

HABILITATION TREATISE

Advances in Integrated Building Design and Planning Methodology

Exploratory Studies for the Optimisation of
People – Process – Technology Interaction
in the Architecture, Engineering and Construction (AEC) Industry

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This habilitation treatise presents the results of my research and research led teaching carried out at the Institute for Interdisciplinary Building Process Management, Department for Industrial Building and Interdisciplinary Planning. The conducted research projects and generated results build a fundament for a long-term research activity and establishment of the Research Centre for Integrated Planning.

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List of abbreviations

AEC	Architecture, Engineering and Construction
BIM	Building Information Modelling
CE	Concurrent Engineering
EPOS	The Engineering Project Organization Society - a society of interdisciplinary researchers and professionals focused on the support and enhancement of scholarship, research, and exchange in the field of organization studies as applied to the engineering domain
IBD	Integrated Building Design
ICE	Integrated Concurrent Engineering (method)
IP	Integrated Planning
IPD	Integrated Project Delivery
KPI	Key Performance Indicator
R&D	Research and Development
SP	Sequential Planning
TU Wien	Vienna University of Technology

1. INTRODUCTION

1.1. Current issues in the AEC industry

Despite a very long and renowned Austrian, and Austrian-based Central European, building design and construction culture, today's architecture, engineering and construction (AEC) industry stands at a tipping point. Traditional design and engineering methods cannot address the numerous challenges facing the industry, such as climate change, scarcity of energy and resources, an ageing society, the economic crisis, and global competition. The development of new, collaborative planning methods and approaches, using historic building tradition and expertise, is therefore necessary to address these challenges, and to enable sustainable construction and refurbishment, while preserving economic, environmental and social assets.

This Habilitation Treatise explores the practice of integrated collaborative planning, and seeks to advance design and planning practice in Central Europe, and in Austria in particular. Integrated Building Design (IBD), as a stage within Integrated Project Delivery (IPD), is advocated as being crucial for achieving a sustainable built environment, as well as being the way to deal with increasing complexity in the construction industry.

The construction sector is Europe's largest employer. It is responsible for 11% of gross national income, and is a leader in world export markets. However, it is also renowned as one of the least innovative industries, while having a large environmental impact. The reasons for this low-innovative culture are numerous: because the industry uses highly durable products (required to last 50 years or more), consumers tend to prefer conservative solutions, to avoid risks; it is a 'low-profit' sector, with limited R&D budgets; and it is typically a fragmented industry – out of two million enterprises, 92% have fewer than ten employees (Geissler et al, 2005).

Although the Austrian AEC industry is characterised by high levels of planning and engineering expertise, it exhibits the same characteristics as the wider European industry – a very fragmented, small-enterprise industry, lacking experience in collaboration – characteristics which are seen as major obstacles to improving innovation. The expertise is segmented, lacking in synthesis, and

cannot be transferred to other stakeholders or even future users – all of which is necessary for resource-efficient, whole-life optimised construction.

The majority of Austrian construction companies have between 1—9 employees (Statistik Austria, 2014, a). The largest Austrian construction company, STRABAG, employed 5.600 people in 2003, whereas global players, such as SKANSKA or Hochtief, employ over 12.000 (Ahammer and Stöcher, 2005).

The majority of architecture and engineering offices have between 1—4 employees. Based on the EU definition, 96,5% of Austrian architecture offices are micro-enterprises (Statistik Austria, 2014, b). Only four architecture offices employ more than 50 people, and only 21 offices (2,1%) have revenues larger than €5,1 Million (Eichmann and Reidl, 2006).

Innovation is linked to the size of an enterprise: 84% of large Austrian enterprises are involved in innovation activities, whereas only 49% of small enterprises (10—49 employees) report innovative activities (Statistik Austria, 2014, c). Austrian architects and engineers, as micro-enterprises, are able to engage in even less innovation than small enterprises.

The research presented here explores the possibilities and potential for raising the level of integration in the domestic and Central European AEC industry, in order to foster process innovation and optimisation, and guarantee a more sustainable, high quality built environment as its legacy.

For this reason, the focus of this study is on collaboration in the early planning stages of the building life-cycle, as these are the stages most likely to influence future, whole-life, building performance. The study focuses primarily on collaboration between architects, planners, consultants and users/investors.

1.2. Proposed solution: Integrated Planning (IP)

There is currently a shift in emphasis from traditional, sequential project delivery towards Integrated Project Delivery, as the latter is claimed to be superior when addressing current issues in the AEC industry, such as resource and energy efficiency, emission reduction, and optimisation of the building life-cycle in general.

In this context, Integrated Planning (IP) is defined as the early collaboration of all planning process participants, from the earliest design stages, supported by: information and communication technology (ICT) for team collaboration and

communication; powerful modelling tools, such as Building Information Modelling (BIM); and design analysis and simulation, for building life-cycle optimisation.

BIM, as an emerging technology, facilitates the creation and interdisciplinary exchange of three-dimensional, parametric, information-rich building models, while simultaneously providing a shared, comprehensive, knowledge data-base for life-cycle management of a building.

Early, BIM-supported, interdisciplinary collaboration facilitates the capture of shared, systemic knowledge which is necessary for innovation and the achievement of sustainability aims. In theory, it also minimises uncertainties, risks, costs and delivery timescales.

1.3. Challenges for the implementation of IP

Although BIM-supported IP is advocated as a logical solution to current issues in the AEC industry, IP is still only rarely practised in Central Europe, and BIM-adoption is still in its infancy, with planners sceptical about its use.

There are several reasons for this. Firstly, the IP methodology originated in the English-speaking world – primarily in the USA, where the AEC industry and knowledge domain differs significantly from that in Central Europe. The IP model cannot be transferred to Central Europe unaltered; instead, it is necessary to build a localised knowledge domain and IP methodology.

Secondly, the early design stages of a project are especially difficult. They are of short duration, yet crucial for the subsequent performance of the building throughout its life-cycle. However, in these early stages, tools are not available and project information is lacking. The process is design-oriented, based on an intuitive-interpretative methodology, and although familiar to architects, it may not be familiar to engineers who work with analytical methods. Subject knowledge is implicit, complex and difficult to codify, which again may present obstacles to collaboration.

Only in the later planning stages, when information becomes explicit and easy to codify, are more tools available. This is one of the reasons why planners, using mainly tacit knowledge, are sceptical about BIM, whereas the construction sector, dealing with explicit knowledge, is more positive about its adoption.

In order to achieve the full potential and benefits of Integrated Planning, more differentiated research is required, which is dedicated to the exchange of both

tacit and explicit knowledge within the planning process, and which addresses the analysis of interdependencies within the triangular “people-process-technology” model.

1.4. Research Question

The focus of this research – the Research Question – is how to advance and use the full potential of Integrated Planning in the AEC industry, with reference to the people-process-technology model.

One part of the research also focuses on the development of a teaching methodology for introducing and embedding IP in the university curriculum – thereby educating future practitioners and changing practice in the medium to long term.

To support the Research Question, three hypotheses have been developed:

Hypothesis 1: Integration and collaboration (bundled knowledge) between various disciplines is necessary from the early planning stages onwards, since these stages determine the future life-cycle performance of the building.

Hypothesis 2: Integrated Planning is superior to Sequential Planning in terms of both design quality (result) and process quality (efficiency).

Hypothesis 3: The introduction of BIM into the planning process enhances process integration.

2. STATE OF THE ART

The origins of Integrated Planning lie in Concurrent Engineering (CE), which was first introduced in the automotive and aeronautical industries. Lessons learned there, however, are only partially transferable to building design.

In recent years, Integrated Project Delivery (Lahdenperä, 2012; Prins and Owen, 2010), collaborative planning (Dossick and Neff, 2011; Dewulf and Kaderfors, 2012), and project organisations engaged in collaborative practice (Hartmann and Bresnen, 2011; Love et al, 2010), have emerged as topics that have increasingly been discussed in the literature, in the context of Concurrent Engineering in the AEC industry.

2.1. Concurrent Engineering (CE)

The identified advantages of Concurrent Engineering, or concurrent design, originate in the integration of the concept, design and production phases, and the overlapping of activities, resulting in a reduction in changes, in rework, and consequently in the number of possible errors. The identified advantages of CE are that: constraints and conflicts can be detected in the early design stages, when changes can be carried out at low cost; the number of design alternatives is increased through early collaboration between all parties; and the requirements of suppliers and users can be better understood through early collaboration, to improve overall product quality (Wang et al, 2002).

The early phases (like conceptual design) play a crucial role in future product performance, with design decisions accounting for 75% of product cost (Hsu and Liu, 2000). The research community has generally advocated CE as a successful method for improving lead-time, reducing costs, and improving product quality (Smith and Eppinger, 1998; Pennell and Winner, 1989).

However, several studies identify deficiencies in Concurrent Engineering, by analysing different CE models in terms of risk when applied to radical (breakthrough) product development, and to incremental product development. Yazdani and Holmes (1999), in their study of the automotive industry, provide a comparison of Sequential and Concurrent Engineering models, in terms of risks, and the main drivers of time, cost and quality. The study distinguishes four models: the traditional Sequential Model; the Design-centred Model (a two-phase model with concurrent design, and subsequent prototyping and testing); the

Concurrent Engineering model (review stages with stage gates); and the Dynamic Concurrent Model (simultaneous start of all phases, with extended prototyping and testing). The study shows that both the Concurrent Engineering model and the Dynamic Concurrent model display high risks in the case of radical innovation which features high uncertainty, complexity and novelty. The Design-centred Model displays a high level of design quality, as does the dynamic concurrent model.

Valle and Vazquez-Bustelo (2009) investigate the impact of CE on radical innovation and incremental innovation, demonstrating that CE proves beneficial for incremental innovation in terms of reduced lead-time and higher product quality. However, for radical innovation involving uncertainty, novelty and complexity, this is not the case. They conclude that, if the main driver is to reduce lead-time and increase product quality, it is inadvisable to apply CE to a radical innovation. If the top priority is to reduce costs, it is inadvisable to apply CE to an incremental product innovation.

We can conclude that, for different drivers (cost reduction, reduction in lead-time, increase in quality) and different innovation-types, customised rather than generalised models should be applied, based on a thorough analysis of each company's objectives and goals.

2.2.CE in the AEC industry

As regards the transferability of insights from CE for the AEC industry, it is important to understand the specific characteristics of the industry. CE was essentially developed to support the introduction of serial products, whereas building design and construction belong in the domain of prototyping, because of unique characteristics such as the building site, building orientation, the varying needs of users and investors, and the variety of planning teams, which are rarely in-house teams.

CE in industry, and Integrated Planning in architecture and construction, also differ in their project organisation: in industrial design the whole team (designers, builders and testers) are known from the beginning and are mostly in the same company. This is not the case in the Central European AEC industry, where one team carries out the project development and feasibility study; the next (competition-winning) team carries out the actual design; and the contractor is

only known after the bidding process ends and the design is already complete. Architecture and construction projects are multi-party projects, with no unity of ownership, command or culture. This is in complete contrast to in-house industrial design (van Aken, 2003).

Chachere, Kunz and Levitt (2004), investigating the Integrated Concurrent Engineering (ICE) method, claim that the critical factor limiting the speed of engineering processes is response latency – or the time spent waiting for the solution to a problem, in communication between two experts (engineers).

These differences between industries have led to specialisation in Integrated Building Design, which makes it distinct from standard CE and calls for additional research.

2.3. Integrated Building Design (IBD)

ACE industry practice identifies the need for changes to the traditional design process, which is sequential in nature and with little communication between participants in different phases: *'There seems to be thinking out there that there's got to be a better way to do this than the way we've been doing it.'* (AIA, 2009)

The IBD approach has evolved in the context of sustainable building (IWBDP, 2008; AIA, 2009; König et al, 2009), the related issue of increasing complexity, and awareness of the need for whole life-cycle oriented design. Integrated Planning has been advocated as a more suitable method for the design and planning of sustainable buildings (von Both and Zentner, 2004; Owen et al, 2010; van Aken, 2003), since it empowers cooperation between the various planning disciplines – including building contractors – in the early design stages, and facilitates knowledge transfer from the design phase through to the operation phase. There has already been a significant amount of research into the tools and technology required to support Integrated Planning, such as BIM (Building Information Modelling), LCA (Life-Cycle Assessment) and LCC (Life-Cycle Costing) tools.

Several studies identify BIM technology as having the greatest potential to revolutionise fragmented planning practices, through its intrinsically integrative character. However, it requires high levels of technical expertise, the reorganisation of planning networks, and restructured organisations (Prins and Owen, 2010). The research shows that the relatively slow adoption of BIM by the

building industry is not only because of technology and software interoperability issues, but much more because of the need to redefine working practices – and redefine the role of participants in the planning process – when BIM technology is involved (Kiviniemi et al, 2008).

We can conclude that the main emphasis of research into integrated design for sustainable buildings has been on the development of building and building services technology, and on methods and tools to support planning, analysis and optimisation. Meanwhile, improving our understanding of design methods and processes has been largely neglected. Because of the prototypical nature of building projects, the design process is reinvented on each new project.

2.4. Integrated Project Delivery (IPD)

It is the author's understanding that Integrated Planning in the AEC industry is perceived from two different perspectives: design-oriented, and management-oriented.

Most management-oriented methods, such as ICE, are based on Concurrent Engineering, and are driven by cost, time and quality (process) requirements. To date, the effects, principles and impacts of CE-based collaboration have been well researched in the field of project management – being a new discipline, keen to employ knowledge from management and social science.

By contrast, the aims of the design-oriented Integrated Planning models – such as Integrated Building Design (IBD) – are driven by the requirement to increase the performance of a building throughout its life-cycle. Even though both approaches, ICE and IBD, are based on similar pre-requisites – such as a flat hierarchy, collegial and respectful relations, early involvement of stakeholders, a workshop setting and close collaboration – they are used to achieve different aims. For example, ICE advocates knowledge sharing, to reduce the number of changes, whereas Integrated Whole Building Design (IWBD, 1998) fosters the recognition of design opportunities. The two approaches also have different temporal perspectives, with ICE looking at an already defined pre-design (project formed), whereas IBD is employed during the pre-design, project-forming stage.

The newly introduced concept of Integrated Project Delivery (IPD) marries the two approaches – the management perspective and integrated design perspective –

using BIM technology as a common knowledge-base for management of the building throughout its life-cycle (Prins and Owen, 2010).

This study argues that, as a method, IBD has advantages for the planning of sustainable buildings, as a result of close collaboration between planning stakeholders from the beginning, and the bundling of knowledge and information in the early design phase – a phase which is crucial for later building performance. By contrast, the main driver for design in general industry is, in many cases, the reduction in lead-time for design and production, in order to address market demand for short product life-cycles – especially in the information technology and automotive industries. For the design of sustainable buildings, this is not normally the case. The relatively short design phase (one year) critically affects the next 50 years of the building's existence, and should therefore ensure the optimal life-cycle performance of the building. The main driver for Integrated Planning is therefore a superior building, in terms of sustainability, rather than a reduction in planning time or the cost of planning. With this in mind, closer attention needs to be paid to optimising the integrated design process, in order to increase the quality of the building.

2.5. Building Information Modelling (BIM)

As an emerging technology, BIM has been recognised by research and practice as a suitable tool for supporting collaborative planning, for facilitating communication and information exchange between diverse planning process participants, and ultimately for maximising efficiency and quality, and reducing time and effort.

The common understanding of BIM terminology in the AEC industry, in both the practical and academic realms, is multifaceted: as the “new CAD”, it represents an advanced type of digital drafting tool; while for more advanced users, it is a building modelling tool, offering the possibility of interaction with non CAD-based tools, such as those in quantity surveying or project management (von Both, 2011).

A predecessor to BIM was so-called product modelling, originating in the 1980s (Penttilää, 2006). Product models provide object-oriented modelling of data-rich building components – such as windows, doors and slabs – and incorporate 3D

geometries, spatial information, thermal values and material properties, upon which data interoperability can be established (Fisher and Kam, 2003).

The academic community tends to see BIM as a process with its focus on model-building and data exchange – or as Penttilä (2006) describes it: *".. a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle"*.

One of the main problems with recent research into BIM-supported IP has been the prevailing focus on the issue of technology, and on the coding and structuring of explicit knowledge in a way which reflects the traditional, mono-disciplinary analytical process – while neglecting the issues of technology adoption in the actual design process, and the creation of a framework for successful adoption.

2.6. People – Process – Technology

The concept of IPD (**process**) brings great potential for innovation in building practice, but the need for collaboration can also be challenging if individuals (**people**) do not fully embrace the IPD approach (Nofera and Korkmaz, 2010). Jassawalla and Sashittal (1998) claim that the personality traits of participants influence the level of cooperation, and that openness to change, willingness to cooperate, and trust are pre-requisites of high-level integration, and can be endangered by personal attitudes such as disdain for the collaborative process. This suggests that the Integrated Planning process depends on team performance and on the personality characteristics of teams.

Furthermore, Rekkola et al (2010) find that the slow implementation of both BIM (**technology and process**) and IPD (**process**) in planning practice is due to the dearth of development **interplay** between technology, people and process, even though individual aspects are well researched and developed. They propose an evaluation framework for technology-bound, process-bound and people-bound problems and benefits – for BIM-supported IPD processes – in which process is related to workflows, timing, procurement and contracts; people are related to competences, skills, knowledge and communication; and technology is related to software (tools).

Based on the literature review, on conducted observation, and on the author's experience of planning practice, the adaptation of Concurrent Engineering methods for IPD practice in the AEC industry has largely focused on:

- the optimisation of project management in construction – based on a delivered pre-design by the architect – achieved by reducing delivery time and cost, through the integration of discipline-specific knowledge and improvements in communication and collaboration;
- the use of technology or tools to support integration.

There are, however, several gaps in the body of literature and research. Firstly, research seldom focuses on the earliest design phases, where the design is created, and which have the greatest impact on the life-cycle performance of the building. Instead, research explores the impact and effects of CE in situations where the initial design is already developed. Where pre-design is within the scope of the research, the emphasis is mostly on the use of simulation or modelling tools for design optimisation or integration – rarely on the joint collaborative efforts required to create an initial model.

