🏆 *reviewed paper*

Assessment of BIM Potentials in Interdisciplinary Planning through Student Experiment and Practical Case Study

Iva Kovacic, Lars Oberwinter, Christoph Achammer, Michael Filzmoser

(Assistant Prof. Dr. Iva Kovacic, Vienna University of Technology, Industrial Building and Interdisciplinary Planning, iva.kovacic@tuwien.ac.at)

(DI Lars Oberwinter, Vienna University of Technology, Industrial Building and Interdisciplinary Planning, loberwinter@industriebau.tuwien.ac.at)

(Univ. Prof. DI Christoph Achammer, Vienna University of Technology, Industrial Building and Interdisciplinary Planning, christoph.achammer@tuwien.ac.at)

(Assistant Prof. Mag.rer.soc.oec. Michael Filzmoser, Vienna University of Technology, Institute for Management Sciences, michael.filzmoser@tuwien.ac.at)

1 ABSTRACT

It is argued that Building Information Modelling technology bears significant potentials for enhancement of more integrated design and planning process, and further more for life cylce managament of built environmet. Through creation of a joint model, serving as common knowledge base for parttaking disciplines, the knowledge from the design pahse can easily be transferred into the operational phase. BIM offers a powerfull tool for monitoring, optimization and simulation of building operation, building as such a platform for data transfer and management necessary for the management and governance of the smart city.

This paper will presens the results of the empirical research – a multidisciplinary student experiment carried out at the Vienna University of Technology, with the students of architecture, civil engineering and master of building science. In the course of the empirical research a multidisciplinary design for energy efficient building structure is simulated, using various BIM tools (for architectural and structural modelling and simulation, thermal and light simulation) and testing the interoperability as well as the process integration.

The special focus lies on the test of interfaces, as crucial factor for process integration, satisfaction and efficiency, which was demonstrated in the pilot experiment. Two BIM models “one-platform-BIM” using proprietary interfaces and “open-BIM” using IFC interface will be evaluated and compared in terms of efficiency of data-exchange and transferability, as well as in terms of satisfaction with process and collaboration.

Finally, the results obtained from the experiment will be compared to the experiences gained from the practical case study – BIM use in two planning firms – in order to identify optimization potentials for the planning practice as well as key performance indicators for integrated design supported by BIM tools.

2 INTRODUCTION

2.1 Why Building Information Modelling

The AEC (archtecture, engineering, construction) industry is under growing presssure in terms of reduction of time and cost, and upkeeping of quality with simultaneous increased requirements in terms of energy and ressources efficiency. New tools are needed for increasing of process integration on the one side and for the successful life cycle management on the outher. BIM (Building information Modelling) Tools as emerging technology has been advocated to be able to meet all of the mentioned requirements. C. Eastman (1976), a BIM pioneer, introduced building modelling concept based on the notion of a database of building elements (building description system) in the seventies. The early technology has been developed in 1980, through introduction of ArchiCAD as the first BIM software, however the break through on the market was only possible in the new millenium, due to the maturing of ICT, which again enabled the data exchange between different toos (HVAC, RFM, cost calculation time sceduling – 5D BIM).

Numerous BIM definitions are used by academics and practitioners, ranging from the view as software application, as a process for design and management of the building through out the lifecycle (Aranda-Mena et al, 2008), or as a whole new approach to the practice based on so called integrated project delivery (Prins and Owen, 2010). There is a joint agreement that successful BIM implementation is supported by technology (software, interfaces, data mangement), people, process and policy and carried out in several stages (Succar, 2009): pre-bim, modelling, collaboration and finally integration.

ISBN: 978-3-9503110-6-8 (CD-ROM); ISBN: 978-3-9503110-7-5 (Print)
Editors: Manfred SCHRENK, Vasily V. POPOVICH, Peter ZEILE, Pietro ELISEI

Through integration of the multiple models of different parttaking disciplines and through capapility of visualization, simulation and management of the building through out the life cycle BIM is a promising tool to support life cycle oriented integrated planning.

