse lists for project management and quantity surveys, reduced slab model for structural engineering to complete spatial representation of architectural model in the full geometric complexity.

Reliable management, filtering, and synchronization of this information in the context of still dominant heterogeneous software-structures, require high effort in organization, administration, interdisciplinary communication, and know-how. A standard solution offering the complete software package for this large spectrum does not yet exist, and it is a question whether such solutions are viable for every building as every design process is of prototypic nature.

The high fragmentation of the design and construction process disables the management of complexity. The linear planning process of highly specialized disciplines proves as not suitable in order to accomplish sustainable buildings. The necessity to change the way buildings are designed, constructed, and operated is being continually pointed out by the current practice. The emerging of highly developed BIM tools together with a paradigm shift from a linear, fragmented process towards a more integrated practice that would not only bring benefits for the planning and construction but even more so for the optimization of the operation of a building. A life-cycle oriented approach brings whole-life value, enabling knowledge management and -transfer from life-cycle phase to phase and integrating building services and automation systems (Owen et al. 2010).

The BIM research has mainly been focused on problem-solving of software-interoperability and efficient data exchange. Recently the academic community has realized that the successful BIM-adoption towards more integrated design and delivery is not related to the handling of technical issues only. Rather the design process itself needs to be organized (Succar 2010, Penttilä 2008). This relates to the internal organization and standardization of the workflows, role descriptions and related responsibilities of the stakeholders, as well as to the general commitment towards collaborative planning attitude. Rekkola et al. (2010) argue, that the lack of knowledge beyond technological issues, regarding workflow and business practices, is crucial. Within the case study, they identified problems and benefits of a BIM-supported integrated process and assigned them to the following categories: (1) people (competence or knowledge problem), (2) process (workflows, timing, contracts, roles), and (3) technology (software). Rekkola et al. (2010) argue that for enhanced integrative practice a participative process is necessary and that the slow BIM-adoption in the practice is caused by the difficulty of interrelation (triangulation) of the people-process-technology problems.

Therefore, the greatest challenge for holistic concepts, such as Building Life-cycle Management (BLCM) (von Both 2011) or Integrated Design and Delivery Solutions (IDDS), (Prins and Owen 2010) are the people and the process. An integrated, interdisciplinary building model requires close cooperation and coordination of the planners and contractors, the industry and the facility management, a highly skilled project team and detailed conventions on an inter-organizational level (Sacks et al 2010; Plume and Mitchell 2007; Arayici et al. 2011).

2. METHODOLOGY

In order to evaluate BIM-supported interdisciplinary planning, the use of BIM tools in an interdisciplinary context was tested in a design class. The experiment is part of an ongoing research project 'BIM-Sustain: Process Optimization for BIM-supported Sustainable Design'. This project involves three institutes of Vienna University of Technology and seven BIM-software developers. This interdisciplinary collaboration between university and industry enables the development of customized strategic concepts for the individual BIM-settings within multi-disciplinary planning environment. The aim of the project is the development of a framework for a BIM-supported planning process. This includes recommendations for data exchange, suggestions regarding the improvement of software interoperability, and recommendations for a BIM-supported design process.

An experiment within an interdisciplinary design class involving 40 students was set up. Therefore, the collaborative, multi-disciplinary BIM-supported planning process of designing an energy-efficient office building was simulated. The class was divided into 11 teams. Each team consisted of at least one architect (ARCH), one structural engineer (ENG) and one building physicist (BS). A survey on software experiences and preferences was conducted and different software combinations, as described in Table 1, were assembled. The teams were formed according to prior experiences and preferences regarding the software tools.

Team	**Architectural Model**	**Structural Engineering Model**		**Building Science** (Simulation in TAS)	
	CAD	**CAD**	**FEM**	**CAD**	**Calculation**
1	Allplan	Allplan	Scia Engineer	Allplan	Allplan
2	Revit	Revit	Sofistik	Revit	Plancal
3	ArchiCAD	Tekla	Dlubal RFEM	Plancal	Plancal
4	ArchiCAD	Allplan	Dlubal RFEM	Plancal	Plancal
5	Revit	Allplan	Scia Engineer	Plancal	Plancal
6	ArchiCAD	Allplan	Dlubal RFEM	Revit	Plancal
7	Allplan	Tekla	Sofistik	Revit	Plancal
8	Revit	Tekla	Scia Engineer	Allplan	Allplan
9	ArchiCAD	Revit	Dlubal RFEM	Plancal	Plancal
12	ArchiCAD	Allplan, Tekla	Dlubal RFEM	Revit	Plancal
13	ArchiCAD	Tekla	Sofistik	Revit	Plancal

Table 1: Software constellation within the student groups – Open-Platform BIM

The software constellation shows different workflow models: One-Platform BIM (proprietary) and Open-Platform BIM using IFC 2x3 (Industry Foundation Class) interface.