Secondly, as already observed by Rekkola et al (2010), IPD research mostly focuses on the individual issues of people (communication, collaboration), process (regulations, procedures, contracts, organisation) or technology – thus disregarding the systemic interrelations and interactions within this triangle.

3. METHODOLOGY

The research conducted for this study, to provide answers to the Research Question – how to enhance the adoption of IP within the triangle of people-process-technology – was carried out within the context of two large interdisciplinary research projects, and conceived, coordinated and led by the author. The research was funded by FFG (the Austrian Research Promotion Agency), under the *Co_Be* (grant No. 82561) and *BIM_Sustain* (grant No. 836461) projects.

In both projects, the case-study methodology is used as one of the main research methods. Case-study methodology is advocated by social and management sciences as a proper instrument for gaining rich empirical evidence – not by isolating phenomena, as laboratory experiments do, but by emphasizing the real world context (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). Case-study analysis, as an inductive methodology, can answer research questions where existing theories can offer no feasible answer. The research question is typically of a qualitative nature (how, why, who), rather than of a quantitative nature (how often, how many, etc.). As already described, there are gaps in the current state of research in the field of Integrated Planning methodology, which were addressed by studying multiple cases and developing our own theories, appropriate to the Central European AEC market (fragmented, tradition-rich).

An additional research method was to apply exploratory research, using experimental studies with undergraduate students. These experimental studies, carried out as part of teaching (process-simulation, role-playing games), are often the only way to undertake studies that focus on process design, because they provide the opportunity to establish controlled conditions, which would not be possible within an organisation. Intervention in real organisations or projects is seldom possible, not least because it could have harmful and expensive outcomes.

The research project *Co_Be* (COst-BENefit Analysis of Integrated Planning) was funded from Austrian climate and energy funds within the program “New Energies 2020”. The project is under the auspices of the Institute for Interdisciplinary Building Process Management (within the Department for Interdisciplinary Planning and Industrial Building, Faculty of Civil Engineering, TU Wien), with I.

Kovacic as initiator and project coordinator. Other partners are the Department for Real Estate Development (within the Faculty of Architecture and Urban Planning, TU Wien) and the company, ATP Sustain, a partner from practice.

The subsequently reported experiment was carried out as part of this research project, and in cooperation with the Institute for Management Sciences (within the Faculty of Mechanical and Industrial Engineering). The cooperation of three different faculties fostered and encouraged an integrated and interdisciplinary approach within the project itself.

Co_Be is based on research primarily into **people and process**-related issues. As a first step, the case-study methodology – based on an analysis of best practice – is used to develop a theory by using a number of questions: *Why, and for whom, is the current AEC practice unsatisfactory? What are the crucial issues in the people-process-technology framework? What are the Key Performance Indicators (KPIs) for Integrated Planning in a regional context?*

As a next step, the general theories developed in the course of the case-study were tested in a laboratory-based student experiment, where – using two different planning approaches (IP and SP), under controlled conditions – the performance of Sequential Planning teams was compared to the performance of Integrated Planning teams. As a result of this laboratory-based experiment, it was possible to observe and evaluate the individual objectives described in the general theories – such as design quality, satisfaction (with teamwork, results, process), stress and workload levels – based on the specific planning approach adopted (integrated or sequential). The results of the Co_Be project were compiled and published in the Integrated Planning Guidelines for Public Policy, Planners and Investors (Kovacic et al, 2012).

The BIM_Sustain project: ‘Process Optimisation for BIM-supported Sustainable Design’, funded by FFG as part of the BRIDGE Program, involves cooperation between three institutes of Vienna’s University of Technology: the Institute for Interdisciplinary Building Process Management (within the Department for Interdisciplinary Planning and Industrial Building, Faculty of Civil Engineering, TU Wien, with I. Kovacic as initiator and project coordinator); the Institute for Management Sciences (within the Faculty of Mechanical and Industrial Engineering); and the Department of Building Physics and Building Ecology (within the Faculty of Architecture and Urban Planning).

Seven BIM software developers and vendors also participated: ANull (Graphisoft), Artaker (Autodesk), Construsoft Tekla, Plancal, Allplan Austria, Dlubal REFM, and b.i.m.m. Gasteiger.

This interdisciplinary collaboration between university and industry facilitates the development of customised, strategic planning strategies to configure BIM for a multi-disciplinary planning environment.

The BIM_Sustain project focuses on all three aspects – **people, process and technology** – where, as well as people and process, an additional technology aspect is introduced, and the impact of technology on the interplay of people and process can be analysed. As part of this project, the case-studies (student-projects) used various BIM tools within a multi-disciplinary design class – comprising architecture, structural engineering and building physics disciplines – with 48 students in the first experiment-cycle, and 36 in the second. The case-studies are documented in the deliverables of the teams, including digital building models, time and communication protocols, and mistake trees. The case-studies were evaluated using statistical analysis on the data collected, via questionnaires completed by the student participants, and via focus-group interviews. Focus-group interviews and discussions serve as de-briefings for the experiment, and provide large amounts of information-rich data, by collecting participant feedback (Krueger & Casey, 2009).

The development of domain knowledge for a BIM-supported planning process is documented and published in a BIM Roadmap for Sustainable Planning (Kovacic, et al, 2014), which includes recommendations for data exchange, suggestions for improving software interoperability, and recommendations for a BIM-supported design process. The BIM_Sustain project is a ‘world first’, uniting unparalleled numbers of software developers and tools – as well as three disciplines – in a single project, thereby facilitating the collection of a very extensive sample of interoperability-related data.

This research into integrated, collaborative planning, as part of the Co_Be and BIM_Sustain projects, is linked to an international scientific network – the Engineering Project Organization Society (EPOS) – under the auspices of which further work has been initiated into global, transnational, interdisciplinary collaboration using BIM.

4. RESULTS

This cumulative Habilitation Treatise is based on the following peer-reviewed articles, which provide insights into, and results for, research dedicated to the enhancement of IP, based on the triangular people-process-technology model.

People – Process

A1 I. Kovacic:

"Integrale Planungsmethodik für nachhaltig gebaute Umwelt";
ÖIAZ - Österreichische Ingenieur- und Architektenzeitschrift (eingeladen),
158. Jahrgang (2014), 1-12, pp. 61 - 66.

A2 I. Kovacic, C. Müller:

"Challenges for the Implementation of Integrated Design in the Planning Practice";
Procedia - Social and Behavioral Sciences Corresponding, 119
(2014), pp. 529 - 538.

A3 I. Kovacic, M. Sreckovic:

"Designing the planning process for sustainable buildings: from experiment towards implementation";
Engineering Project Organization Journal, 3
(2013), 1, pp. 51 - 63.

A4 I. Kovacic, M. Filzmoser:

"Key Success Factors of Collaborative Planning Processes";
Engineering Project Organization Journal, 4 (2014), pp. 154 - 164.

Technology – People

A5: I. Kovacic, L. Oberwinter, C. Müller, C. Achammer:

"The 'BIM-sustain' experiment - simulation of BIM-supported multi-disciplinary design";
Visualization in Engineering (invited), 40327 (2013),
1-13, pp. 11.

People – Process – Technology

A6: I. Kovacic, M. Filzmoser:

"Designing and Evaluation Procedures for Interdisciplinary BIM Use – An Explorative Study".
Engineering Project Organization Journal, 2014
<http://dx.doi.org/10.1080/21573727.2014.989426>

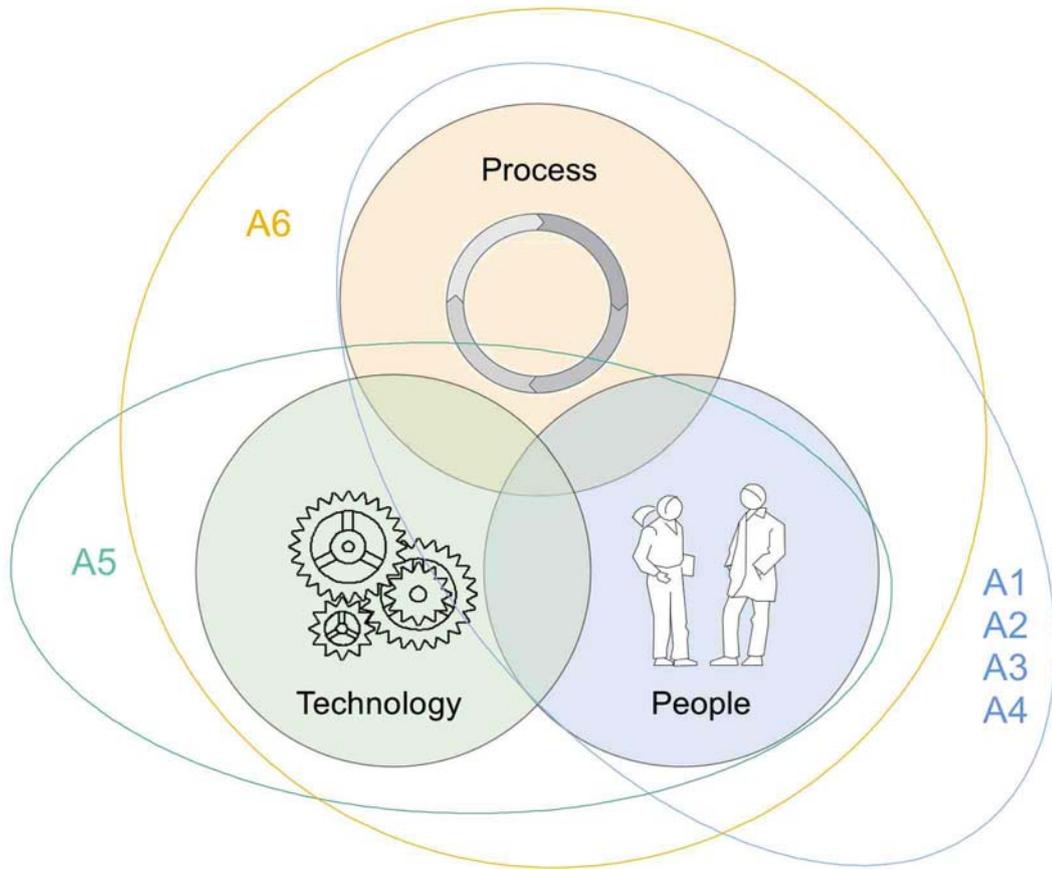


Figure 1 : The People-Process-Technology model and associated articles

The first four articles (A1 – A4) are based on the **Co_Be Project**, and address **People and Process**-related issues.

The first article (A1) gives an overview of the project, and describes: current issues and challenges for the regional AEC industry; research conducted and methods used; and summarised results. A theoretical framework for Integrated Planning is proposed as a 3-pillar model – people (planning process participants), tools (qualitative / quantitative), and building quality (planning aims) – all embedded in a procedural framework.

The second article (A2) presents a multiple case-study of best practice energy-efficient buildings, where Key Performance Indicators (**KPIs**) were identified using open-ended interviews with 20 planning process stakeholders, together with project and process analysis. The analysis identified the following KPIs: early collaboration and involvement of all stakeholders; inter-disciplinarity; transparent communication and knowledge transfer; and usage of decision making tools (BIM). Based on the identified KPIs, guidelines for IP were compiled and verified in a stakeholder-workshop. The best practice case-studies showed that, despite perceived professional antagonism, all of the interviewed professions basically wanted the same things: early collaboration; transparent communication and knowledge transfer; inter-disciplinarity; and tools for decision-support. The deficiencies in current practice were identified as: information loss; lack of knowledge/skills; wrong criteria used in setting up a planning team; and wrong planning priorities.

The third article (A3) presents the design and results of a student role-playing experiment, which simulated and compared Sequential Planning (SP) and Integrated Planning (IP) processes. The study evaluated the performance of 160 students, split into teams comprising an architect, an engineer, an investor and a business consultant – and divided into two treatments: SP and IP. The study focused on individual issues – such as design quality, efficiency, stress and conflict level, and satisfaction (process, team and result) – depending on the specific planning approach. The role-playing experiment demonstrated the improved performance of Integrated Planning in terms of both productivity and efficiency, and in terms of increased satisfaction, reduced conflict and better balanced stress-levels. However an improvement in terms of design quality could not be proven.

The fourth article (A4) – based on the first insights of the student role-playing experiment which divided students into Sequential Planning and Integrated Planning groups (the psychological term is ‘treatment’) – further explores the relationship between personality traits and performance in the treatment. The correlation between team member personality traits, in relation to the treatment (IP or SP), and subsequent design quality, is evaluated using statistical analysis. The analysis shows that, for Integrated Planning, groups with higher levels of conscientiousness achieved worse results, whereas groups with higher levels of conflict and workload achieved better results. We conclude that there is no ‘silver bullet’ solution when choosing the right planning method. Instead, a customised process, based on the integration of various disciplines, but giving room to various personality traits, should be considered when choosing or designing the optimal planning process for a team. Inter-firm collaboration, requiring changes in planning culture, represents an interesting topic for future research.

The following two articles present research results from the **BIM_Sustain** project. As BIM technology was one of the KPIs identified, we examined its potential to enhance integration and reduce fragmentation in traditional planning processes, in a student experiment which simulated a BIM-supported design process.

The fifth article (A5) focuses on the interoperability of **Technology**, on data transfer issues, and on related data-losses. Within this context a data-exchange benchmark was established to extensively test the interoperability of various BIM tools. A number of complex geometries were transferred between software tools used by the various disciplines, and any defects which occurred during the transfer were analysed and classified. The main defects related to the different modelling semantics used by each discipline – for example, to model pillars or rooms stamps. These defects resulted in significant re-modelling work, as well as in large amount of people-related issues.

The sixth article (A6) addresses all three aspects: **People – Process – Technology**. It presents an evaluation of the case-studies (student-projects) in terms of satisfaction with technology (usability, usefulness, ease of use), and satisfaction with collaboration (team, result, process). The usability of the tools achieved the highest appreciation, whereas interoperability achieved the lowest. In terms of working time and effort, the highest number of man-hours is spent on

modelling, with face-to-face communication in second place. Skills are once again critical to achieving good results, as well as professional experience, while domain knowledge of other disciplines has a generally positive effect on team performance.

In conclusion, BIM technology has still not achieved a level of maturity sufficient for it to be used in the regional AEC culture and tradition. However it has the potential to significantly advance planning practice – albeit that interoperability issues were uppermost in focus-group discussions.

5. CONCLUSION

The research conducted into the effects of Integrated Planning on the interaction of the people-process-technology triangle, has only partially confirmed the three hypotheses which were developed to support the Research Question. The exploratory research has also thrown up new questions.

In the Co_Be Project laboratory experiment, all of the participating roles (architects, engineers, investors, business experts) were generally more satisfied with the Integrated Planning process. This prompts the conclusion that socially-rich, or information-rich knowledge transfer methods – which in the IP planning approach consisted of personal discussions and continuous communication throughout the design process – were more successful in achieving the overall goals of better communication, satisfaction and teamwork **confirming Hypothesis 1.**

However **Hypothesis 2 could not be proven**, as the results of student-competition, which served as a parameter of quality, did not show statistical significance when assessing the impact of a specific planning approach on the quality of design or on the achieved energy efficiency level.

As a follow-up step, closer data analysis was carried out to identify the factors contributing to the relatively good performance of sequential planners. The impact of personality traits on treatment-related team performance was examined. The analysis demonstrated that the success of design processes depends on both the skills and personality traits of team members.

The results of the experiment were verified in the practitioners' workshop (with planners, investors, academics and facility managers), which confirmed the need for further exploration of people-related and process-related issues, such as the level of social skills, the allocation of responsibilities, and the commitment of planning teams.

In the next step, and as part of the BIM_Sustain project, the use of BIM technology to enhance Integrated Planning was tested within a multi-disciplinary design class, which involved collaboration by students of architecture, structural engineering and building science.

Hypothesis 3 could not be proven. This stated that the introduction of BIM technology alone would enhance process integration and collaborative working,

due to the integrative nature of the tool. However this did not happen, and the teams worked sequentially until shortly before project close, when a joint model had to be delivered.

Claims about the main benefits of BIM – improvement in efficiency and efficacy, and a reduction in timescales and cost – originate from the realm of software development or organisational science, and are not from the professional domain. There is still a general lack of knowledge and understanding about exploiting the full potential of BIM in the AEC domain. This was also confirmed by the results of the study, where, along with interoperability issues, there were issues around questions of responsibility, workload distribution and credit-awards. In general, BIM-supported planning requires higher levels of coordination and communication than traditional planning processes.

The early design phases have crucial importance for the entire life-cycle of the building. The working methods employed in this planning stage are more intuitive and interpretative than analytical. The results of the research conducted indicate that “design-based” knowledge is complex, tacit and difficult to codify, therefore mechanisms such as face-to-face communication, ‘messy talk’ and informal information exchange have a critical effect on the efficient transfer of knowledge. This type of knowledge is more easily transferable in an integrated, collaborative setting, which allows the building of a broad, common knowledge base for project teams, and is therefore more conducive to innovation. BIM, however, is still perceived as a tool which is too “heavy” for the earliest design stages, as it does not support informal information exchange, and thus hinders problem-solving, despite its extensive problem-visualisation features. New methods are needed for transferring this tacit design knowledge from the intangible realm to the tangible, explicit BIM environment.

The goal of improving the design process, and the subsequent quality of the building, is still a trade-off, as it requires the simultaneous introduction of both BIM tools and interdisciplinary collaboration. Skill and experience are therefore crucial factors in exploiting the full potential of integrated, collaborative planning supported by BIM. Education is therefore essential, and should be encouraged, particularly at university level.