2.2 Problem Statement

BIM is experiencing much slower utilization by the AEC practice than the CAD at the time, especially in the Central European region. Even the Western European market is lagging behind the US market in BIM implementation – according to the McGraw Hill (2009) study, the BIM utilization in Western Europe is 36% where as in North America 48 %. The architects are identified as main BIM adopters.

What are the possible reasons? One of them is the still highliy fragmented planning practice, lacking the integrative experience, which is a precondition to successful BIM implementation. Secondly the standards and policies are lacking, differently so in e.g. the United States (Penn State 2012, AIA 2014) or in the UK where BIM is obligartory in publc projects from 2016 (Kiviniemi, 2014). Further on, the investors are important driving force for BIM break through on the market – as long as IFC models are not required by the public investors such as it is the case in the Scandinavian countries (in Finland since 2007, in Norway since 2010) (Wong et al 2010) it cannot be expected that BIM use will be accelerated in the AEC market.

3 RESEARCH DESIGN

3.1 Research intention

This paper presents the first results of the research project BIM_sustain, funded by FFG, carried out as cooperation of Vienna University of Technology and seven BIM software developers and consultants. Through the project the strategies for time- and cost-efficient BIM-supported planning should be developed, where by not only technology issues (software compatibility, data exchange and transfer, information losses) but also people (skills, knowledge) and process (organization of work-flow, model building, coordination, change management) should be assessed, and finally serve as basis for policy making and standardization on national level. The cooperation with the industry enables immediate compilation of customized software solutions and improvement of the tools after identification of the deficits through research.

In order to identify potentials and deficites of BIM in interdisciplinary building design, we organized a student experiment. We simulated a BIM supported integrated design of energy efficient structure in interdisciplinary teams consisting of architecture-, structural engineering- and building science students. The teams worked with different software constellations, two teams in so called one-platform BIM using proprietary interfaces, the other 10 teams in open-platform BIM, using IFC interface. We analysed the people-process-technology triangle, testing process- and software satisfaction (people), efficiency and work-flow organization efforts (process), respectevly software compatibility and data exchange (technology). The simulation thereby enabled quantitative (time sheets, activity protocols, inquiry) and qualitative (focus group interwievs) assessment of the BIM supported planning.

In the next step we analysed the BIM use in two large general planners' offices (both comprising the architectural, structural and HVAC modelling); where one of the offices works with open BIM and the other in one-platform BIM environment. The analysis was carried via open-ended interviews with BIM managers and responsible planners, and the results were compared with the data we obtained from the experiment.

3.2 Student experiment

Through explorative research - an experiment with the students of architecture, structural engineering and master of building science in the framework of the BIM-Sustain research project - we simulated different a collaborative, interdisciplinary design for sustainable building of complex geometry. Thereby an architectural, structural and thermal model should be compiled and optimized by the student teams using various BIM tools. In the winter semester 2012/13 the first experiment was organized serving as pilot, and in the winter semester of 2013/14 the subsequent experiment has taken place. The experience gained through the pilot experiment especially related to the team building, modelling and model exchange, and software combinations was used for the improvement of the following experiment.

In this paper we will present the results of the first experiment, and compare these to the BIM perception in the AEC practice.

In the pilot experiment 40 students took part, forming 11 teams. Each team was using different set up of software combinations for architectural, structural and ventilation modelling, structural calculation, dimensioning of ventilation and thermal simulation, thereby testing the software and the interdisciplinary data exchange (Table 1). Special emphasis was on the assessment of the benefits of one-platform BIM (teams 1 and 2) versus the open-platform BIM combinations (teams 3-11).

Through the analysis of the primary BIM data and related process documentation we were able to identify the heterogeneous problems of BIM supported planning.