The Open-Platform BIM uses different software products and works with a central architectural building model. The data is exchanged via IFC. IFC is a standardized interface to describe a building model digitally (buildingsmart 2013). The One-Platform BIM works with one software family. In this experiment this applies to Nemetschek Allplan (2012) or Autodesk Revit (2012) which use proprietary standards.

The groups were given an assignment consisting of a functional program, site-plan with orientation and set origin, layer-structure and color scheme for room-stamps. Table 2 gives a short overview of this assignment.

Type	office
Gross area	7500 m^2
Employees	300
Location	Vienna
Concept	low energy
Construction	Concrete
Heating demand	< 50 $kWh.m^{-2}.a^{-1}$

Table 2: BIM_sustain class assignment

The design class was scheduled for one semester and a timetable with deadlines was set. Apart from weekly crits, three presentations were scheduled for different phases. The first one focused on the architectural design. In the second presentation the structural and thermal solutions were discussed. The final presentation covered the optimized, full model including all information. Figure 1 describes the workflow and the discipline related tasks. By means of the mandatory protocols and time-sheets the technology related problems (data transfer inconsistencies or losses, semantics) and also to the process-people related problems (conflicts, communicational difficulties, lack of work-flow definitions or responsibilities etc.) were identified. Additionally an e-learning platform has been set up, with a forum for tutor feedback as well as for student-communication. This platform was also used for scheduling and posting of tasks.

The students had to protocol their work throughout the semester. These timesheets were then analyzed. In this way, information was gathered on workloads and time spent on specific tasks. The analysis of the protocols revealed the technology and communication related problems and challenges, as well as the applied solutions. In this paper we will present the qualitative analysis of the process, based on the protocols, using the so called fault tree analysis (FTA) for one of the participating teams (team 2). Team 2 is working in ‘One-Platform-BIM’ modus, using Autodesk Revit for both architectural and structural modeling. For the structural calculation Sofistik is used by the means of a plug-in imbedded in Revit.

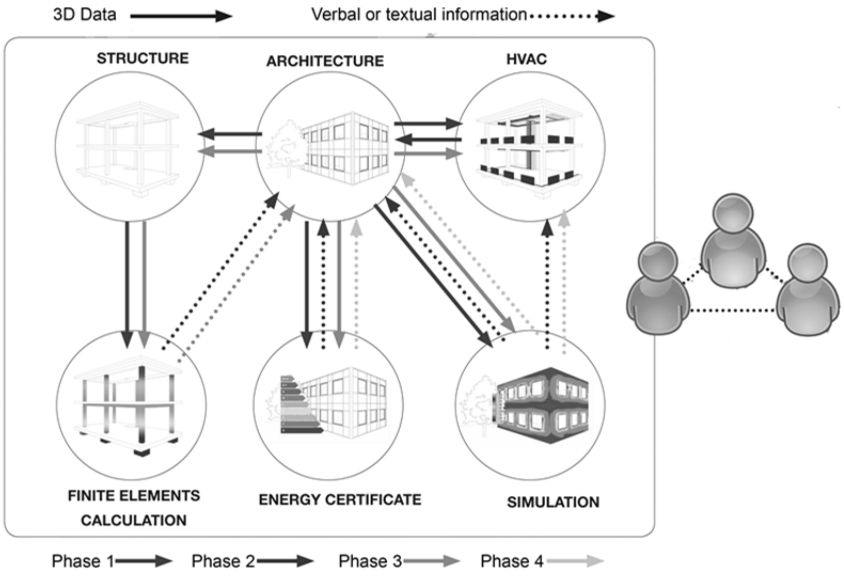

Figure 1: Discipline related Tasks and Models

3. FIRST FINDINGS

The architectural model was set up in Revit and exported with Revit Structure, a proprietary interface (Sofistik plug-in). The structural calculation was carried out in Sofistik. It is not possible to use an IFC interface to export from Revit to Sofistik. Figure 2 shows the fault tree analysis for architect and civil engineer.