As a next step in future research, therefore, the Department for Industrial Building and Interdisciplinary Planning will establish an Integrated Design Lab as an

interdisciplinary research centre and research-led teaching centre. One of the aims will be to empower education in multi-disciplinary collaboration and integrated design for students, and thereby to educate future process-innovators. Another aim – in collaboration with industry – will be to bring together domain-specific knowledge on BIM-supported interdisciplinary planning.

6. LITERATURE

- Achammer C., Stöcher H. (Ed.) (2005): *Bauen in Österreich*. Birkhäuser Verlag, Basel, 224 S.
- AIA (2009): *Experiences in Collaboration: On the Path to IPD*, American Institute of Architects California Council, p. 5.
- Chachere J., Kunz J., Levitt R. (2004): *The Role of Reduced Latency in Integrated Concurrent Engineering*. CIFE Working Paper #WP116, April 2009, Stanford University.
- Dewulf G., Kaderfors A. (2012): *Collaboration in public construction – contractual incentives, partnering schemes and trust*. *Engineering Project Organization Journal*, 2(4), 240–250.
- Dossick C.S., Neff G. (2011): *Messy talk and clean technology: communication, problem-solving and collaboration using building information modelling*. *Engineering Project Organization Journal*, 1(2), 83–93.
- Eichmann H., Reidl S. (2006): *Rahmenbedingungen für die Produktion von Baukultur*. Österreichischer Baukulturreport. ARGE Baukulturreport (Plattform Architekturpolitik und Baukultur und T.C. Bauträgergesellschaft mbH
- Eisenhardt K.M. (1989): *Building Theories from Case Study Research*. *The Academy of Management Review*, 14(4), 532–550.
- Eisenhardt K.M., Graebner M.E. (2007): *Theory Building from Cases: Opportunities and Challenges*. *Academy of Management Journal*, 50(1), 25–32.
- Fischer M., Kam C. (2003): *The Product Model and Fourth Dimension Project*. *ITcon*, 8, 137.
- Geissler S., Leitner K., Schuster G. (2005): *Industriell produzierte Wohnbauten - Untersuchung der Entwicklungspotentiale für industriell produzierte Wohnbauten. Recherche internationaler Fertigungsentwicklungen und Untersuchung möglicher Umsetzungsstrategien für die österreichische Wohnbauwirtschaft*. Berichte aus Energie- und Umweltforschung, Bundesministerium für Verkehr, Innovation und Technologie (Herausgeber), Krems.
- Hartmann A., Bresnen M. (2011): *The emergence of partnering in construction practice: an activity theory perspective*. *Engineering Project Organization Journal*, 1(1), 41–52.
- Hsu W., Liu B. (2000): *Conceptual design: issues and challenges*. *Computer-Aided Design*, 32(14), 849–850.
- IWBDDP (2008): *Integrated Whole Building Design Guidelines*, New Zealand Government, Ministry for the Environment, available at www.mfe.govt.nz (accessed 26 November 2013).

- Jassawalla A.R., Sashittal H.C. (1998): An examination of collaboration in high-technology new product development processes. *Journal of Product Innovation Management*, 15(3), 237–254.
- Kiviniemi A., Tarandi V., Karlshøj J., Bell H., Karung O.J. (2008): Review of the Development and Implementation of IFC compatible BIM. EraBuild Report.
- König J.E., Kohler N., Kreißig J., Lützkendorf T. (2009): Lebenszyklusanalyse in der Gebäudeplanung, Detail Green Books, Munich.
- Kovacic I., Achammer C., Müller C., Seibel H., Wiegand D., Sreckovic M., Glöggler J. (2012): INTEGRALE PLANUNG. Leitfaden für Public Policy, Planer und Bauherrn. TU Wien 112 p.
- Kovacic I., Oberwinter L., Filzmoser F., Kiesel K. (2014): BIM Roadmap für Integrale Planung; Konsortium Projekt BIM_sustain, TU Wien, 2014, 58 p.
- Krueger R.A., Casey M.A. (2009): Focus groups. A Practical Guide for Applied Research. Sage, Los Angeles.
- Lahdenperä P. (2012) Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery. *Construction Management and Economics*, 30(1), 57–79.
- Love P.E.D., Mistry D., Davis P.R. (2010): Price competitive alliance projects: identification of success factors for public clients. *Journal of Construction Engineering and Management*, 136(9), 947–956.
- Nofera W., Korkmaz S. (2010): Design process integration for sustainable, high performance buildings, in Working Paper Proceedings Engineering Project Organizations Conference, South Lake Tahoe, CA, 4–7 November 2010.
- Owen R., Amor R., Palmer M., Dickinson J., Tatum C.B., Kazi A.S., Prins M., Kiviniemi A., East B. (2010): Challenges for integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, 6(4), 232–240.
- Pennell J.P., Winner R.I. (1989): Concurrent engineering: practices and prospects, in Global Telecommunications Conference, 1989, and Exhibition. *Communications Technology for the 1990s and Beyond*, GLOBECOM '89, IEEE, Vol. 1, pp. 647–655.
- Prins M., Owen R. (2010): Integrated design and delivery solutions. *Architectural Engineering and Design Management*, 6, 227–231.
- Rekkola M., Kojima J., Mäkeläinen T. (2010): Integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, 6(4), 264–278.
- Smith R.P., Eppinger S.D. (1998): Deciding between sequential and concurrent tasks in engineering design. *CE (Concurrent Engineering): Research and Application*, 6(1), 15–25.

- Statistik Austria (2014, a): Wirtschaftskennzahlen der Bauunternehmen (ÖNACE 2008: Abschnitt F) 2012 nach Beschäftigtengrößenklassen. Leistungs- und Strukturstatistik 2012.
- Statistik Austria (2014, b): Aktive Unternehmen sowie Beschäftigte im Kultursektor 2011. Unternehmensdemografie.
- Statistik Austria (2014, c): Pressemitteilung 10.810-119/14. 54% der österreichischen Unternehmen setzen Innovationen; Änderung in der Organisation ist häufigste Innovationsart.
- Valle S., Vazquez-Bustelo D. (2009): Concurrent engineering performance: Incremental versus radical innovation. *Int.J. Production Economics*, 119, 136–148.
- van Aken J.E. (2003): On the Design of Design Processes in Architecture and Engineering: Technological Rules and the Principle of Minimal Specification, Eindhoven Centre for Innovation Studies, Eindhoven University of Technology.
- von Both P., Zentner F. (2004): LuZie – Lebenszyklusbezogene Einbindung der Zielplanung und des Zielcontrolling in den Integralen Planungsprozess. In Technical report, FIA Projekt, Bundesministerium für Wirtschaft und Arbeit, Bundesministerium für Bildung und Forschung.
- Wang L., Shen W., Xie H., Neelamkavil J., Pardasani A. (2002): Collaborative conceptual design – state of the art and future trends. *Computer-Aided Design*, 34(13), 981–996.
- Yazdani B., Holmes C. (1999): Four Models of Design Definition: Sequential, Design Centered, Concurrent and Dynamic. *Journal of Engineering Design*, 10 (1).

7. ACKNOWLEDGEMENT

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A handwritten signature in black ink, appearing to read 'Achammer', written over a horizontal line.

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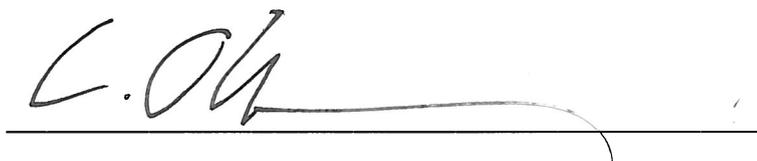
A handwritten signature in blue ink, appearing to read 'Michael Filzmoser', written over a horizontal line.

Dipl.-Ing. Christoph Müller



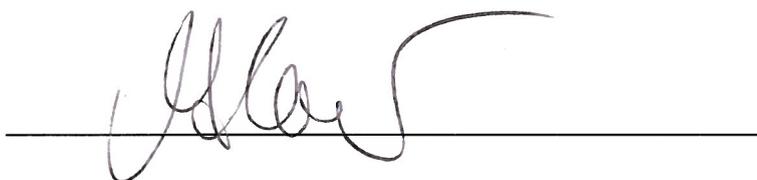
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APPENDIX: JOURNAL (PEER-REVIEWED) ARTICLES

A1

I. Kovacic:

"Integrale Planungsmethodik für nachhaltig gebaute Umwelt";
ÖIAZ - Österreichische Ingenieur- und Architektenzeitschrift (eingeladen),
158. Jahrgang (2014), 1-12, pp. 61 - 66.

Integrale Planungsmethodik für nachhaltig gebaute Umwelt

Integrated Planning Method for Sustainable Built Environment

Von I. Kovacic, Wien

Mit 2 Abbildungen und 1 Tabelle



Dipl.-Ing.
Dr. Arch. Iva Kovacic

Kurzfassung

Die verschärften Anforderungen der EU punkto Klimaschutz und Minimierung der CO₂-Emissionen deuten auf die dringende Notwendigkeit der Vertiefung des Bewusstseins und der Sensibilität für Nachhaltiges Bauen unter Planern, Investoren und Nutzern hin. Dabei ist ein interdisziplinärer, lebenszyklusorientierter Planungsprozess die Grundlage einer nachhaltigen Architektur, die ein soziales, ökonomisches und ökologisches Optimum während des gesamten Lebenszyklus gewährleistet.

Abstract

Increasing requirements and regulations on the EU regarding climate protection and minimization of CO₂ emissions underline the urgent necessity of awareness and sensitiveness for sustainable design and construction among planners, users and investors. Thereby a lifecycle oriented planning process is seen as a fundament for sustainable architecture, which provides for social, ecologic and economic optimum throughout the life-cycle.

1. Gebaute Umwelt und Nachhaltigkeit

Dynamischer Wandel prägt unsere Gegenwart. Einerseits ist es der Klimawandel, der auf CO₂- und Treibhausgas-Emissionen zurückzuführen ist, sowie die Ressourcenknappheit, wobei neben Energie und Material auch Zeit und Raum zu den knappen Ressourcen zählen. Andererseits befinden wir uns in konstantem wirtschaftlich-technologischem Wandel, initiiert durch die rasante Entwicklung der Informations- und Telekommunikationstechnologie, resultierend in globaler Marktwirtschaft, Dezentralisierung der Arbeitsplätze und kurzen Produktlebenszyklen.

Die Gebäude weisen eine lange Lebensdauer auf, wodurch sie mit Beständigkeit und Stabilität in Verbindung gebracht werden. Diese Wahrnehmung wandelt sich langsam hin zu ständig in Veränderung befindlichen Strukturen. Die Immobiliengesellschaften schätzen die gegenwärtige Lebensdauer der Büro- und Administrationsgebäude auf 50 Jahre, wobei die ursprüngliche Funktion zwei bis drei Mal im Laufe der Lebensdauer geändert wird. Durch diese mehrfachen Veränderungen steigt der Initialverbrauch an Energie, Ressourcen und Kapital sowie den Emissionen in die Umwelt.

Als die größte Herausforderung der Bauindustrie des neuen Millenniums gilt die Realisierung von flexiblen und anpassungsfähigen Gebäuden unter verschärften Anforderungen an Klimaschutz und Energieoptimierung.

Die jetzige Entwicklung zeigt aber das Gegenteil: die Österreichischen CO₂-Emissionen überschreiten die Kyoto-Zielvereinbarung um 22% in 2010 – anstatt um 13% Reduktion, 8% Steigerung [1]. Um die Vereinbarte 2° Erwärmung einzuhalten, sollen die Industrieländer die Emissionen um 25 bis 40 Prozent

bis 2020 reduzieren, und um 80 bis 95 Prozent bis 2050 in Relation zu 1990 [2].

In der EU wird 40% Energie für Heizung und Kühlung von Gebäuden verbraucht, innerhalb Österreich verbrauchen Gebäude 35% der Energie (Austrian Energy Agency, 2012), und verursachen ein Fünftel der CO₂-Emissionen [3].

In der Bauindustrie wird Nachhaltigkeit immer noch als „Added Value“ anstatt inhärente Gebäude-Qualität begriffen. Bei den gängigen Gebäudeperformance-Evaluierungen liegt der Schwerpunkt meist auf der Energieeffizienz, mit Berechnung und Erfassung des Heiz-Energieverbrauchs als Gegenstand des Energieausweises. Der lebenszyklische Energieverbrauch – Primärenergieverbrauch einschließlich Herstellung und Abbruch sowie jener für die Kühlung, Beleuchtung und den Betrieb – werden in den seltensten Fällen berücksichtigt. Oft wird die Bewertung der Nachhaltigkeit auch gern mit reiner Ökobilanzierung verwechselt, welche nur einen Aspekt des Nachhaltigkeitsdreiecks berücksichtigt und somit dem ganzheitlichen Ansatz widerspricht.

Das Prisma der Nachhaltigkeit von Spannberg [4] definiert neben den ökologischen und sozialen Dimensionen, die Wirtschaftliche und Institutionelle Dimension, welche Rahmenbedingungen für das politische Entscheidungsfindung und Nachhaltigkeitspolitik definieren.

Für die Bauwirtschaft gelten als

- ökonomische Interessen: die Erfüllung der ökonomischen Zielsetzungen über die kalkulierte Lebenszeit der Immobilie
- ökologische Interessen: Schonung von Ressourcen, energiegerechte Bauweise, geringe Eingriffe und Emissionen in die Umwelt, Drittverwendbarkeit
- soziale Interessen: Befriedigung der Grundbedürfnisse, Verteilungsgerechtigkeit, Chancen-Zugänglichkeit und Verteilung von Ressourcen

2. Gebäudezertifikate

Die aufkommende Anzahl von internationalen Standards zur Zertifizierung von Gebäude-Nachhaltigkeit sollte die Qualität des Alleinstellungsmerkmals garantieren und somit nachhaltige Mieten und Erträge sichern. Zu diesen zählen das weltweit bekannteste amerikanische – The Leadership in Energy and Environmental Design Green Building Rating System™ LEED [5], oder das britische, hauptsächlich auf Minimierung des CO₂-Ausstoßes orientierte Building Research Establishment Environmental Assessment Method BREEAM[6]. Der mitteleuropäischen Bauweise am meisten entsprechende sind das aus Deutschland stammende Deutsche Gütesiegel Nachhaltiges Bauen – DGNB [7] und das Äquivalent von Österreichischen Gesellschaft für Nachhaltige Immobilienwirtschaft – ÖGNI [8] sowie das von Österreichischen Gesellschaft für Nachhaltiges Bauen entwickelte Total Quality Building – TQB [9].

Gemeinsam ist allen Zertifizierungssystemen, trotz aller Kritik, die Kategorisierung der quantifizierbaren Planungs-Ziele, welche weit mehr als den rein wirtschaftlichen Nutzen umfassen – mehr oder minder basieren alle drei Systeme auf Energieeffizienz, Ressourcenschonung, Emissionsschutz, Landschaftserhaltung und gesundem Innenklima. Die Gebäude-Zertifizierung reprä-

sentiert auf jeden Fall, sowie auch von DGNB proklamiert, ein Marketing-Instrument; aber darüber hinaus werden die grundsätzlichen Ziele der nachhaltigen Entwicklung schon während der Planung angedacht und zumindest mit der geplanten Gebäudequalität angestrebt.

Die ambivalente Natur des Gebäudes als Komposition aus den „messbaren“ (quantitativen) und „schwer messbaren“ (qualitativen) Eigenschaften bringt Probleme für eine ganzheitliche Gebäudeperformance-Evaluierung, da die qualitativen Eigenschaften und der daraus resultierende Mehrwert schwer messbar sind.

Als *quantitative* Eigenschaften gelten:

- ökonomische: Bauwerkskosten, Lebenszykluskosten, (Betrieb, Reinigung, Instandhaltung und Wartung), Erträge und
- ökologische: Ressourcenverbrauch – Energie, Material, Land, Emissionen

und als *qualitative*

- soziale: Bedeutung im städtischen Gefüge, behindertengerechtes Bauen, Wohnraum und Arbeitsplatzschaffung, Flexibilität, Gesundheit
- formal-ästhetische und kulturelle (Baudenkmal und Denkmalschutz)

Die sogenannten Nachhaltigkeitsindikatoren sind ein Werkzeug zur Bewertung des Nachhaltigkeitspotentials des Gebäudes. Dabei werden die quantitativen und qualitativen Eigenschaften als lebenszyklische In- und Outputs dargestellt und bewertet.

Abschließend lässt sich ein urgenter Handlungsbedarf für ganzheitliches nachhaltiges Planen und Bauen feststellen, jedoch mangelt es immer noch selbst in Fachkreisen an Basiswissen und Verständnis der lebenszyklischen Zusammenhänge. Ein Grund dafür sind die mangelnden Daten über Gebäudebestände oder die Erfahrungswerte, da großmaßstäbliche energieeffiziente Gebäude erst seit kurzem auf dem Markt vorhanden sind. Um den britischen Architekten Frank Duffy zu zitieren:

„The unit of analysis ... isn't the building, it's the use of the building through time. Time is the essence of real design problem.“

3. Zielsetzungen für das Nachhaltige Planen und Bauen

Die Maßnahmen zur Sicherung der Nachhaltigkeit sind also dringend fällig, die Umsetzung wird durch einige essentielle Probleme wesentlich erschwert.

An erster Stelle ist die Überfälligkeit des traditionellen, linearen *Planungsprozesses*, mit der Gebäudefertigstellung als letztem Horizont zu nennen. Die lineare Anreihung der Planungsleistungen resultiert oft aus Gebäuden mit sub-optimaler Konstruktion, falscher Orientierung und schwer handelbarem inneren Klima. Als Konsequenz: unzufriedene Benutzer, hohe Lebenszykluskosten, hoher Ressourcenverbrauch – Faktoren, die zu kurzer wirtschaftlicher Lebensdauer, baldigem Leerstand und letztendlich zu Abbruch, oder – als günstigeres Szenario – umfangreichem Umbau oder Sanierung führen.

Schon die Tatsache, dass die Gebäudeherstellungskosten nur 20% sämtlicher Lebenszyklus-Kosten darstellen und die restlichen 80% während der Betriebsphase anfallen, deutet darauf hin, dass ein Umdenken dringend notwendig ist.