Team	Architecture	Structural Engineering		HVAC (Ventilation) (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
10	ArchiCAD	Allplan, Tekla	Dlubal RFEM	Revit	Plancal
11	ArchiCAD	Tekla	Sofistik	Revit	Plancal

Table 1: Teams and software combinations used in experiment

Through so called fault-tree analysis the data flow diagrams were compiled for each group, describing data transfer and software compatibility issues.

The fault-tree analysis shows, that transfer to the building physis software (EDSL TAS, Dialux, Archyphysik) is equally difficult in one-platform as in open-platform BIM, resulting with numerous problems, due to the fact that most of the software does not support IFC interface, but the proprietary interfaces, e.g. Gbxml. Reported problems: roomstamp does not work, software crashes at import, walls are not recognised correctly, blinds are missing, building elements not recognised, missing elements, windows not imported, result with remodelling or complete new modelling in the building physics software. (Fig.1, Fig.2).

In terms of model transfer for structural engineering the one-platform BIM (via proprietary interface) teams report less difficulties, however even here problems appear with complex geometry (round walls) and creation of simplified architectural model is necessary.

The transfer-analysis in HVAC modelling displays as general problem in data transfer via IFC that room stamps are not recognised, or interpreted wrongly.

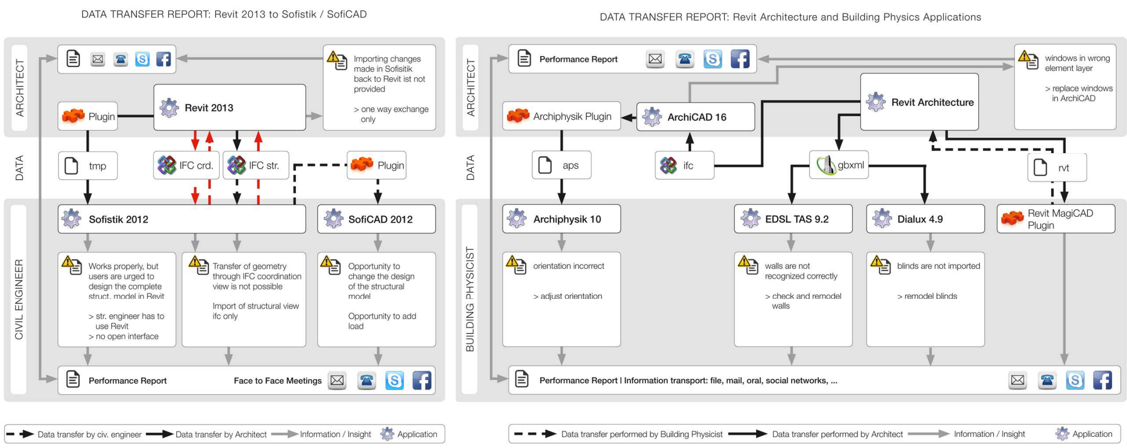

Fig. 1: Fault tree analysis for data transfer to structural engineering and building physics software for Team 2 (one-platform BIM)