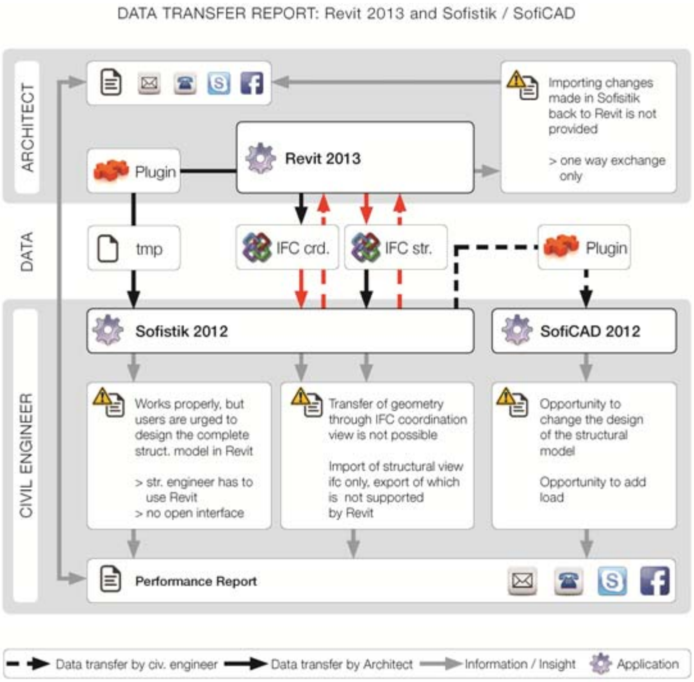

Figure 2: Fault tree analysis: architectural to structural model

The building physicist tested the architectural design for energy efficiency and thermal performance. To yield location specific results for Austria, special software with different interfaces had to be used. Figure 3 illustrates the data exchange between the architect and the building physicist. With the aim to report improvement suggestions of the construction concerning the thermal performance of the building, BS calculated an energy certificate, created a 3D model for thermal simulation, checked lighting possibilities, and planned a ventilation concept for the given model.