Der lebenszyklusorientierte Planungsprozess, der die simultane Mitwirkung der diversen Disziplinen (Architektur, Tragwerksplanung, Haustechnik, Facility- und Energie-Management) schon vom Vorentwurf bis hin zur Abbruchphase voraussetzt, ist für eine nachhaltige Architektur entscheidend.

Die jüngste Energie-Krise und energetische Abhängigkeiten haben bereits zur Veränderung der Denkprozesse unter Mie-

tern als auch Bauherrn beigetragen – wenn bis vor kurzem das einzige Kriterium für die Bauentscheidung die Herstellungskosten waren, wird jetzt zunehmend die Berücksichtigung der Lebenszykluskosten, mit Berechnung der Folgekosten und des Abbruchs schon den frühen Planungsphasen abverlangt. Zwar verlangen die Investoren verstärkt nach „Green Buildings“, sind jedoch noch nicht bereit in die komplexe, interdisziplinäre Planung von solchen Gebäuden mehr zu investieren als in die Planung von Standard-Objekten.

Die optimierte Planung kann bis zu 40% der Lebenszykluskosten senken [10] – Änderungen der Honorarordnung, welche integrale Planung unterstützen würde, Anreize für die Belohnung erfolgreicher Planung im Sinne der nachgewiesenen Kosteneffizienz im Betrieb oder gar neue Vertragsmodelle für lebenszyklische Planung sind notwendig.

4. Erfolgsfaktoren für Nachhaltiges Bauen

Die prägendsten Eigenschaften der nachhaltigen Gebäude – eine weitgehend ressourcenschonende und dem lokalen Gegebenheiten entsprechende Bauweise mit möglichst geringen Eingriffen in die Natur sind in der Architekturgeschichte schon längst ausformulierte Anforderungen an die Bauplanung. Die Grundsätze der Moderne: „Licht, Luft und Sonne“ decken im Wesentlichen auch die Kriterien der Sozialen Nachhaltigkeit ab. Die neuen Herausforderungen, wie stetig steigender Energieverbrauch durch IKT-Entwicklung, und angestiegene Anforderungen an Innenraumklima (Durchgängiges Temperaturniveau zwischen 22–24° Grad), wachsende Projektgröße (Mega-Projects) und die Anzahl der Planungsbeteiligten bei gleichzeitig immer kürzerer Planungs- und Bauzeit steigern die Komplexität der Planung. Die lebenszyklische Prognostizierung der Optimierung des Energie- und Materialverbrauchs, Einsatz von erneuerbaren Energien, Langlebigkeit aber gleichzeitige Flexibilität der Konstruktion setzen hohe Anforderungen an die traditionelle Planung und Herstellung der Gebäude.

Der Erfolg von „nachhaltigen“ Projekten wird durch eine relativ geringe Anzahl von maßgebenden Kriterien definiert: Integrale Planung, frühzeitige Zielsetzung, Bauherr als treibende Kraft für die Verfolgung dieser Ziele, organisiertes Monitoring, Know-how Transfer von Planungs- und Betriebsphase aber auch vice versa [11].

Als Voraussetzung für die Realisierung der nachhaltigen Gebäude kann vordergründig die integrale Planung genannt werden. Diese ursprünglich in der Autoindustrie entwickelte Methode, um die Planungszeiten bei gleichbleibender Qualität zu verkürzen [12], wird von Chachere, Kunz und Levitt [13] als Integrated Concurrent Engineering definiert, wobei fortgeschrittene Modellierung- und Simulationsmethoden und Analyse-Werkzeuge, unter simultaner Mitwirkung des Experten-Planungsteams in bestimmten sozialen Rahmenbedingungen (Setting) Entwürfe für komplexe Systeme schaffen.

Integrale Planung wird mittlerweile von mehreren öffentlichen Institutionen wie beispielsweise dem Umweltministerium von Neuseeland [14], oder dem American Institute of Architects [15] als Methode für die Realisierung von nachhaltigen Gebäuden empfohlen. Die Integrated Whole Building Design Guidelines [14] definiert die Methode, welche das Gebäude als Ganzes betrachtet und die Beteiligung aller Stakeholder – von Planungsteam bis zu Nutzer und Betreiber abverlangt. Es ist eine planungsgeleitete Methode, welche sich auf die Verflechtung der Planungsziele fokussiert; Multiple Feedbackloops nach Planungsphasen sind dabei die Voraussetzung, um die multiple Stakeholder-Perspektiven abzudecken. Das Whole-Building-Design von Pawler [16] basiert auf zwei Komponenten: die integrale Planung und der integrale Team-Prozess, wobei die Planung das Prinzip der

Ganzheitlichkeit verfolgt und der Team-Prozess das Prinzip der simultanen Mitwirkung und Multiperspektivität der Planungsbeteiligten. Alle Teilnehmer am Planungsprozess sollten schon von Planungsbeginn an bzw. davor an einem Tisch sitzen, um die Aufgabe zu verstehen und gemeinsam meistern zu können. Die komplexen Zusammenhänge sollten so früh wie möglich erkannt und simuliert werden, da alle späteren Veränderungen während der Planung oder gar Ausführung extrem kostspielig werden und somit nur eine Annäherung an das gewünschte Planungsziel darstellen.

Im deutschsprachigen Raum wird die integrale Planung tatsächlich selten in der Praxis umgesetzt oder gar von den Planungsbeteiligten erwünscht. Die interdisziplinäre Planung verlangt nach einer Atmosphäre des gegenseitigen Vertrauens – eine organisierte und kultivierte Kommunikation und Projektstruktur kann die Planungs-Effizienz wesentlich steigern.

Eine klare Definition der Projektziele am Projektbeginn noch vor der Vorentwurfphase bildet die Grundlage für die tatsächliche Verfolgung und Erreichung der Nachhaltigkeitsziele. Alle Planungsprozesse bestehen grundsätzlich aus zwei Hauptgebieten: jener der Analyse und Synthese [17]. Der analytische Teil soll in der Definition der Planungsziele resultieren, die Synthese hingegen bildet das eigentliche Design. Die Analyse steht zurzeit im Schatten des kreativeren Teils, die Synthese (Entwurfphase) jedoch gewinnt erfolgsentscheidend gesehen deutlich an Bedeutung. Die Performance-Ziele und -Benchmarks betreffend Energieeffizienz und anderer Aspekte der Nachhaltigkeit (LZK, Emissionen etc.) sollten am Anfang vor Entstehung jeglicher Entwurfskonzepte definiert werden. So können sich diese Quantitäten tatsächlich in den Qualitäten des Entwurfs widerspiegeln – die Nachhaltigkeit als inhärente Qualität des Gebäudes anstatt des Add-On Values.

Die Investoren und Bauherren repräsentieren die wichtigste Antriebskraft für „Green Buildings“, da sie letztendlich die finanziellen Entscheidungsträger sind. Ein Engagement bzw. eine Absichtserklärung fürs nachhaltige Bauen fängt grundsätzlich schon bei der Wettbewerbsauslobung an – um diese Haltung durchhalten zu können ist einiges an Mut und Überzeugung auch seitens des Investors notwendig.

Des Weiteren funktionieren die energieeffizienten, nachhaltigen Gebäude selten wie geplant. Die Gründe dafür sind zahlreich: erstens handelt es sich hier um extrem komplexe Systeme, für deren Steuerung Schulung und Weiterbildung von Facility-Personal notwendig ist. Nicht oft ist der Betreiber/Bauherr bereit, diese Investition zu tätigen. Weiters entsteht oft ein Wissens- und Informationstransfer-Verlust zwischen Planung und Betrieb. Diesbezüglich sind bessere Wissensmanagementsysteme notwendig, beziehungsweise Verträge, welche den Planern ermöglichen würden, das Gebäude auch während des Betriebs zu begleiten.

Neben dem transparenten Informationsmanagement brauchen intelligente Gebäude auch einfach ein Fine-Tuning, um das Performance zu optimieren, welches durch Monitoring und wiederholte Post-Occupancy Evaluation (POE) möglich ist.

Um die nachhaltigen Gebäude erfolgreich bauen und betreiben zu können ist ein Paradigmenwechsel in der Wahrnehmung von Gebäuden als Objekt hin zum Gebäude als Projekt notwendig. Die meisten Planungsbeteiligten haben kein Interesse an der Performance ihrer Objekte nach Gebäudefertigstellung – nachdem die Projekte zu fertigen Objekten geworden sind.

Gebäude verändern sich laufend während des Lebenszyklus, nicht nur während der Planungsphase. Die Betriebsphase bietet viele Antworten und Erkenntnisse zur Performance von in der Planung entwickelten innovativen Technologien und Konzepte und bildet somit eine große Wissens-Datenbank. Um an diese Datenbank zu gelangen und sie richtig nutzen zu können, sind

neue Vertragsarten nötig, um die planenden Architekten und Ingenieure als Wissensträger für den gesamten Lebenszyklus von Gebäuden zu gewinnen.

5. Forschungsprojekt CO_BE: Cost Benefits of Integrated Planning

Das Projekt Co_Be (Cost Benefits of Integrated Planning) untersucht Planungsprozesse nachhaltiger Gebäude, um die Vorteile einer integralen Planungsmethodik gegenüber der traditionellen, sequentiellen Methodik qualitativ und quantitativ zu bewerten. Das Projekt wurde von Klima Fond und FFG im Rahmen von „Neue Energien 2020“ gefördert, unter Koordination vom Institut für Interdisziplinäres Bauprozessmanagement, Forschungsbereich Industriebau und interdisziplinäre Bauplanung, TU Wien mit dem Institut für Städtebau und Entwerfen, dem Institut für Städtebau, Landschaftsarchitektur und Entwerfen, Fachbereich Projektentwicklung und -management, TU Wien und ATP Sustain als Projektpartner sowie mit Unterstützung des Instituts für Managementwissenschaften, Arbeitswissenschaft und Organisation, TU Wien.

Die Planungsprozesse für nachhaltige Gebäude sind vordergründig durch steigende Komplexität gekennzeichnet, welche einerseits in der großen Anzahl der Planungsbeteiligten begründet ist, andererseits werden sophisticatede Werkzeuge wie thermische Gebäude-Simulation, Ökobilanzierung und Gebäudezertifikate verwendet. Dadurch ist ein Anstieg der Planungskosten zu erwarten, dem gegenüber steht aber eine wesentliche Reduktion der lebenszyklischen Kosten (Betrieb, Reinigung, Instandhaltung, Wartung) sowie eine Steigerung der ganzheitlichen Gebäudequalität.

Des Weiteren brauchen diese Prozesse eine andere Planungskultur und ein anderes Planungsbewusstsein, also einen Paradigmenwechsel von der traditionellen, fragmentierten und sequentiellen Planung weg, hin zu einer integralen, gemeinsamen Kollaboration. Kurz gefasst, ein Miteinander statt Gegeneinander; letzteres ist in der gängigen Planungspraxis oft der Regelfall geworden (Claim Management). Bei einem erfolgreichen Miteinander im Prozess spielen aber intangible Werte wie Vertrauen, Commitment und gemeinsame Zielverfolgung eine weitaus größere Rolle, als die bis jetzt gültigen Prämissen: Kosten-Termine-Qualität.

Das Forschungsprojekt Co_Be soll erstmalig im deutschsprachigen Raum die Benefits der Integralen Planung (IP) durch ein Rollenspiel-Experiment empirisch untersuchen. Dabei wird die integrale und die sequentielle Planungsmethodik simuliert und qualitativ wie quantitativ bewertet.

Weiters sollten die Methoden für effiziente integrale Planung erarbeitet werden. Im Fokus steht die Untersuchung der Planungsprozesse energieeffizienter Gebäude – in speziellem Hinblick auf die unterschiedlichen Projektorganisationen (Einzelplaner, Einzelunternehmen, Generalplaner, Totalübernehmer) und auch die sozialen Komponenten der Team-Interaktion, welche es zu hinterfragen gilt [18].

Letztendlich soll eine Bewusstseinsbildung für die Komplexität des energieeffizienten Bauens und Planens unter Investoren und Bauherren geschaffen werden. Langfristig soll das Projekt die Veränderungen in den Honorarordnungen für Architekten und Ingenieure bewirken, um den Weg der integralen Planung zur tatsächlich gelebten Planungspraxis zu ermöglichen.

Die Forschungsmethode der Praxis-orientierten Fallstudie basiert auf der Untersuchung des Best-Practices Energie-Effizienten Gebäude (BEEB). Für fünf ausgewählte Gebäude (Fallstudien) wurden Planungsprozesse und Gebäudeperformance anhand von Experten-Interviews, Beobachtungen und informeller Kommunikation untersucht, um die Potentiale sowie Defizite

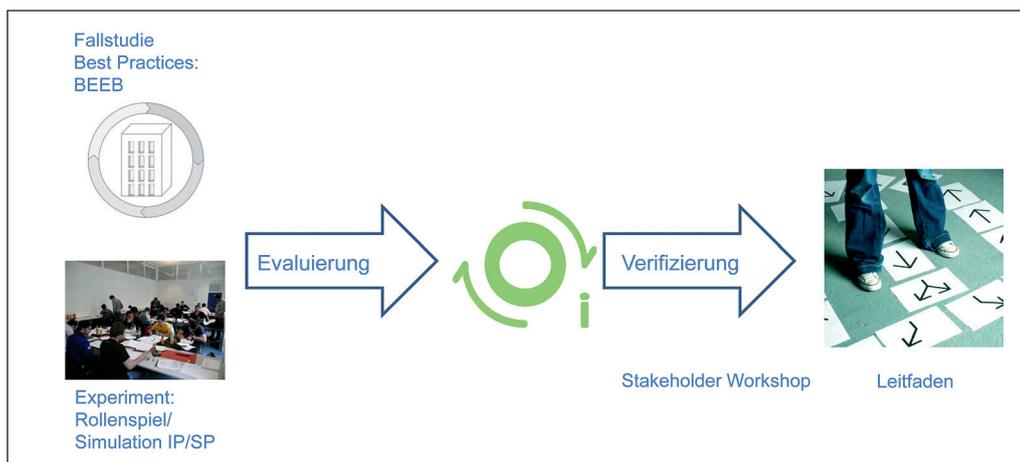


Abb. 1: Forschungsmethode
Fig. 1: Research Method

der Prozesse identifizieren zu können. Durch die Interviews wurden die Key Performance Indikatoren identifiziert.

Parallel zu den Fallstudien wurde die empirische Forschung im Rahmen des Rollenspiel-Experiments durchgeführt. Diese Simulation der sequentiellen und integralen Planungsmethode wurde als Studentenwettbewerb im Rahmen einer Lehrveranstaltung an der TU Wien organisiert. Das Experiment-Design sah zwei Treatments vor: integrale (IP) und sequentielle (SP) Planung, um diese zu vergleichen sowie qualitativ und quantitativ zu bewerten.

Mit Stakeholdern wurde im Abschluss ein Feedbackworkshop abgehalten, um die Ergebnisse der Forschung (Fallstudien und Experiment) zu verifizieren. Als Endergebnis wurde der Integrale Planung – Leitfaden für Public Policy, Planer und Bauherren verfasst.

5.1. Forschungsergebnisse

Das Experiment: Das Planungs-Rollenspiel wurde als Studentenwettbewerb mit 160 Studierenden der Studienrichtungen Architektur und Bauingenieurwesen im Rahmen der Lehrveranstaltungen Planungsprozess und Bauprozessmanagement sowie Bauprojektmanagement-Übung durchgeführt. Um die wissenschaftliche Methodik der sozial-empirischen Untersuchung zu gewährleisten, erfolgte eine enge Zusammenarbeit und Unterstützung durch das Institut für Managementwissenschaften, Fakultät für Maschinenbau der TU Wien.

Das Rollenspiel-Experiment [19] simulierte eine Planung für eine energieeffiziente, temporäre Smoothie-Bar. Das Experiment-Design sah zwei Treatments vor: integrale (IP) und sequentielle (SP) Planung, um diese zu vergleichen und qualitativ und quantitativ zu bewerten.

Die Planungsteams wurden aus folgenden Rollen gebildet: Bauherr, Architekt, Ingenieur für Tragwerk und TGA, Betriebs-experte.

Integrale Teams arbeiten als Team von Anfang an zusammen, die sequenziellen sind pro Rolle räumlich getrennt, die einzelnen Planungsschritte folgen nacheinander.

Das Experiment wurde als Studentenwettbewerb abgehalten, um einerseits die Studierenden zu motivieren und um andererseits die Vorteile der Methoden in der zu bewertenden Kategorie zu identifizieren. In einem anonymisierten Verfahren, bei welchem die unterschiedlichen Treatments durch Kodierung neutralisiert wurden, fand durch eine unabhängige 4-köpfige Jury die Bewertung der Studentarbeiten statt. Die Ergebnisse wurden auf eine Web-Plattform hochgeladen und der Jury zur Verfügung gestellt.

Die Bewertung der Jury erfolgte nach festgelegten Kriterien:

Entwurf, Einsatz der erneuerbaren Energien, Konstruktion und Realisierbarkeit, Wirtschaftlichkeit, Gesamteindruck. Der Gesamteindruck war unabhängig von den einzelnen Kriterien zu bewerten, also nicht Mittelwert oder Summe der einzelnen Kriterien. Dadurch wurde ermöglicht, die Jury-Gewichtung der einzelnen Kriterien zu evaluieren.

Zusammenfassend performt die integrale Planung besser in den Kategorien der Produktivität und Zufriedenheit. Gesamtwirtschaftlich gesehen sind die wesentlichen Vorteile eines integralen Planungsprozesses, insbesondere in Bezug auf soziale Nachhaltigkeit, das geringere Stress- und Belastungsniveau, das sich positiv auf Gesundheit und Wohlbefinden auswirkt. Besonders vorteilhaft zeigt sich eine Ersparnis von 30 min auf einen 8 Stunden-Arbeitstag, welche wesentlich zur Reduktion der in der Baubranche üblichen Überstunden beiträgt und somit für eine ausgeglichene Work-Life Balance sorgt.