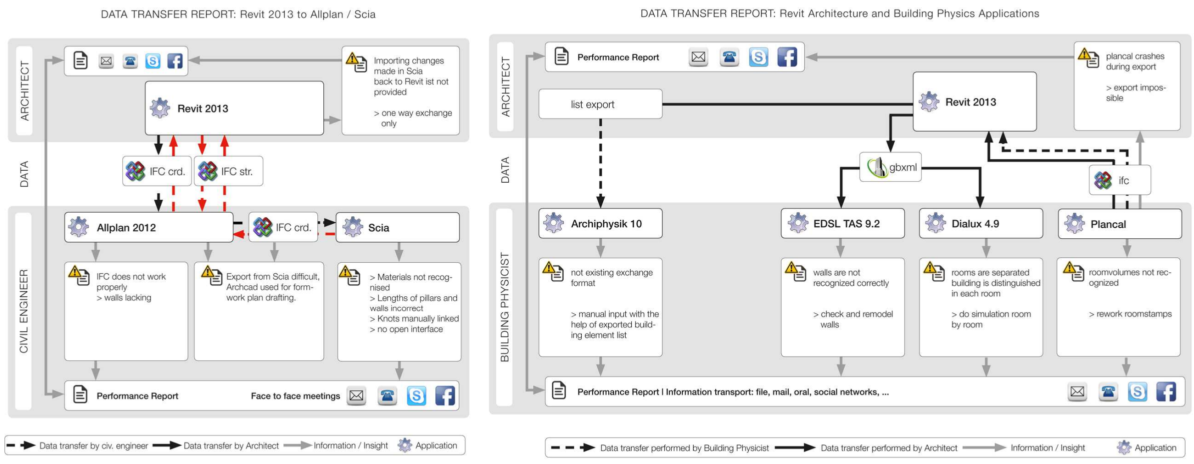

Fig. 2: Fault tree analysis for data transfer to structural engineering and building physics software for Team 5 (open-platform BIM)

For the detailed process-analysis the time sheets were used for the analysis of activities and related time-efforts. This allows drawing the conscusions on the workflows and efficiency of the planning process as well as the identification of the problems. Next to the inquiries for the evaluation of the satisfaction with the software and the planning process, the focus group interviews were conducted for the tree functional groups of architects, structural engineers and building scientists. The content analysis allows the identification of the concrete problems of the each discipline in the context of interdisciplinary cooperation and in the nexts step the compilation of best practices for the improvement of the planning processes.