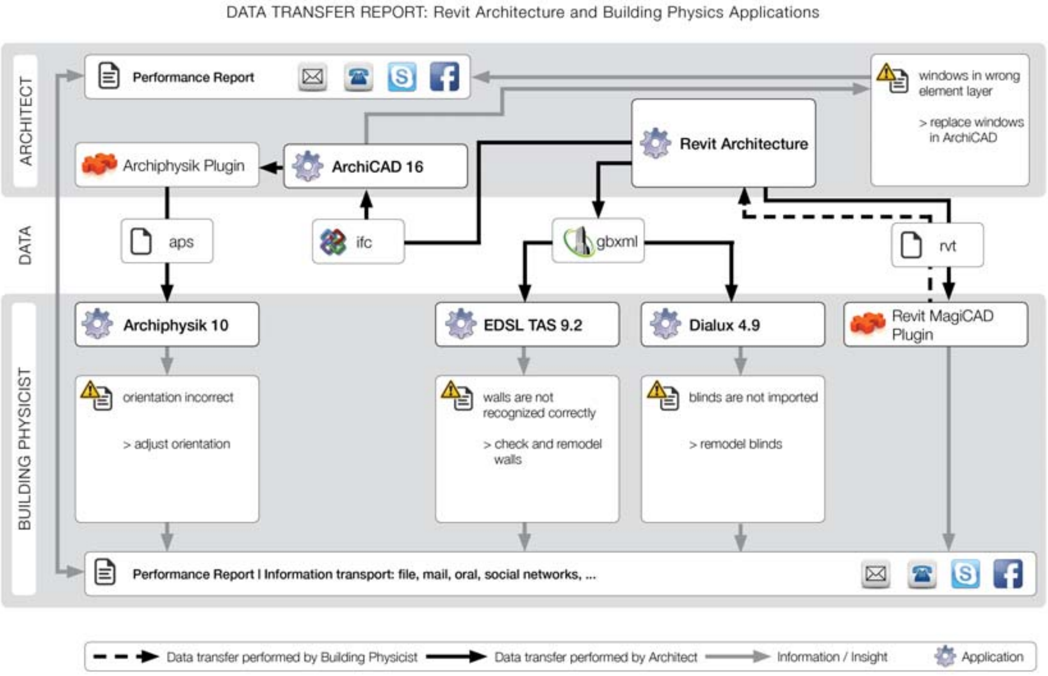

Figure 3: Fault tree analysis: architectural model to building physics software

In team 2, BS received the architectural model as Revit file (.rvt) according to the software constellation. In order to generate the energy certificate for this building, an .aps file was required to import the information to the according software, in this case we used Archiphysik 10. Neither was Revit able to export an .aps file, nor was Archiphysik capable to import any other file format. Archicad was interposed with a special plugin to create an .aps file out of the .ifc file received from Revit. For thermal simulation we used EDSL Tas(EDSL Tas 2013) and for illumination scenarios Dialux (Dialux 2013). Both simulation programs accepted .gbxml format only. Green building markup language (gbxml) provides information about building elements and its characteristics in a structured hierarchical manner (xml.com 2013). Revit is capable to export this format as well. To draw the HVAC system, a plugin for Revit was necessary. This did not affect the workflow or data exchange.

After the files were imported into the simulation and calculation programs, incomplete data exchange and models were noticed by the building physicist. Consequently, adjustments had to be performed in order to receive the original model, e.g. correct the orientation, check and remodel walls and other missing elements.

In Archiphysik the orientation of the building was ignored by the program. This had to be corrected manually. EDSL Tas had problems recognizing building elements correctly. Especially walls had to be redrawn in most cases. In Dialux, shading devices were not imported and had to be added manually. Furthermore, no detailed information about the windows was transferred. Figure 3 illustrates the data exchange as well as the major problems with the data import.

The experiment showed that one of the main challenges is the preparation of the architectural model so it can be used for structural analysis and calculation. In the architectural model the wall construction line is commonly drawn on altering sides of a wall, the structural calculation requires the line to be centered in order to recognize the vertical connections and to be able to carry out the calculation. Without this knowledge it takes additional time to prepare and rework the model. The question arises whose task it is to prepare the model accordingly: the architect's or the engineer's?

After the calculation the structural model was adapted directly in Revit by the structural engineer, which was reported to be a complex task.

Shared problems reported by other groups are mostly related to the interpretation of geometry. The .ifc format but also the proprietary interface from architecture into FEM cause wrong geometry interpretation: recesses in wrong positions, missing walls, etc. Complex geometries such as round walls are also problematic.

A common problem was the incapability of ArchiCAD and Allplan to export structural-analysis-type ifc data, since FEM applications like Sofistik are only able to import this type (no ifc coordination view support)

Table 3: Compatibility with IFC – Structural Analysis

CAD		FEM	
Archicad		Dlubal RFM	⇄
Allplan		Scia Engineering	⇄
Revit	⇄	Sofistik	⇄
Tekla	⇄		

It was observed that teams in that case applied the software which was not part of original matrix in order to enable export, a solution which could not be viable in the practice.

4. CONCLUSIONS

The case study has shown that a BIM-supported planning process requires thorough coordination and standardization in order to achieve its full benefits. Both, proprietary as well as open data exchange interfaces, face large problems in the interpretation of geometry, which often calls for complete rework of the architectural model in the discipline specific model. Some software combinations are even incompatible, which should be considered in the beginning of the planning to prevent high latter costs.

In addition, attempts to create building information models for full-on interdisciplinary use still face many contradictions concerning issues like wall construction lines (FEM vs. Building

Physics), multi-story building elements such as columns, facades or elevators (ARCH vs. Tendering vs. FEM) and many more. It seems that currently, no matter how an architectural model is build up, it will cause problems in one or the other involved discipline – regardless of the used software environment and the creator's skill level. Besides from all technical issues concerning the data exchange interfaces, it seems that the agreement on how (and how detailed) a BIM model is to be created remains one of the most delicate issues for a successful integrated BIM supported planning process.

The fault tree analysis has shown that BIM as used in the experiment is still a one-way BIM. The way how the specific disciplines return the information in the basic model is quite different – with buildings physicists this can currently only be done by communication (report, mail, meeting); for the structural models this could in most cases be carried out digitally in the initial model. How the information should be fed back into the original model still remains unanswered, posting the question of rights to change the model and introducing the new planning profession such as BIM-manager.

BIM-based software-packages that fully support integrated, interdisciplinary planning practice and holistic life-cycle oriented data integration are still rather seldom. One-stop solutions for architecture and structural engineering, MEP (mechanical and electrical engineering), energy optimization, cost- and life cycle cost calculation are not available for the needs of central European planning practice and building policy. Due to different project-constellations and changing stakeholders with each new project, different combinations of software tools are to be met with each new project.

For a successful implementation of life-cycle oriented planning and management strategies, smooth data exchange without information losses are important. Therefore, further development regarding open data-exchange formats is required.

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