Das Experiment zeigte, dass die durchgeführte Simulation der integralen Planung keinen Vorteil in den Punkten Entwurf, Realisierbarkeit, Energieeffizienz und Wirtschaftlichkeit gegenüber einer sequentiellen Planung aufwies. Signifikant jedoch war die eindeutig bessere Produktivität (Zeitersparnis von 30 min) sowie die Zufriedenheit und ein niedrigeres Stress- und Belastungsempfinden der integral Planenden.

Im nächsten Schritt wären die Methoden zu entwickeln, welche auch die Qualitätssteigerung der Planung unterstützen.

Ergebnis der Fallstudien: Die ursprüngliche Annahme, dass das Generalplaner- oder sogar Totalunternehmer-Modell sich wegen der gesamthaften Verantwortungsübernahme in einer Instanz für eine integrale Planung als vorteilhafter erweisen würde, wurde nicht bestätigt. Den Gebäuden, dabei insbesondere den energieeffizienten, die einen vorwiegend prototypischen Charakter aufweisen, werden auch maßgeschneiderte Prozesse und Vergabemodelle pro Projekt abverlangt. Die untersuchten Fallstudien zeigen ähnliche Probleme auf, obwohl sie unterschiedliche Organisationsstrukturen haben (Netzwerk der Einzelplaner, Generalplaner, Totalübernehmer usw.) Vielmehr hängt der Projekterfolg von Faktoren wie Engagement, Motivation, Know-how des Bauherrn, Kompetenz der Planenden, Commitment der Beteiligten ab. Die Fallstudien zeigen den immer noch experimentellen Charakter der energieeffizienten, nachhaltigen Gebäude auf. Insbesondere wichtig wäre deshalb eine gezielte und geplante Monitoring-Strategie samt Auswertung zwecks System-Optimierung und Nachjustierung. Oft sind dafür keine finanziellen Ressourcen mehr da, Gebäude aber funktionieren nicht wie geplant. Eine Benutzer-Befragung (Post Occupancy

Evaluation) ist als kostengünstige Variante zur Identifikation der Defizite in jedem Fall empfehlenswert.

Im Rahmen der Fallstudien wurden die *Experteninterviews* mit Planungsprozess-Teilnehmer mittels Leitfaden-Interviews geführt. Somit konnten die von Experten angesprochenen Themen in Kategorien gebündelt und diese nach Häufigkeit der Aussage evaluiert werden (Tab. 1).

Die Interview-Auswertungen wurden für jedes Projekt wie auch für jede Berufsgruppe evaluiert, um die unterschiedlichen Perspektiven der Stakeholder abbilden zu können. Signifikant ist, dass alle interviewten Berufsgruppen (Bauherr, Architekten, Fachplaner für Tragwerksplanung, TGA und Energie-Konsulenten, FM, Projektsteuerung) eine frühere Einbindung aller Disziplinen wünschen sowie mehr Interdisziplinarität fordern.

Tab. 1: Auswertung der Interviews nach Identifikation der Kategorien der wichtigsten Aussagen, meistgetätigte Aussagen nach Kategorie/Reihung nach Häufigkeit der Aussage

Tab. 1: Interview-Evaluation – Identification of Categories according to most significant statements, sequencing according to statement-frequency

Erfolgsfaktoren	Verbesserungsvorschläge	Defizite
Frühe Einbindung	Änderung der Prioritäten	Geringe Qualifikation im Nachhaltigen Bauen
Interdisziplinarität	Tool als Entscheidungshilfe	Orientierung an Gewinnmaximierung, Nachtragsmanagement
Offene Kommunikation	Mehr Interdisziplinarität/Simultanität	Geringe Flexibilität/Offenheit der Planer
Gemeinsame Zielsetzung	Offenere Kommunikation und Information	Innovationsverlust durch interne Prozesse des Generalplaners
Wissensweitergabe	Frühere/gemeinsame qualitative Zielsetzung	Falsche Planungsprioritäten
BH als Entscheidungsinstanz, Engagement des BH	Professionelle Leitung der Kommunikation	Konservative Rollenverteilung
Flache Hierarchie	Frühere Einbindung von Fachplaner, Sonderkonsulenten und Nutzer	Falsche Kriterien bei Auswahl der Beteiligten
Professionelle Leitung der Kommunikation	Bessere Ausbildung der Beteiligten	Vergaberichtlinien bei öffentl. Projekten

2. Bessere Ergebnisse: Kosten, Zeit, Ressourcen, Planungsqualität, Fehlervermeidung
3. Wissensmanagement, Höhere Aufnahmefähigkeit von Komplexität
4. Nachhaltigkeit
5. Langfristige Vorteile, Stabilität

„Welche Hindernisse sind dabei zu erwarten?“

- „Mensch als Gewohnheitstier“: Änderungen verursachen Widerstand
- Jemand muss Impulse geben
- Kurzfristiges Denken – Baukostenerhöhung
- „Gruppenblindheit“ Group Think
- Wie bringt man Planer dazu WIRKLICH Integral zu planen?

Der *Stakeholder-Workshop* mit 22 Teilnehmer (Architekten, Konsulenten, Generalplaner, Ausführende, Projektsteuerung, CAD-Spezialisten) hatte die Ergebnisse der Studie bestätigt und auf den weiterführenden Forschungsbedarf eindeutig hingewiesen. Bemerkenswert ist das große Interesse der Praktizierenden für diese Thematik, wie auch das Bewusstsein der Notwendigkeit nach Änderung des traditionellen, segmentierten Planungsprozesses und der gängigen Planungskultur.

Die Frage: „Wo liegen (Ihrer Meinung nach) die zentralen Vorteile von integralen Planungsprozessen?“ wurde beantwortet mit:

- Fachübergreifendes Verstehen
- Gute Projektpartner für langfristige Zusammenarbeit
- Gemeinsame Zielsetzung
- Viel mehr Know-how
- Teamwork und effizienter Know-How-Austausch
- Fehler minimieren – gegenseitige Erfahrungen nutzen
- Kosteneinsparung
- Zeiteinsparung
- Höhere Zufriedenheit im Prozess

Das Clustering der Antworten (in Zusammenarbeit) ergab folgende Schlussfolgerung zu *Vorteilen von IP*:

1. Kommunikation: Verständnis, Vertrauen, Entscheidungsfindung,

- Wie komme ich als öffentlicher Bauherr zu den „richtigen“ Planern?
- Was passiert (Sanktionen), wenn nicht integral geplant wird?
- Problem mit Experiment – es wurde nicht gebaut!
- selten werden Honorare gleichmäßig auf die beteiligten Planer aufgeteilt Verständnis für andere Beteiligte fehlt, weil Kompetenzen nicht vorhanden sind! IP nicht im Entlohnungssystem abgebildet wenn Kernprozess des BH nicht verstanden wird
- Ausbildung fehlt! – IP als Thema inhaltlich nicht genug vorhanden mangelnde Sozialkompetenz – generell das Fehlen von Kompetenzen für IP

„Weiterer Forschungsbedarf“:

- Neues Leistungsbild – Gesamtverantwortlicher?
- Ausbildung – muss der alles können?
- Adaptierung der Honorarordnung der IP?
- Gegensteuern Gruppendynamik – Kontrolle?
- Soziale Kompetenz im Planungsprozess

6. Schlussfolgerung und Ausblick

Um integrale Planungsprozesse gestalten zu können, wird ein 3 Säulen-Modell vorgeschlagen (Abb. 2):

Gebäudequalität – Werkzeuge – Menschen.

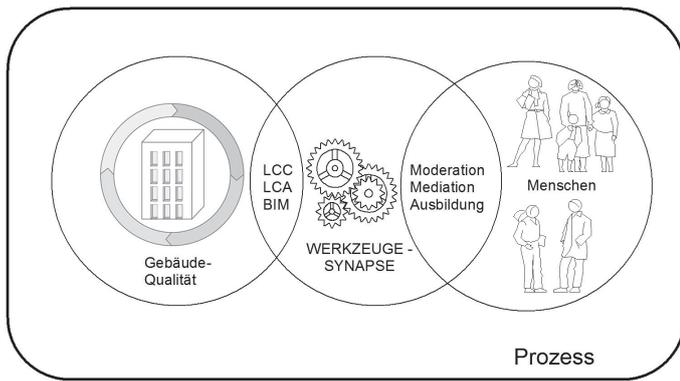


Abb. 2: Drei-Säulen Modell: Gebäudequalität-Werkzeuge-Menschen, als Bestandteile des Gesamtsystem Planungsprozess
 Fig. 2: Three-Pillars-Model: Building Quality-Tools-People, as basic elements of planning process system

Dabei umfasst das Feld der „Menschen“ alle am Planungsprozess Beteiligten, also Planende, NutzerInnen, Behörden, Konsultanten, usw.

Die Gebäudequalität umfasst das Gebäude – also Zielsetzungen für die Planung, sämtliche Repräsentationen im Planungszustand (Modell, Plandokumentation usw.) bzw. das physisch gebaute Objekt und sein Verhalten im Lebenszyklus.

Unter Werkzeuge werden einerseits tangible Tools wie CAD, BIM (Building Information Modelling) [20] Simulation, LCA (Life Cycle Assessment), LZK (Life Cycle Costing) [21] etc. sowie auch intangible Tools wie die Gestaltung der Kommunikation durch Kick-Off Meeting, Moderation, Mediation, Kollaborationsplattform, Kommunikationsarena, Workshops usw. verstanden.

Das 3-Säulen-Modell bildet das Gesamtsystem „Prozess“ ab. Wegen des prototypischen Charakters eines Gebäudes (im Gegensatz zu einem in der industriellen Serien- oder Massenproduktion gefertigtem Produkt) soll der Prozess für jedes Gebäude neu konfiguriert werden, je nach Rahmenbedingungen und Planungs-Bedarf. Es kann also davon ausgegangen werden, dass es keinen idealen Prozess gibt, sondern immer nur ein „maßgeschneidertes“ Prozess-Design – je nach Projekt.

Die nächsten Forschungsschritte sollen nun mehr Fokus auf die Gestaltung eines integralen Planungsprozesses legen. Dabei sollten die „intangiblen“ Faktoren und Werkzeuge genau untersucht werden, nämlich die Mechanismen zur Unterstützung und Gestaltung der Team-Kommunikation und Kooperation – konkret folgende Fragestellungen:

- Wer macht was und wann? Wer gestaltet den Prozess und wie?
- Wird die Rolle der Projektsteuerung durch einen Moderator des Integralen Planungsprozesses ersetzt?
- Wie kann man Vertrauen unter Planungsbeteiligten aufbauen, mit welchen Mechanismen das Commitment unterstützen?

Weitere nähere Betrachtung gilt dem Building Information Modelling (BIM) Werkzeug welches eine integrale Arbeitsweise voraussetzt. Die Technologie ist bereits ausgereift, jedoch zeigen die Forschungsstudien aus Ländern, in denen BIM bereits weitaus breitere Anwendung als in Österreich findet, dass es an einer rascheren BIM Implementierung in der Praxis an intangiblen Prozesseigenschaften scheitert [22] – also People und Prozess. Beim BIM-Einsatz sind neben einem ausgereiften Werkzeug eine durchdachte Prozess- und Kommunikationsgestaltung und Schnittstellen, die den reibungslosen Datenaustausch ermöglichen, notwendig.

Zur Zeit werden die meisten Anstrengungen in die Entwicklung und Umsetzung der innovativen Technologien gesteckt – zu diesen zählen die Technologien zur Energiebereitstellung (Gewinnung der erneuerbaren Energien); zur effizienten Energienutzung oder eben die Planungstools zur Simulation, Prognostik und Optimierung des Energieverbrauchs. Vergleichsweise wenig Aufwand wird der zwischenmenschlichen Interaktion gewidmet, schließlich funktioniert jede Technologie nur so gut wie die Menschen, die dahinter stehen. Als weiteres Problem ist die 20-20-20 Zielsetzung anzusprechen, welche nur durch einen energieeinsparenden Lebensstil verwirklichtbar ist. Dazu gehört aber eine wesentliche Lebensstiländerung, welche wiederum mit Verhaltensänderung zu tun hat, in der Mechanismen wie Kommunikation, Motivation und Wissenstransfer eine wesentliche Rolle spielen. In der zukünftigen Forschung sollen diese Themenfelder in einer transdisziplinären Arbeitsweise behandelt werden.

Literatur

[1] Umweltbundesamt 2012. KLIMASCHUTZBERICHT 2012, Wien
 [2] Umweltbundesamt 2012 <http://www.umweltbundesamt.at/umweltsituation/klima/klimaschutz/>
 [3] Köppl, A. 2009. Business and Buildings, Fakten und Handlungsbedarf, Ökosoziales Forum, Wien
 [4] Spangenberg J.H.2002. Environmental space and the prism of sustainability: frameworksfor indicators measuring sustainable development, Ecological Indicators 2 (2002) 295–309
 [5] LEED 2012, <https://www.leedonline.com/irj/servlet/prt/portal/prtroot/com.sap.portal.navigation.portallauncher.anonymous>
 [6] BREEAM, 2012 <http://www.breeam.org/>
 [7] DGNB, www.dgnb.de
 [8] ÖGNI, 2012 <http://www.ogni.at/de/themenfelder/>
 [9] TQB, 2012 <https://www.oegnb.net/tqb.htm>
 [10] Schwarz, D. (2007), Nachhaltiges Bauen, in: Detail 2007/6, Detail-Verlag 2007 pp. 600-604
 [11] Torcellini P., Pless S., Deru M., Griffith B., Long N., Judkoff R. 2006. Lessons learns from Case Studies of Six High-Performance Buildings, Technical Report, Golden, Colorado, USA: National Renewable Energy Laboratory
 [12] Yazdani, B., Holmes, C. (1999): Four Models of Design Definition: Sequential, Design Centered, Concurrent and Dynamic. In: Journal of Engineering Design, Vol. 10, No. 1, 1999.
 [13] Chachere J., Kunz J. und Levitt R. ,2004. Observation, Theory, and Simulation of Integrated Concurrent Engineering: Risk Analysis Using Formal Models of Radical Projekct Acceleration, CIFE Working Paper ,WP088, Stanford University
 [14] IWHBDG, Integrated Whole Building Design Guidelines 2008. New Zealand Government, Ministry for the Environment, www.mfe.govt.nz
 [15] AIA, American Institute of Architects California Council 2009. Experiences in Collaboration: On the Path to IPD
 [16] Prowler D. (2007), Whole Building Design. <http://www.wbdg.org/>
 [17] Penna W., Parshall S. 2001. Problem seeking: an architectural programming primer, USA: John Wiley and Sons
 [18] Prins, Owen (2010): Integrated Design and Delivery Solutions, Architectural Engineering and Design Management 6: 227-231
 [19] Kolarevic, B., Schmitt, G., Hirschberg, U., Kurmann, D., and Johnson, B., 2000. An experiment in design collaboration. Automation in Construction, Vol. 9, pp. 73-81
 [20] Succar, (2010): The five components of BIM performance management, in Proceedings of CIB World Congress, Salford
 [21] Kohler, Moffatt, (2008) Conceptualizing the built environment as a social-ecological system. In: Routledge: Building Research & Information. 2008. 36(3). S. 248-268.
 [22] Rekkola, Kojima, Mäkeläinen, 2010. Integrated Design and Delivery Solutions, Architectural Engineering and Design Management 6: 264-278

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An Integrated Planning method for a sustainable built environment

It is essential that planners, users and investors improve their awareness of sustainable construction, because of increasingly stringent EU requirements and regulations relating to climate protection and the minimisation of CO₂ emissions. For this reason, a life-cycle oriented design process should be seen as a fundamental requirement if sustainable architecture is to balance social, ecological and economic interests.

1. Sustainability of built environment

Our contemporary world is characterised by constant change. On the one hand there is climate change, linked to greenhouse gas emissions as a result of industrial and post-industrial human activity. Then there is the exhaustion of resources, where, next to energy and raw-material shortages, time and space are increasingly scarce resources. We are also experiencing constant socio-economic and technological change, as a result of rapid developments in information and communication technology, linked to the globalised economy, with ever shorter production cycles.

Buildings have a relatively long life-duration, compared to industrial products, and are generally perceived as having stability and consistency. This perception is slowly changing towards the idea of buildings as structures in a state of constant transformation. Real estate experts estimate that the current life-duration of non-residential facilities is 50 years, with the original function being changed up to three times over the life-time of the building. As a result of these repeated changes, the initial energy, resource and capital consumption is constantly increasing, as are emissions with their environmental impact.

The greatest challenge facing the AEC (architecture, engineering and construction) industry of the new millennium is how to design flexible and adaptable buildings which also meet climate protection and energy-efficiency aims.

Current trends are in the opposite direction: Austrian CO₂ emissions in 2010 exceeded the Kyoto target by 22%. Instead of achieving a reduction of 13%, emissions increased by 8% [1]. In order to meet the agreed maximum 2°C increase in global temperature by 2050, industrial countries will need to reduce their emissions by 80—95%, compared to 1990 levels [2]. Meanwhile, 40% of total energy consumption in the EU is used for heating and cooling buildings. In Austria, buildings consume 35% of total energy, and cause one fifth of all CO₂ emissions [3].

Yet the construction sector still regards sustainability as 'added value' rather than as an inherent quality. Current building performance evaluation methodologies still focus mainly on energy-efficiency performance – with an obligatory energy certificate as evidence of operational energy consumption, focused mainly on the assessment of HED (heating energy demand). Only in rare cases is there a requirement for life-cycle oriented assessment of energy demand, covering not just the operation of the building, but also its construction (manufacture of materials), refurbishment and eventual demolition.

The assessment of building performance in terms of sustainability is often confused with life-cycle assessment (eco-balance), which considers only one

aspect of sustainability (ecology) and does not address social or economic issues. A holistic approach to sustainability-assessment should combine life-cycle costing with life-cycle assessment (eco-balance).