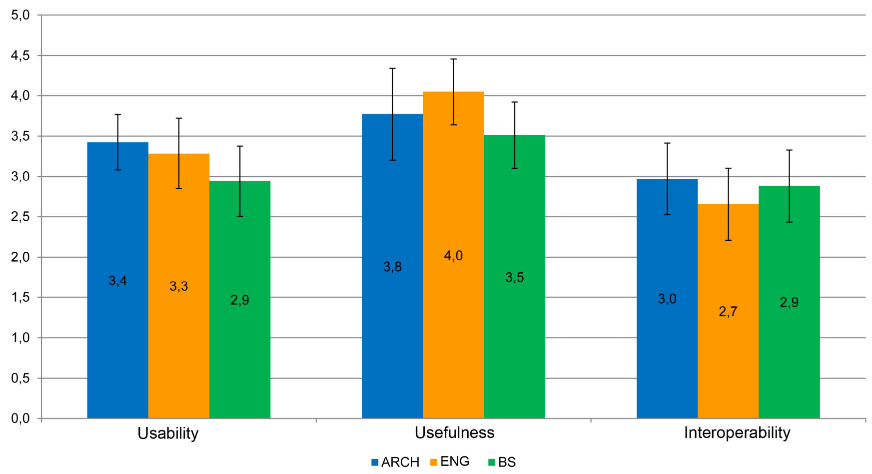

Fig. 3: Results of the inquiry for the technology aspects

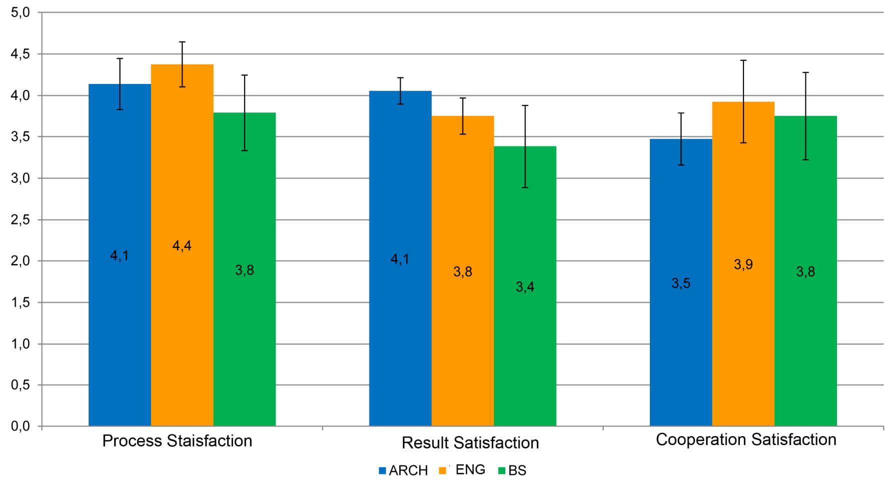

Fig. 4: Results of the inquiry for the people aspects

Focus group analysis shows that the topic of interoperability and content related discussions dominate the focus groups, the early cooperation (team, organization and software) are seen as positive for future work, which implies on necessity of a teaming workshop for the future experiment (or planing practice). Positive experiences outnumber the negative ones, especially with the successive disciplines (structural engineering, HVAC). The stress and time pressure in the latter planning phases require for better time management, which can be met by more careful design of the planning process, through definition of workpackages and milestones.

The inquiries show that interoperability is of great importance for structural engineers and building scientists in the interdisciplinary team, but is seen as very problematic. They are also satisfied with the process and result, where as the architects are less satisfied with the cooperation. (Fig. 3, Fig. 4).

3.3 Case Study – BIM in the planning practice

In order to verifiy the data obtained through the student experiment, we conducted a research of the BIM-use in the planning practice on the cases of two large firms, which both pioneered BIM on the market (early users). Via open ended interviews with BIM managers and responsible planners, following issues were questioned:

1. Which software do you use in the office for:

Architectural design, Structural Modelling, Sturctural Simulation/Calculation, HVAC Modelling/Calculation, Building Physics, Cost Estimation

2. Describe the BIM work-flow in your firm - for which constellations you use 3D data transfer, for which other (2D, lists)? How does the information flow back in the originary model?

3. Where are you experiencing the largest data losses? How do you solve this problem?

4. Where do you see the largest improvement potentials?

5. Can you clearly identify the benefits of BIM in your company?

3.3.1 <u>Case A</u>

Case A is an integrated building design and planning firm, counting to the largest in Europe, using BIM since 2008, comprising architecture, structural and HVAC engineering, construction mangement however no building physics.The services range from the programming, architectural competition till project turnover, including architectural, structural and HVAC building design, planning and management (cost planning and management, site management). The firms’ focus is on collaborative integrated design involving architectural, structural and HVAC design. The firm employs app. 500 engineers and architects and is located at several locations across Europe, distributing the work along locations. The firm works in one-platform BIM using Revit for architectural, structural and HVAC modelling. Interviewed were BIM manager and BIM responsible planner (Table 2).

The company works in one-platform BIM (Revit) employing Revit Architecture, Revit Structure via proprietary interface in Dlubal REFEM or RSTAB for calculation, Revit MEP with PlugIn Magi Cad with all of the object libraries for HVAC modelling, Solar and Gebis for Ventilation calculation

5D BIM (cost planning and scheduling) is carried out via ITwo and RIB, by automated calculation through extraction of masses, interfaces for bidding procedure are still in development.

Quality control is carried out using Solibri check for clash detection, check of loadbearing elements, using IFC interface. The firm does not employ BIM assesment management tools or instruments.

3.3.2 <u>CASE B</u>

Case B is a general planer, offering full scope of services from construction planning till project turnover; structural engineering, HVAC, building physics, fire protection; construction management, cost planning and management. The firms’ focus is on engineering services and construction management, less on architectural design. The firm employs app. 180 mainly engineers and some architects, consisting of the headquater and two futher smaller locations, also using joint ICT infrastructure and joint project set up. The firm is using BIM since 2011, as open-BIM, which allows working in heterogenous software environment allowing data exchange among specific tools of each discipline.

Interviewed was BIM manager, who was responsible for BIM introduction, implementation and setting of firm's standards (Table 3).

Interviewees Categories	BIM Manager	BIM Planner
DATA LOSSES	The largest data losses towards building physics, since these do not read IFC. Further dataloses are experienced towards all firms out of the house – construction companies etc.	It is simplier in the house – all use the same model, more difficult out of the house – problems with construction companies the interfaces do not work, data loss.
BENEFITS	A benefits is better integration, everybody needs to communicate with each other, less clashes (Solibri), finally possibility for quality management,	Time-reduction in project-execution, some projects would not be possible without BIM, due to the time pressure. Design phase is faster.
		Calculation of structure is faster due to the premodelled structure from architectural model.
		Benefits for subsequent planners – e.g indusrial planner can use the digital building model and for the positioning of 3d machines, which before BIM was not possible.
		Quantitative assesment is difficult.
IMPROVEMENT POTENTIALS	Improvement is necessary towards building physics; it takes huge effort to remodel when data is transferred.	Satisfaction – the education is important, easier handling increases satisfaction
	There is still a break between competition and architectural planning (competitions are not modelled in Revit).	Largest amount of time is used for the decision making, which cannot be taken over by Revit
		Definition of the level of deatiling –a lot of effort was put in to too high level of detailing for design model
		Life cycle management : BIM as built who should update the planning stage BIm model?
		Data exchange across locations does not work well, technical problems with central model
		Inhouse: bi directional BIM; out of the house - one way BIM

Table 2: Categorised statements Case A

Interviewee Categories	BIM Manager
DATA LOSSES	Greatest data losses are experienced in the REFM transfer (structural simulation).
BENEFITS	The greates advantage is the workflow systematization as well as the automatised project set up, which substantially contribute to the improvement of collaboration and data exchange.
	Very difficult to asses quantitative BIM benefits – every project is different, how to compare?
IMPROVEMENT POTENTIALS	The highest improvement potentials can be identified in data exchange between building model and building physics, since these do not work with IFC.
	Still dificult is to generate usable 2D drawings from digital modells, that would go along with e.g. ÖNORM standard.

Table 3: Categorised statements Case B

The firm is using a wide spread of different software. Building modelling is carried out in ArchiCad (as originary model), structural modelling in Allplan, calculation in Scia and Tower; HVAC modelling as well as the calculation in Cats (Autocad Plugin), cost planning uses BIM modell for automatised mass and volume extraction for customised xls-based calculation, building physics is using Archphysik, TAS (which is de-coupled from the BIM process) and Dialux.

All of the models are coupled in one joint project-set up in Navisworks or Tekla BIMsight, which carries out collision proof and quality management, directly adressing the affected planners via mail.

Basis for this procedere is the standardised structure for all projects and all disciplines, using the same project set up. The advantage of such set up is, that every user is working in the existing, already known software environment, however in structured way, which enables data transfer and exchange.

From the originary Archicad model both 3D and 2D data is transferred to the structural engineering and HVAC; bidirectional exchange is given between structural model and ventilation model into the originary model.

The firm does not employ BIM assesment management tools or instruments.

4 CONCLUSION

The examined cases, seen in the context of one-platform BIM versus open-platform BIM show similarities in identifed benefits and deficites. In both cases the improvement of data exchange towards building physics tools is seen as the most important issue. Both cases see as largest BIM-benefit the enhancement of integration and collaboration. Both cases identify the necessity of standardization and policy (level of detailing, modelling normative or standard).

The cases confirm the experiment findings, where the transfer towards the building physics software (thermal simulation, daylight simulation) was burdened with numeous problems. Further implication from both experiment and cases, is the necessity for thorough work-flow and process organization - more intensive than in 2D CAD design and planning - in order to gain full BIM benefits.

The experiment and case study could not identify significant advantages in terms of data transfer efficiency of one platform BIM over open-platform BIM. In the experiment, the teams 1 and 2 must employ other BIM software as intermediate step or use Gbxml interfaces to transfer data to thermal simulation software, both cases resulting with data transfer losses, team 1 even experiences problems in the ransfer of structural data using proprietary interface in own family.