In addition to an economic, ecological and social dimension, the 'prism of sustainability', as defined by Spannenberg [4], identifies an institutional dimension, which defines a framework of political decision-making policies for achieving sustainability. For the architecture, engineering and construction (AEC) industries, these dimensions (interests) are:

- Economic interests: fulfilment of economic aims over the expected life-time of the building (asset);
- Ecological interests: reduction in resource usage; energy-saving construction; minimisation of emissions and environmental impact; and adaptability;
- Social interests: satisfaction of needs; social equity; affordability; accessibility; and equitable resource distribution.

2. Building certification schemes

The increasing number of international building certification schemes, affecting the AEC industry, should guarantee building sustainability as a unique selling proposition, and thereby ensure sustainable rents and income. The leading certification schemes include those in the USA – the Leadership in Energy and Environmental Design Green Building Rating System™ (LEED) [5] – and a UK scheme focused mainly on CO₂ reduction – the Building Research Establishment Environmental Assessment Method (BREEAM) [6]. The schemes which are most relevant to the Central European construction sector are the German Sustainable Building Council – DGNB [7] – and the equivalent Austrian Sustainable Building Council – ÖGNI [8] – as well as the certification scheme of the Austrian Association for Sustainable Building, so-called Total Quality Building – TQB [9].

Despite some criticism, all of the building certification schemes aim to categorise and assess quantifiable planning aims, and cover much more than just economic factors. All of the schemes are based on the evaluation of energy and resource efficiency, emission reduction, landscape protection and conservation, and a healthy interior climate.

As described by DGNB, the building certificates themselves represent a marketing instrument, but they also support the process of embedding sustainability aims in planning processes and building quality.

The ambivalent nature of building, as a combination of tangible (quantitative) and intangible (qualitative) features, raises problems for standardised building performance evaluation, since the qualitative features, and the resulting added value can be difficult to measure.

The most common *quantitative* features used for evaluation are:

- Economic: initial, following and life-cycle costs; rents and incomes;
- Ecological: resource consumption (energy, materials, land); emissions.

The most common *qualitative* features used for evaluation are:

- Social: affordability; accessibility; fulfilment of social needs (housing, schools); flexibility; human health;
- Formal aesthetic and cultural (monument protection).

The so-called sustainability indicators are a means of assessing the sustainability potential of a built structure. They reflect and benchmark both qualitative and quantitative features, with benchmarking often based on a flow-method, balancing life-cycle inputs and outputs.

We can conclude by saying that the need for holistic, sustainable planning and construction is urgent, however the general level of understanding and knowledge about life-cycle oriented planning is still poor. One of the reasons for this is the shortage of data on building performance – together with a lack of professional experience – since large volume, energy-efficient buildings are still largely a recent phenomenon. To quote the British architect Frank Duffy:

“The unit of analysis...isn't the building, it's the use of the building through time. Time is the essence of the real design problem.”

3. Objectives for sustainable planning and construction

Despite the urgent need for action to achieve a sustainable built environment, there are still major obstacles slowing progress. One of these obstacles is the traditional, linear planning process, with the final horizon set on building completion. The linear succession of planning services results in buildings with sub-optimal construction, poor orientation, and an interior climate that is difficult to control. Frustrated users, high running costs and excessive resource consumption are factors which contribute to the short life-expectancy of buildings which are all too soon vacated and most probably demolished, or – in a best-case scenario – refurbished and transformed.

Construction costs are only a small percentage (20%) compared to costs incurred over the rest of the building life-cycle (80%). This knowledge alone should prompt a rethink of current planning processes.

The adoption of life-cycle oriented planning, and the introduction of collaboration between all participating disciplines – architecture; structural engineering; mechanical, electrical and plumbing service (MEP) engineering; and facilities management – would be a major step towards sustainable construction.

The recent gas crisis and raised awareness of our high energy dependency, have already prompted changes in the way tenants and investors think about sustainability. Until recently, initial investment was the key decision-making criterion in construction. However, life-cycle cost analysis is increasingly a required deliverable in the early planning stages.

Investors increasingly call for “green buildings”, however they are seldom ready to pay for the complex, interdisciplinary planning processes which cost more than those for standard buildings. Optimised planning can help reduce follow-up costs by up to 40% [10], however its introduction will require changes to fee structures – to support Integrated Planning – together with incentives for successful planning (e.g. for cost-optimised operation) and new life-cycle oriented contract models.

4. Success factors for Integrated Planning

The key features of “green buildings” – enhanced resource conservation, construction appropriate to the local climate and setting, and minimal impact on the environment and landscape – are well known and long established guiding principles in the history of architecture. The modernist principles of “light, air and sun” reflect these criteria, particularly in terms of social sustainability.

However, new challenges are contributing to rising complexity in planning and construction. These new challenges include: constantly increasing energy consumption due to life-style changes and the increasing use of technology; additional requirements relating to the interior climate (a constant temperature level between 22-24°C); increasing project size (mega-projects); and the increasing number of planning process participants required during the ever-shortening planning and construction phases.

Meanwhile, prediction and optimisation of energy and resource consumption, increasing use of renewable energy, and demands for greater building flexibility, are all challenging traditional design and planning methods.

The success of “sustainable” projects can be predicted using a relatively small number of key criteria: Integrated Planning; early aim-setting; investors as the driving force behind planning goals, and engaged in their realisation; organised monitoring and smart metering; transfer of knowledge from planning through into operation and from operation back into planning [11].

Integrated Planning (IP) is considered to be a precondition for the achievement of sustainability aims in construction. It originated in the automotive industry to reduce development and production timescales while retaining quality [12], and was introduced into the AEC industries – for example by Chachere, Kunz and Levitt [13] – under the name Integrated Concurrent Engineering (ICE). In ICE, advanced modelling, simulation and analysis tools are used collaboratively by expert team members, in defined social conditions (settings), for the design of complex systems.

IP is the method recommended by several public institutions for developing sustainable buildings – e.g. the New Zealand Ministry for the Environment [14] and the American Institute of Architects [15].

The Integrated Whole Building Design Guidelines [14] mandate IP, based on its holistic approach and the involvement of all stakeholders – the planning team, users and managers. The Guidelines also advocate a design-oriented approach, focusing on coordinated planning aims, with multiple feedback loops after each design stage, to reflect multiple stakeholder perspectives.

Whole Building Design, as defined by Prowler [16], is based on two components – Integrated Planning and integrated team processes – in which planning is committed to holistic principles, and the team processes are committed to the principles of simultaneous collaboration and a multi-perspective view of planning participants. All of the participants should be included from the start of design, in order to develop mutual understanding of the task. This also encourages the identification and simulation of complex design inter-relations and issues, as early as possible, since most changes in the later stages of design or construction are extremely costly and can typically only be partially implemented (re-active).

In German-speaking regions, Integrated Planning is still a novel approach, and can be difficult to establish among planning teams. Interdisciplinary planning requires an atmosphere of mutual trust, and organised and cultivated communication – both of which can significantly increase efficiency, but which require significant changes in work culture.

A clear definition of planning aims, ideally before the start of the conceptual design phase, provides a firm basis for tracking and achieving sustainability-related planning aims. Essentially, all design and planning procedures consist of two main activities – analysis and synthesis [17]. Analysis results in a clear definition of planning goals and settings, whereas synthesis is the actual design

process. Analysis is often neglected – standing in the shadow of the more creative synthesis – however it is crucial for project success. Performance requirements and benchmarks for buildings, related to energy-efficiency and other aspects of sustainability (life-cycle costs, emissions), should be defined before design concepts start evolving. In this way, performance requirements will be translated into design concepts, and sustainability will be embedded as an inherent building requirement, rather than just ‘added value’.

Investors and clients represent the most important driving force behind the development of “green buildings”, as they are the ultimate decision-makers. Sustainability goals may have been included in the initial invitation to tender (ITT), but adhering to these initial goals also requires commitment and courage on the part of investors.

Energy-efficient and resource-optimised buildings rarely operate as simulated and designed. The reasons for this are numerous. Firstly, it is necessary to train building managers in the successful operation of these extremely complex HVAC (heating, ventilation and air-conditioning) and building automation systems – yet the investor is rarely prepared to bear the cost of such training. Then there is typically a gap in the transfer of knowledge between the planning and operational stages, so better knowledge management systems and processes are required to bridge this gap.

Even with transparent knowledge management systems and processes, intelligent buildings often require fine-tuning to optimise performance, which can only be carried out on the basis of formal monitoring and repeated post-occupancy evaluation.

In order to design and plan a sustainable built environment, a paradigm shift is required, from the perception of “building as object” to the notion of “building as project”. Most planning process participants have little or no interest in the performance of projects after building completion – after projects became objects. Yet buildings change continuously throughout their life-cycle, and the operational phase can provide many answers to questions about the effectiveness of the planning methods adopted or the technological concepts applied. As such, the operational phase represents a valuable knowledge-base for future projects. In order to access and utilise this knowledge-base, new contractual procedures are required to empower planning architects and engineers as experts in the entire life-cycle of buildings.

5. Research project CO_BE: COst BEnefit Analysis of Integrated Planning

The interdisciplinary research project, Co_Be (Cost Benefit Analysis of Integrated Planning), examined planning processes for sustainable buildings, with the aim of identifying, and qualitatively and quantitatively evaluating the benefits of Integrated Planning, compared to traditional Sequential Planning.

The project is funded from climate and energy funds provided by the Austrian Research Promotion Agency (FFG) within the programme “New Energies 2020”. The project is under the auspices of the Department for Industrial Building and Interdisciplinary Planning (within the Institute for Interdisciplinary Building Process Management, Faculty of Civil Engineering, TU Wien). Other partners are the Department for Project Development and Management (within the Institute for Urban Planning and Design, TU Wien), and the company, ATP Sustain, a partner from practice. The project was also supported by the Institute for Management Science, TU Wien.

Design and planning processes for sustainable buildings are highly complex, because of the greater number of participating disciplines, the need to use sophisticated computer analysis and simulation methods and tools, and building certification schemes.

It is to be expected that the adoption of these methods and tools will increase planning costs, however it will also significantly reduce subsequent building operation costs, as well as increase the overall quality of the building. Such process integration, however, requires a change in planning culture and consciousness, away from traditional, fragmented design towards more collaborative planning practices – in short, cooperating rather than competing – something which is uncommon in AEC practice. For successful collaboration, intangible values such as trust, commitment and mutual respect play a far more important role than the

classic project management parameters of time-cost-quality.

For the first time in the German-speaking region, the research project Co_Be explored the benefits of IP using empirical research – a role-playing experiment – which compared Integrated and Sequential Planning approaches to design.

A particular focus of the case-study research was to assess the suitability of IP in different organisational structures – single-supplier, network of planners, managing planner, and total contractor (single company responsible for planning and construction) – and to assess social aspects of team interaction [18]. The aim of the project was to increase investor and client awareness of the complexity of energy-efficient design and construction. In the long term, the project should also encourage changes in fee structures, to ensure that Integrated Planning becomes business-as-usual rather than best practice.

A practice-oriented, case-study research method was used to explore best practice energy-efficient buildings (BEEB). For each of the five case-studies (buildings) the design process was analysed using open-ended expert interviews, observation and informal communication. Building performance was also assessed using data capture and analysis, to identify potentials and deficits resulting from the applied design process. Coded interview material was then used to establish key-performance indicators (KPIs) (Figure 1).

Following the case-study research, a laboratory role-playing experiment was conducted. In the context of an interdisciplinary undergraduate class, a building design was simulated, as a student competition, using two design approaches – Integrated Planning (IP) and Sequential Planning (SP) – which were compared and evaluated.

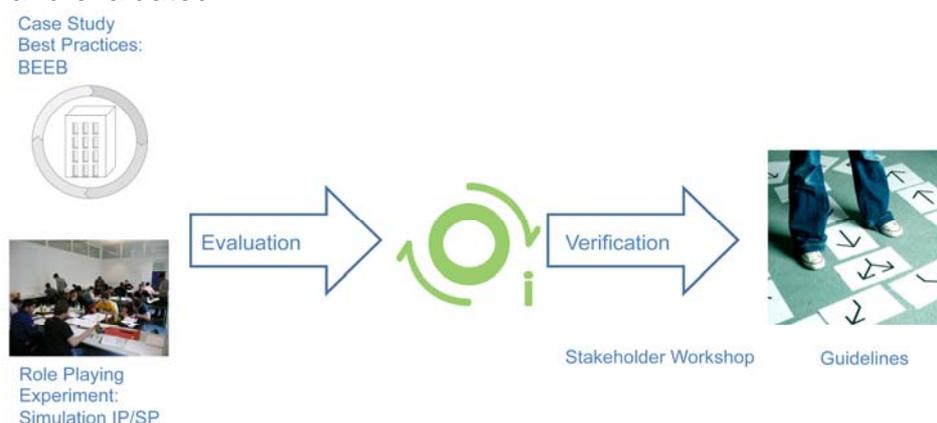


Figure 1: Research method

In the feedback workshop with practitioners, the results of the case-study research and the role-playing experiment were discussed and verified. The insights were then used to establish best practice planning processes for energy-efficient buildings, which were compiled and published as the Integrated Planning Guidelines for Public Policy, Planners and Investors (2012).

5.1 Research results

Results of the experiment: The role-playing exercise involved 160 students of architecture and civil engineering who were taking part in the courses: “Planning process and Project Management in Construction” and “Project Management – Exercise”. There was also close collaboration with the Institute for Management Sciences (Faculty of Mechanical Engineering, TU Wien), to ensure the scientific rigour of the social-empirical research methodology.

The role-playing experiment [19] simulated the design of an energy-efficient, temporary smoothie bar, using two design approaches (treatments) – Integrated Planning (IP) and Sequential Planning (SP). The 160 students were split into 40 teams (20 IP and 20 SP), each comprising four roles: an architect, a structural & MEP engineer, a management consultant and an investor. The Integrated Planning teams collaborated from the start, whereas the Sequential Planning teams were segregated in separate rooms, according to discipline, and the design steps were organised sequentially.

The role-playing experiment was organised as a student competition, both to motivate the students and to facilitate the evaluation of each project in terms of its treatment. A four-person jury anonymously assessed the student designs, each of which had also been anonymised using coding to remove evidence of the adopted treatment. The results were uploaded to a web-platform, and the jury evaluated each design using the following criteria: architectural design; use of renewable energy; structural quality; constructability; economic efficiency; and general impression.

‘General impression’ was evaluated separately from the other criteria (not as a mean or median value for all the categories), as this provided insights into the weighting applied to criteria by jury-members.

To summarise, IP performs better in terms of efficiency and satisfaction. In terms of overall economic performance, the major advantages of Integrated Planning are mainly in the area of social sustainability, since this approach leads to lower levels of stress and anxiety, which has positive effects on health and well-being. The time saving of 30 minutes per 8-hour working day, in comparison to SP, is also particularly advantageous as it brings the benefit of a more stable work-life balance to a professional field where overtime is normal rather than exceptional.

The *results of the competition*, serving as a quantitative evaluation of the role-playing experiment, showed that simulated Integrated Planning does not provide evidence of improved architectural design, better use of renewable energy, constructability, or of economic efficiency, when compared to Sequential Planning.

The evidence of improved productivity (30 minute time saving) is significant, as are both the higher satisfaction, and lower stress and anxiety levels.

Future research should explore methods for increasing design quality and assessing the impact of personality traits on team performance, based on the treatment adopted.

Results of the case-study: The initial hypothesis was that the ‘managing planner’ and ‘total contractor’ models – because they denote a single point of responsibility – would prove more suitable for IP, as they have fewer interfaces in terms of responsibility. However this was not confirmed by the case-study, so the initial hypothesis was not proven.

Energy-efficient buildings are, by their nature, prototypical, and therefore require customised processes and contractual models which are different for every project. The multiple case-studies displayed similar problems, despite different organisational models (network of planners; managing planner; total contractor). Project success is linked much more to factors such as engagement, motivation, the commitment of stakeholders, investor knowledge, or planner competence, than to the organisational model adopted. The study suggests that energy-efficient buildings are still experimental in nature.

As optimised buildings do not perform as planned, an organised monitoring and metering strategy is especially important for system evaluation and optimisation. A post-occupancy evaluation involving users is recommended as an economical but still efficient way of identifying potential system failures.

In the course of the case-studies, *open-ended expert interviews* were conducted. Each topic addressed in the interviews was bundled and categorised according to its frequency of occurrence – see Table 1.

Success factors	Proposed improvements	Deficiencies
Early involvement	Change of priorities	Low skill levels in sustainable construction
Inter-disciplinarity	Tools for decision-support	Orientation towards profit maximisation, claim management
Transparent communication	More inter-disciplinarity / simultaneity	Low level of flexibility / openness of planners
Joint aim-setting	More transparent communication / information	Loss of innovation due to managing planner’s (rigid) design processes
Transfer of knowledge	Earlier / joint setting of qualitative aims	Wrong planning priorities
Investor as driving force / Investor engagement	Professional communication management	Conservative roles
Flat hierarchy	Early involvement of planning disciplines and users	Wrong criteria for the choice of planners
Professional communication management	Better training & education of planning process participants	Award of contracts in public projects

Table 1: Interview-evaluation – identification of criteria (by statement significance, sorted by statement frequency)

The interviews were evaluated and codified for each project and each discipline, in order to assess the different perspectives of each planning process stakeholder. It is significant that all of the interviewed disciplines (investors, architects, structural engineers, MEP engineers, energy-consultants, facility

managers, project managers) requested greater inter-disciplinarity and earlier involvement of the different discipline.

Results of the *feedback workshop*: The stakeholder feedback workshop involved 22 participants (architects, consultants, engineers, contractors, project managers, CAD specialists) and verified the results of the research. It also identified areas for further research into Integrated Planning. The most striking finding was the great interest practitioners had in the research project topics, as well as their expressed need for a change in traditional planning procedures and culture.

The question: “*What in your opinion are the main benefits of Integrated Planning?*” prompted the following responses:

- Understanding of the interdisciplinary approach
- Project partners for long term collaboration
- Joint aim-setting
- Increase in knowledge
- Teamwork and efficient knowledge transfer and exchange
- Minimisation of mistakes – through sharing of experience
- Cost savings
- Time savings
- Increased satisfaction with the process

The question: “*What obstacles can be expected?*” prompted the following responses:

- Humans as “creatures of habit”: changes cause resistance
- Impulse-givers necessary
- Short term thinking causes increased costs
- “Group Think”
- How to motivate planners to really plan in an integrated way
How to access the right planners as a public investor (bound by EU tendering and contracting law which mandates Europe-wide competition among bidders – many of whom may have no experience of IP)
- What happens (sanctions) if the Integrated Planning method is not followed?
- Limitations of the experiment – it was not built!
- Planning fees are seldom equally distributed among planners. IP is not reflected in current fee structures (e.g. no provision to pay for structural engineers from the beginning of design, if traditionally they only start at stage 2).
- Education is lacking – IP as a topic is not sufficiently represented in university schedules; lack of social capabilities; general lack of IP competence.

The question “*What areas were identified for further research?*” prompted the following responses:

- Allocation of responsibility (Who carries collective responsibility within an integrated team?)
- Education and training of integrated planners (experts or generalists?)
- Adaptation of fee structures to support IP
- Group Think – development of counter steering control mechanisms
- Social competencies in IP

Collaborative grouping of answers, using moderated group discussion, gave the following summary *advantages of IP*:

1. Communication: understanding, trust, decision-making
2. Better results: cost, time, resources, planning quality, error avoidance
3. Knowledge management, better perception of complexity
4. Sustainability
5. Long term benefits, stability

6. Conclusion and way forward

In order to design an Integrated Planning process, we propose a 3-pillar model (Figure 2), based on 'Building Quality', 'Tools' and 'People', as follows:

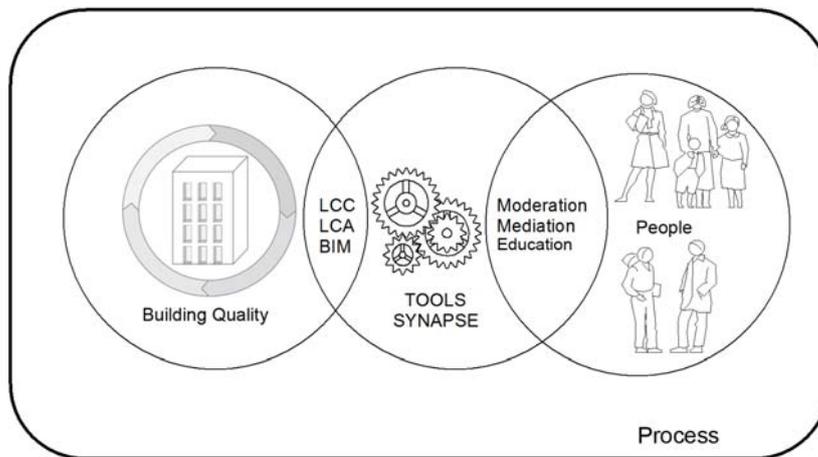


Figure 2: The 3-pillar model – Building Quality, Tools and People as the basic elements of a planning process

'People' includes all planning process participants and stakeholders, such as planners, users and investors, but also neighbours, public policy, etc.

'Building Quality' describes the building, aim-setting for planning, representations of the planning stages (models, documentation), and eventually the physical object and its performance throughout the life-cycle.

'Tools' are either tangible, such as CAD, BIM (Building Information Modelling) [20], computational design analysis and simulation tools, Life-Cycle Costing [21] – or intangible, such as social competencies empowering communication design, including moderation, mediation, kick-off meeting, collaboration platforms, communication arena, workshops, etc.

The 3-pillar model represents the basic elements of a planning process. Due to the prototypical nature of buildings (as opposed to industrially manufactured, mass-produced or serial products), the design process inevitably needs to be reconfigured for each new project, depending on boundary conditions and concrete needs. The hypothesis is that there is no "ideal" process, but that each project requires a customised process-design.

Future research should focus on the design of a design process. In this way, intangible tools can be investigated on the same terms as tangible tools – such as mechanisms to support and design team-communication and collaboration – in order to address the following research questions:

- Who does what and when? Who defines the design process?
- Is the IP moderator the future alternative to a project manager?
- How do you build trust in a planning team which requires support and commitment?

Further research will be carried out to explore the potential of BIM tools to support Integrated Planning. The technology is mature enough, however studies from countries with much greater BIM utilisation than Austria show that BIM implementation is, in practice, impeded less by technological challenges, than by people-related and process-related issues [22]. When implementing BIM, careful design of processes and communication is required – as well as technological maturity – to establish functioning interfaces and to facilitate data exchange.

In current approaches to enhancing a sustainable built environment, most effort is still spent developing and supporting innovative technologies – for example, technologies for energy supply, efficient energy utilisation, or planning tools for the design analysis, simulation and optimisation of energy consumption. By contrast, very little effort is expended on inter-human communication, even though it is well established that any technology is only as good as the people who operate it.

Another challenge is to meet EU 20-20-20 targets, which will only be met by adopting energy-saving life-styles. Achieving this will require radical changes in life-style and behaviour – changes in which mechanisms such as communication, motivation and knowledge transfer will play a crucial role. These mechanisms will be the subject of a future trans-disciplinary research agenda.

Literature

- [1] Umweltbundesamt 2012. KLIMASCHUTZBERICHT 2012, Wien
- [2] Umweltbundesamt 2012 <http://www.umweltbundesamt.at/umweltsituation/klima/klimaschutz/>
- [3] Köppl, A. 2009. Business and Buildings, Fakten und Handlungsbedarf, Ökosoziales Forum, Wien
- [4] Spangenberg J.H.2002. Environmental space and the prism of sustainability: frameworks for indicators measuring sustainable development, Ecological Indicators 2 (2002) 295–309
- [5] LEED 2012, <https://www.leedonline.com/irj/servlet/prt/portal/prtroot/com.sap.portal.navigation.portallauncher.anonymous>
- [6] BREEAM, 2012 <http://www.breeam.org/>
- [7] DGNB, www.dgnb.de
- [8] ÖGNI, 2012 <http://www.ogni.at/de/themenfelder/>
- [9] TQB, 2012 <https://www.oegnb.net/tqb.htm>
- [10] Schwarz, D. (2007), Nachhaltiges Bauen, in: Detail 2007/6, Detail-Verlag 2007 pp. 600-604
- [11] Torcellini P., Pless S., Deru M., Griffith B., Long N., Judkoff R. 2006. Lessons learnt from Case Studies of Six High-Performance Buildings, Technical Report, Golden, Colorado, USA: National Renewable Energy Laboratory
- [12] Yazdani, B., Holmes, C. (1999): Four Models of Design Definition: Sequential, Design Centered, Concurrent and Dynamic. In: Journal of Engineering Design, Vol. 10, No. 1, 1999.
- [13] Chachere J., Kunz J. und Levitt R., 2004. Observation, Theory, and Simulation of Integrated Concurrent Engineering: Risk Analysis Using Formal Models of Radical Project Acceleration, CIFE Working Paper ,WP088, Stanford University

- [14] IWHBDG, Integrated Whole Building Design Guidelines 2008. New Zealand Government, Ministry for the Environment, www.mfe.govt.nz
- [15] AIA, American Institute of Architects California Council 2009. Experiences in Collaboration: On the Path to IPD
- [16] Prowler D. (2007), Whole Building Design. <http://www.wbdg.org/>
- [17] Penna W., Parshall S. 2001. Problem seeking: an architectural programming primer, USA: John Wiley and Sons
- [18] Prins, Owen (2010): Integrated Design and Delivery Solutions, Architectural Engineering and Design Management 6: 227-231
- [19] Kolarevic, B., Schmitt, G., Hirschberg, U., Kurmann, D., and Johnson, B., 2000. An experiment in design collaboration. Automation in Construction, Vol. 9, pp. 73-81
- [20] Succar, (2010): The five components of BIM performance management, in Proceedings of CIB World Congress, Salford
- [21] Kohler, Moffatt, (2008) Conceptualizing the built environment as a social-ecological system. In: Routledge: Building Research & Information. 2008. 36(3). S. 248-268.
- [22] Rekola, Kojima, Mäkeläinen, 2010. Integrated Design and Delivery Solutions, Architectural Engineering and Design Management 6: 264-278

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Challenges for the Implementation of Integrated Design in the Planning Practice

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Abstract

Design and planning process of “green buildings” requires a fundamental change in traditional design planning process, towards more integrated, collaborative practice with life-cycle orientation. The methods known from aeronautical and automotive industry such as concurrent engineering have often been referred to as possible way for radical process improvement of AEC industry, however the implementation of the so called integrated building design (IBD) in the planning practice has not succeeded yet. This paper will present the results of the multiple case study research of best-practice planning processes for five energy efficient buildings, with aim to determine the success factors, optimization potentials and deficits of the processes. The findings identify the early involvement of stakeholders, interdisciplinary, simultaneous collaboration and transparency in communication and information as success factors. The findings were verified in the practitioners’ workshop, where as particularly important step for the implementation, the change of fee structure for architects and engineers (FSAE) and scope of services were identified.

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Keywords: Integrated Design; Collaborative Planning; Sustainability; Energy Efficiency

1. Introduction

The implementation of energy efficiency in the built environment is already embedded in the public policy – by the 2020 new buildings have to be realised as Nearly Zero Energy Buildings (EBPD, 2010). Numerous building

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certificates and initiatives in AEC industry call for life cycle optimisation and holistic approach for realization of sustainability aims. A shift from traditional, sequential design towards more integrated planning practice is has been recognised as a necessary step for achievement of resources and energy efficient built environment. Integrated building design (IBD) is advocated as suitable approach for achievement of sustainability aims. This method enables early collaboration of project stakeholders and therefore the performance-optimization in the earliest planning phase, which has the largest influence on the latter building performance. The interactions between project stakeholders on multiple levels (in virtual environment using ICT tools or in real environment in collaborative workshop setting), support in such way transfer of information of different richness-levels, creation of new knowledge, and therefore of innovation in a holistic manner (Fisscher et al, 2012, Dossik et al, 2012). The customary building certificates include the assessment of utilization of integrated planning, which is reflected in the relevant indicators.

AEC industry is much focused on regional or local level, and strongly constrained by its requirements and traditions, this especially being so in the Central European region with very strong engineering tradition largely relying on expertise of singular disciplines. A knowledge or experience in collaborative planning process for energy-efficient buildings using integrated design method is still largely lacking.

In order to gain knowledge on potentials and deficits of current planning processes for energy efficient buildings, and propose a framework for implementation of IBD in planning practice, we conducted multiple case study research of certified, best-practice energy-efficient buildings. Thereby the success factors, as well as improvement potentials and obstacles were identified through interviews with planning process stakeholders, observation and informal communication. The results were compared to the key performance indicators for integrated planning identified in the literature, which mostly relies on the concurrent engineering method. As final result, a guideline for investors, planners and public policy for IBD was developed.

This paper is structured as follows – after outlining the current shift in the planning practice from segmentation towards integration, in the second part we will briefly outline the development of integrated planning from its origin in concurrent engineering method. The current state of the art will be demonstrated; several industrial documents promoting IBD will be presented and discussed. We proceed with the presentation of the cases, research methods and assessed data in the third part, and present the results in the fourth part. We will conclude with discussion on necessary future steps for implementation of IBD in the planning practice in the fifth, concluding part.

2. Development of Integrated Planning Methods

A bulk of literature presents benefits of concurrent engineering method in the industry, as predecessor of integrated building design, however there is still little knowledge on actual planning and construction process for sustainable buildings using integrated whole building design.

Concurrent engineering (CE) as a method was originally introduced in the 1980ies with the major aim of increasing companies' competitiveness through reduction of the product development lead-time while simultaneously reducing costs and improving quality (Sohlenius, 1992). The method was developed to improve the time-to-market performance, as the product life-cycles were rapidly decreasing (Koufteros et al, 2001). In order to improve the success of the introduction of new products, the shift, from the traditional sequential succession of sub-tasks with a minimum of interaction between constituents of each sequence, towards integration of the conceptual design stage and process- and production- design phases was introduced (Solehnius, 1990). Penner and Winner define CE as: "The concurrent engineering can be defined as a systematic approach to the integrated, concurrent design of products and related process, including manufacturing and support. This approach is intended to cause developers to consider all elements of the product life cycle from conception to disposal, including quality, cost, schedule, and user requirements" (Pennel and Winner, 1989).

As the main pillars of CE the concurrent workflow, i.e. early involvement of participants and teamwork, can be identified (Koufteros et al, 2001, Valle and Vazquez-Bustello, 2009). The concurrent workflow enables overlapping of product- and process-design phases, the time of each activity is not necessarily reduced, but through overlapping activities the overall time is drastically decreased. Simultaneous design, prototyping and testing, so that manufacturability can be evaluated at much earlier stage, result with early detection of major failures of

conceptual design, reduced changes and shorter overall development times. Early involvement of constituents enables the maximization of information-input at the beginning of development, when opportunities are greatest, feedback from multiple sources can reduce information gaps and contributes to higher product integrity (Valle and Vazquez-Bustelo, 2009). Teamwork means that participants work closely together, bound through common goals, with a high degree of transparency, shared risks and rewards (Jassawalla and Sashittal, 1998), strongly supported by the computer and information and communication technology tools and platforms (Prasad et al 1998, Wang et al, 2002).

2.1. Integrated Design in the Planning Practice

Several AEC-industry planning guidelines introduce the integrated design method, based on concurrent engineering principles, such as for example Integrated Whole Building Design or Integrated Project Delivery. The New Zealand Ministry for the Environment proposed the ‘Integrated Whole Building Design Guidelines’ (IWBD, 2008), for better achievement of sustainability goals. This guideline perceives the traditional design process is seen as linear succession of different design tasks, where minimal interaction between design team members is possible due to fragmentation. The structure is front-loaded, which discourages the design team members’ involvement in later phases of construction, post-occupancy and feedback in the use of the building. The IWBD method is a holistic method, involving all stakeholders (planning team, users, tenants) from the early phases, which helps to recognize design opportunities, such as e.g. integrating the building services into the building structure. It is a design led approach, based on interconnectedness of the planning aims and life-cyclic view.

The innovative aspect of the ‘Whole Building Design’ method (Prowler, 2007) compared to CE is the consideration of sustainability issues. Achievement of sustainability goals, i.e. interests of ecology, economy and socio-cultural values, is only possible through collaboration of stakeholders representing their mutual interests, and in such a way different interests of sustainability.

Integrated Project Delivery (IPD) Guide (2007) by AIA is mainly efficiency driven, through time and cost efficiency, sustainability is seen mainly as energy-efficiency issue. It is, however, based on the same principles: mutual respect and trust in team work, mutual benefits and rewards, collaborative innovation and decision making, early involvement of key participants, early goal definition, intensified planning (increased effort in planning), open communication (no-blame culture), appropriate technology (open data exchange), organization and leadership (clearly defined roles).

Chachere, Kunz and Levitt (2004) work with the Integrated Concurrent Engineering Method (ICE) within a design-project class, which was developed upon NASA’s concurrent design approach, with the main driver of radical development-time reduction. They claim that the limitation for speed of engineering processes is the response latency – or the waiting time in the communication between two experts (engineers) for a problem solution. The main focus here is on development of project-management tools for the reduction of lead time and improvement of the reliability. The key performance indicators are similar to the one defined by IPDG or IWBD: Flat organizational hierarchies, clear and congruent team goals, collegial and respectful team culture, low process equivocality, complete team knowledge network, committed participant focus, rich communication media, support by information technology for modelling and visualization.

2.2. Integrated Design in the Building Certificates

Building certificates see as their main task the increase in construction or refurbishment rate of “green buildings” on the real-estate market as well as to promote optimization of building performance in terms of resources efficiency and minimization of emissions. Most of the certificates already incorporate the assessment of the integrated planning method, through explicit accreditation of credits. It can be noted that only LEED is lacking the explicit indicator for integrated planning, however IPD is recommended as project delivery method.

Table 1. Integrated planning as an indicator in building certificates

TQB (2013)	BREEAM (2013)	LEED (2009)	DGNB (2009)
B.1.2 Integrated Planning and Variant Analysis	Man 01 Sustainable procurement Project brief and design Integrated design process	ID Credit 2: LEE D Accredited Professional	Process Quality: Crit. 44 Integrated Planning
Next to the calculation of cost effectiveness, an integrated, network-oriented planning with compilation of different planning variants represents a relevant basis for quality of a building.	„From design brief stage the client, building occupier, design team and contractor (see CN2) are involved in contributing to the decision making process for the project. As a minimum this includes meeting to identify and define their roles, responsibilities and contributions during the following phases: Design, Construction, Commissioning and handover Occupation, i.e. up to and including post practical completion stage.“	Potential Technologies & Strategies Educate the project team members about green building design and construction, the LEED requirements and application process early in the life of the project. Consider assigning integrated design and construction process facilitation to the LEED AP.	Integrated planning team, Team-Qualification, Planning Process Guidelines, User Participation

3. Best-Practice Cases: Research Methods and Data-Assessment

In our exploration of the design and planning processes for the best-practice energy-efficient buildings, we applied the practice-oriented multiple case study (Eisenhard, 1989) employing descriptive research method (Dulk and Hul, 2008). The research methods involved open-ended interviews with planning process participants, observation and informal communication. Based upon this research, project stories were compiled to reconstruct the design and planning process of the cases.

The examined cases include five office buildings in Austria and Germany constructed in the period from 2007 till 2012, build as showcase energy-efficient buildings; four of the cases being certified either DGNB or TQB. The cases feature ambitious energy-efficiency aims, such as passive-house or even energy-plus standard.