The case A, despite working in one-platform environment, uses IFC for quality control via Solibri, and leaves thereby the Revit platform. The BIM manager of the case A even sees a necessity for the building physisc software to support IFC interface, as the universal interface enabling standardized data exchange.

It is questionable if the one-platform BIM as closed system is a viable concept in the practice - as soon as additional consultants or companies are parttaking in the project, a standard must be met to be able to exchange the data bi-directionally, which again is the strenght of open-BIM concepts which allow for infinite expansion and data exchange in the planners network.

The research implies that a thorough analysis of firms’ demands, workflows and working procedures is needed as the first step in BIM implementation. Customized solutions for each firm, based on careful design of workflows and communication, generation of joint data-structures and project-set up play crucial role for sucessful implementation. There is no ideal solution (one-platform or open-platform) or out of box solution.

None of the cases is employing a measurement methodology or assesment procedure in order to evaluate BIM benefits or perform benchmarking, which is a wide spread and recognised problem (Barlish and Sullivan, 2012, Bercerik-Gerber and Rice 2010). Therefore, is still difficult to quantitatively determine the business value of BIM, especially in the Central Europan region where the experience with BIM in interdisciplinary planning is limited. In the next step, a metrics system for measurement of BIM benefits and strategies for stage-wise BIM implementation suitable for Austrian market should be developed.

5 ACKNOWLEDGEMENTS

This paper is a result of an on-going research project “BIM-Sustain” funded by FFG (Austrian Research Funding Agency) and following BIM-software vendors: A-Null, Artaker, b.i.m.m. Gasteiger, Construsoft Tekla, Dlubal REFM, Nemetschek Allplan and Plancal. We gratefully acknowledge the work of the academic partners: Institute for Management Sciences, Prof. S. Köszegi and Institute for Building Physics and Ecology, Prof. A Mahdavi, L. Skoruppa and K. Kiesel, and to the students taking part in this project of Vienna University of Technology.

6 REFERENCES

AIA: AIA Digital Practice Guide and Samples, http://www.aia.org/contractdocs/AIAB095713, last access Feb. 2014

ARENDA-MENA G., CRAWFORD J., CHEVEZ A., FROESE T.: Building information modelling demystified: does it make business sense to adopt BIM? CIBW78. 2008 International Conference on Information Technology in Construction Santiago. Chile. 2008.

BARLISH K., SULLIVAN K.: How to measure the benefits of BIM — A case study approach. In: Automation in Construction, Issue 24 (2012). pp. 149–159. 2012.

BERCERIK-GERBER B., RICE S.: The perceived value of Building Information Modelling in the U.S. Building Industry. In: Journal of Information Technology in Construction. ISSN 1874–4753, at http://www.itcon.org/2010/15. 2010.

EASTMANN, C.: General purpose building description systems. In: Computer-Aided DesignVolume 8, Issue 1, pp. 17–26. 1976.

KIVINIEMI A.: Challenges and Opportunities of BIM in Life Cycle Assesment. In: BIM for LCS, Achammer C., Kovacic I. (ed.), NWV Wien.2014

McGRAW HILL. The business value of BIM: getting to the bottom line. Retrieved from: http://www.bim.construction.com/research/2009. 2009

PENN STATE Computer Integrated Construction Research Program: BIM Planning Guide for Facility Owners, Version 1.01, May, The Pennsylvania State University, University Park, PA, USA. http://bim.psu.edu, 2012

PRINS M., OWEN R. Integrated Design and Delivery Solutions. In: Architectural Engineering and Design Management. 6(4), 227–231, 2010.

SUCCAR B. Building information modeling framework: a research and delivery foundation for industry stakeholders. In: Automation in Construction 18 (2009) 357–375.2009.

WONG A., WONG F., NADEEM A.: Attributes of Building Information Modelling Implementations in Various Countries. In: Architecural Enginnering and Design Management, Integrated Design and Delivery Solutions. Vol. 6, Issue 4, pp.288-302. 2010.