Table 2. Cases: Five best practice energy efficient office buildings

	Building A	Building B	Building C	Building D	Building E
Planning period	3/2010-3/2011	2004-2006	3/2006-4/2007	2007-2008	12/2006-3/2008
Construction	7/2011 – 8/2012	5/2007-6/2008	4/2007-6/2008	4/2008-7/2009	3/2008-11/2008
Size BGF	9.125m2	11.363m2	6.955m2	18.600m2 office and production	3.033m2
Certification	TQB Energy Plus	TQB Passive House	Flagship Project for EnEff	DGNB Silver Flagship	DGNB Bronze
Ownership	Lease	Lease	Own Use	Own Use	Own Use
Number of Interviews/Who was interviewed	Investor, Architect, MEP eng., Structural eng., Energy Consultant	Investor, Architect	Architect, MEP eng Facility Management	Investor, Architect, MEP eng.	Project Manager, MEP eng.
End Energy Consumption	21kWh/m2 without PV	18,91kwh/m2	49,1 kwh/m2	64,2 kWh/m2	58kWh/m2

In order to capture different perspectives of planning process stakeholders, 19 open-ended interviews were carried out in the 2011 and 2012. The interview partners included investors, architects, structural and MEP engineers, facility manager and energy consultants. Through content analysis of the executed interviews (Bogner, 2010), the most often appearing statements in the interviews were identified and structured in the categories of success factors, optimization potentials and deficits of the best-practices. The analysis enabled comparison of the statements according to the profession (Table 3) and project-related (Table 4) comparison of the statements.

Table 3. Professions-related Interviews: Statements structured according to the profession and category: success factors, Optimization Potentials, Deficits

	Investor	Architect	Structural Eng.	MEP Eng.	Consultants
Success Factors	Early involvement of Planners, Consultants and Users	Interdisciplinarity/ Simultaneity	Transparent communication and information	Early involvement of Planners, Consultants and Users	Transparent communication and information
	Interdisciplinarity/ Simultaneity	Early involvement of Planners, Consultants and Users	Early involvement of Planners, Consultants and Users	Strong Involvement of Investor	Interdisciplinarity/ Simultaneity
	Transparent communication and information	Freedom of choice of planners	Interdisciplinarity/ Simultaneity	Interdisciplinarity/ Simultaneity	Early involvement of Planners, Consultants and Users
	Common aims	Transparent communication and information	Common aims	Flat hierarchy	Competences of stakeholders for „sustainable building“
	Optimization in Utilization Phase	Strong involvement of Investor	More freedom in choice of planners	Optimization in Utilization Phase	Regular/repeated cooperation
	Repeated/Regular cooperation	Professional management of communication	Trust	Transparent communication and information	Strong Investor, final decision maker
Optimization Potentials	Tools for decision support	Competences of stakeholders for „sustainable building“	Interdisciplinarity/ Simultaneity	Interdisciplinarity/ Simultaneity	Shift in planning priorities
	Transparent communication and information	Professional management of communication	Early involvement of Planners, Consultants and Users	Shift in planning priorities	Early involvement of Planners, Consultants and Users
	Early and joint aim setting (qualitative)	Shift in planning priorities	Better education/ Competencies in „sustainable building“	Transparent communication and information	Extended responsibilities of Investor
	Professional communication management	Early and joint aim setting (qualitative)	Transparent communication and information	Early involvement of Planners, Consultants and Users	More freedom of choice of planners
	Building Performance Optimization, Optimization in Utilization Phase	Holistic planning approach	Holistic planning approach	Expansion of Investors responsibilities	Better education in „sustainable building“
	Reduction of interfaces	Improvement of competencies in „sustainable building“	Reduction of interfaces	Reduction of interfaces	Business Advisers in Planning Phase
	Innovation-loss through inter-firm processes and communication	Wrong planning priorities	Lack of reliability (code of honour lacking)	Wrong criteria for formation/commissioning of planning team	Low flexibility level of planners
	Profit maximization as primary aim with large contractors (Claim Management)	Low competencies in „sustainable building“	Lack of trust	Innovation-loss through inter-firm processes and communication	Imprecise and belated definition of planning aims
Deficits	Conservative allocation of roles	Incompatible planning partners	Lack of Education/ Competencies in „sustainable building“	Belated involvement of planners and consultants	Belated involvement of planners and consultants
	Commissioning law	Low flexibility level of planners	Belated involvement of planners and consultants	Profit maximization as primary aim for large contractors (Claim Management)	Wrong planning priorities
	Knowledge gap (Pre-Competition/ Post-Competition)	Wrong criteria for formation/commissioning of planning team	Lack of knowledge on interdisciplinary collaboration	Wrong chronology in delivery of planning process	Lack of knowledge in „sustainable building“
		Commissioning law	Cost- and time pressure		Lack of guidelines for interdisciplinary collaboration

Table 4. Cases-related interviews: Positive and Negative Statements structured according to the case (building)

		Positive Statements	Negative Statements
Building A	Investor	General planner (GP) form enabled inter-firm problem solutions	GP - preconceived solutions delivered by GP Lack of creative discussion with Investor, nobody contradicts the investor in GP setting Energy-efficiency was not valued sufficiently by the competition jury Innovation loss through GP
	Struct. Eng.	MEP Eng. from the concept-phase Good communication/holistic thinking Kick-Off Meeting at the beginning Super Investor - mutual trust GP model: short routes	
	Cons.	No problems in communication	Planning team too large Many interfaces Research partners not committed No budget for team building
Building B	Inv.	Uncomplicated communication main topics in focus	
	Arch.	Early involvement of MEP Eng. 2-weekly Jour Fixe	MEP Eng. involved too late Architect and MEP hat not enough knowledge on innovative energy concepts Lack of tools for decision making support Difficult communication between disciplines due to the different vocabulary Monitoring should be scientifically assessed and evaluated
Building C	Inv.	MEP Eng. in concept-phase Strong involvement of Investor with MEP concept Good communication climate Strong engagement of single persons (MEP planners) Enabling of financial buffers in early planning phases Monitoring and Jour Fixe for optimization	Lack of innovation drive from total contractor (TC) and sub-contractors Construction failures Change in commissioning - change of planning partners Commissioning of total contractor down sided the quality Total contractor has exclusively economic interests
	Arch.	Holistic approach of project partners and MEP Eng. Life cycle oriented procurement (operation costs considered) Simultaneous planning, very intensive contact with planners Excellent communication with investor	Double-ended commissioning ends in poor performance TC hardly was involved in development of innovative concepts Fights between disciplines (Planning ambitions vs. Profit-orientation) Information break through commissioning of TC in the middle of the process Greatest difficulty - lack of skills on the TC side TC cost calculation based on standard values, instead of innovative construction
	MEP E.	Strong engagement of investor, visionary architect Intensive, early dialogue with architect, employment of cooling consultant Monitoring and regulation of building operation (on investor side) MEP Eng. before compilation of tender documentation in the team	Bad communication - blaming, claims TC identified as originator for bad communication climate TC has no understanding for innovative concepts Lack of commitment of the TC side

	Users involved in decision making process	Change of construction drawings after TC commissioning
Building D	High competences of architect, personal liking	Sometimes the things were discussed differently than they were later realised
	General planer -all disciplines in house	Would have made gold-certificate if certified from the beginning of the process, and not in Post-planning
	2 persons assigned for sustainability consulting	In important phases insufficient capacities on the investor phase
	GP experienced in "sustainable building"	
	Highly motivated MEP, motivation for the whole team	
	Kick-Off Weekend in the early phase	
	Planners and Investor align on personal base	
Arch.	GP has revealed the lacking planning aims by investor - positive, since re-start possible	
	Very intensive contact with investor	Investor did not deliver the client brief
	Trust in Investor and Team - act as one team	Unforeseen costs
Building E		Post-planning certification difficult
	Since all planners in house – early dialogue possible	Conservative role-assignment on the architect and engineers' sides
	User involved in conceptual planning	Sustainability criteria were not considered in the early stages
	Key to successful planning process early involvement of users and planners	
	Energy concept compiled in early cooperation with users and planners	
	Communication climate very good, everybody pulling together	
	Architect and Engineers working with same CAD software	
Inv.	Communication is the most important aspect, especially transparency	
	When commissioning TC, working together in the past is important for trust	
	Joint aim setting at Kick Off Meeting	
Struct. E.	Due to the former long lasting cooperation experience, very good cooperation and open communication	

4. Discussion of Results

Based upon the conducted interviews in combination with the analysis of project data and formal and informal communication, for the visualisation of results for each case a project story in form of flow-chart was compiled. The project story comprises important phases, milestones and disturbances, and significant statements of the stakeholders. The visualization through project story enables the comparison of the cases in terms of time, commissioning forms, disturbances etc.

On the example of the case D, the disturbance in the planning process was caused by the fact that investor missed delivering a client brief, and carried out an architectural competition without actual client brief. The problems related to the lacking of exact spatial and functional programme and floor-layout requirements became apparent after the predesign was completed. The client brief had to be commissioned, and the predesign re-worked, which caused a delay in the planning of four months, however has proved as very valuable for the overall project success, as the client expressed in the interview. "...the users and myself are very satisfied with the new building, despite the fact we had a few difficulties in the beginning to get used to it." And to the planning process: "Chronology went like this: got contract to do the job (lead the project), found the planner, the planner asked 'what do you really want?', went a step back, commissioned client brief with a consultant with whom we compiled a basic concept for the location. We have thought about some strategic decisions at that point. Important is, that step was initiated by us, not by the planner - the planner just asked what do we really want from the building?"

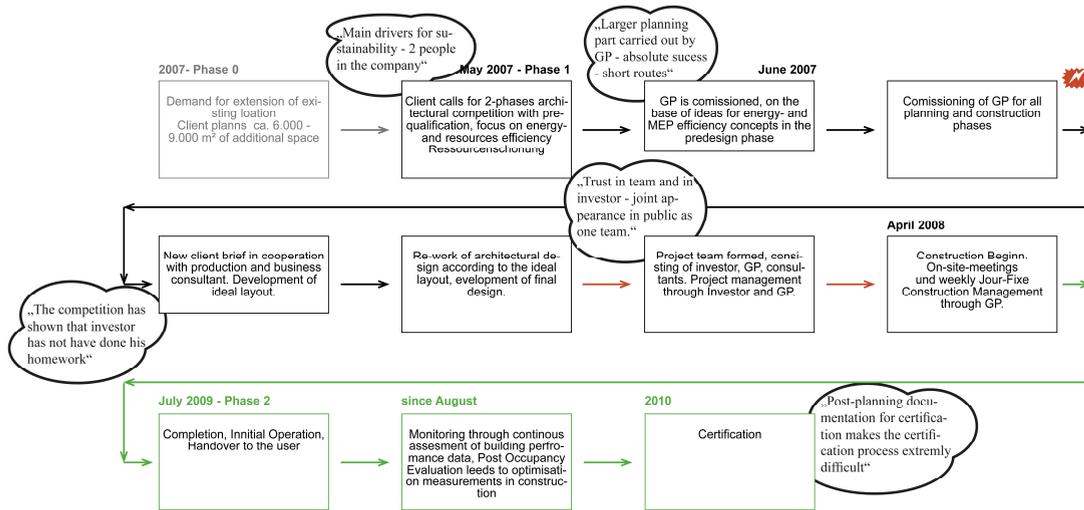


Fig 1. Project Story Case D

The results of the interviews imply on the crucial role of the investor, as driving force for the implementation of sustainability aims, but also for the overall project success. The **early involvement of stakeholders** is defined as success factor by all of the professions, together with interdisciplinarity/simultaneity and transparent communication and information.

There is no single criterion that all stakeholders would share when identifying the optimization potentials. The most shared criterion is optimization of transparent communication and information, of involvement of stakeholders in the early planning phases, and reduction of interfaces (shared in three professions out of five). There is also no single criterion that all stakeholders would share when identifying the main deficits. Belated involvement of planners and consultants is an aspect shared by three out of five professions. Many issues concerning the planning culture can be identified, such as wrong planning priorities, profit orientation, EU comissioning low, conservative allocations of roles.

Flat organizational hierarchies, clear and congruent team goals, collegial and respectful team culture, low process equivocality, complete team knowledge network, committed participant focus, rich communication media, support by information technology (IT) for modelling and visualization, as the KPIs identified for integrated concurrent engineering by Cachere et al (2004), are basically all to be found in statements of the interviewees; with one exception of the IT. There is a wish for tools for support of decision-making, however they have not been explicitly assigned to the IT tools. This can be explained through the fact that the implementation of BIM tools in Central Europe is much slower than the entry of CAD was (McGraw Hill 2010), especially in the years when the interviews were carried out. The analysis of the case-related statements reveals many more statements related to the communication (Good communication/holistic thinking), commitment (Strong engagement of single persons (MEP planners)), trust (Trust in Investor and Team - act as one team) and personal engagement (Highly motivated MEP, motivation for the whole team).

Even though four out of five projects were certified either through DGNB or TQB certificate, the positive impact on the certification on the promotion of integrated planning could not be identified. Even more so, the certification was perceived as hindering for the process, if carried out as back-end process.

The stakeholders, who reported the “integrated” practice, were practicing it due to the striving for innovation; personal commitment and trust in team, much more than imposed through the certificate. Despite the wish by in the first line planners (architect and structural engineers) on holistic planning approach and for interdisciplinary

collaboration by all stakeholders, the interviewees themselves state that there is a lack of knowledge how to actually do it: "...different know-how on inter-firm communication and qualifications of stakeholders, low understanding for interdisciplinary cooperation...", says the architect of the case B.

The EU commissioning low is mainly seen as obstacle for interdisciplinary planning, limiting the freedom in choice of the planners.

5. Future steps

The results compiled through case study research were presented for verification in the framework of workshop with 17 practitioners, including architects, clients, MEP engineers and energy consultants in a moderated round-table setting. The practitioners reported the necessity for changing the current fee structure towards support of integrated planning process, in alignment to e.g. Swiss fee structure SIA, including the new description of scope of services in integrated planning process. Further on, models for incentives for partnering such as shared risks and benefits should be adopted.

Even though the research on integrated building design has been on going topic in intensive discussion in the academic community, especially in the fields of collaborative planning in AEC industry (Dossick and Neff 2011, Dewulf and Kaderfors 2012) integrated project delivery (Owen and Prins 2010, Owen et al 2010) and project-organizations engaged in collaborative practice (Hartmann and Bresnen 2011, Love et al 2010) the scientific models have hardly found adoption in the planning practice.

The Australian collaborative commissioning model (alliancing) has often been quoted by the industry as successful model for the integrative, partnering approach in design and construction. Chen et al (2012) define as main governance mechanisms target cost arrangement, financial risk and reward sharing regime, transparent financials and collaborative multi-party agreement. They also identify informal governance mechanisms as leadership structure, integrated team and joint management system. Love et al (2011) develop risk/reward model for compensation alliance in civil engineering infrastructure projects. They conclude that sharing of risk/reward is crucial for project success when using alliancing. However the evaluation within this research was carried out for large infrastructural projects. The future research should test the transferability of the collaborative commissioning models on the Central European market for design and construction of buildings. In order to transform the AEC industry, the scope of services for professionals engaged in integrated planning process should be defined on public policy and fee structures level.

As final result, we propose the Guidelines for Integrated Planning (Kovacic et al 2012) for investors, planners and public policy, which describe the mechanisms for design of integrated design process, based on tangible and intangible tools. As tangible tools building certificates, building information modelling (BIM) and life cycle assessment with life cycle cost and benefits, post occupancy evaluation methods are introduced. As intangible tools, the basics of client brief (programming), choice of planning team, communication design and management, team-building, decision-making process and know-how transfer are described as guideline for application in integrated building design process.

As building information modelling tools are increasingly emerging on the Central European Market, our future research will be dedicated to the analysis of BIM supported planning processes in relation to the BIM potentials to support the integration in building design, planning and construction. The research should evaluate the triangulation of people-process-technology bound capabilities and its impact on successful integrated building design.

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References

- AIA (2007) Integrated Project Delivery: A Guide, American Institute of Architects California Council
- AIA (2009), Experiences in Collaboration: On the Path to IPD. American Institute of Architects California Council, 5
- Bogner, A. (2005) *Das Experten Interview*, VS Verlag für Sozialwissenschaften, Wiesbaden
- BREEAM (2013) BREEAM New Construction Non-Domestic Buildings, Technical Manual, BRE (Publisher), <http://www.breem.org/page.jsp?id=109>, last access June 2013
- Chachere J., Kunz J. & Levitt R. (2004) The Role of Reduced Latency in Integrated Concurrent Engineering. CIFE Working Paper #WP116, April 2009, Stanford University
- Chen L., Manley K. & Lewis J. (2012) Understanding Formal and Informal Governance on Infrastructure Projects, Technical report, Alliance Research Report
- Dewulf G. and Kadefors A. (2012) Collaboration in public construction—contractual incentives, partnering schemes and trust. *Engineering Project Organization Journal*, 4 (2), 240-250
- DGNB (2009), DGNB Handbuch Neubau Büro und Verwaltungsgebäude, Version 2009
- Dul J., Hak T. (2008) *Case Study Methodology in Business Research*, Amsterdam: Elsevier
- Dossick C., Anderson A., Jlorio J. Neff G., and Taylor J. (2012) Messy Talk and Mutual Discovery: Exploring the Necessary Conditions for Synthesis in Virtual Teams. Working Paper Proceedings, Engineering Project Organizations Conference Rheden, The Netherlands
- EBPD (2010) DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings
- Eisenhard K. (1989) Building Theories from Case Study Research, *The Academy of Management Review*, 4 (14), 532-550.
- Hartmann A. & Bresnen M. (2011) The emergence of partnering in construction practice: an activity theory perspective. *Engineering Project Organization Journal*, 1 (1), 41-52
- Fischer M., Stone M., Liston K., Kunz J., Singhal V. (2002) :Multi-stakeholder collaboration: The CIFE iRoom, International Council for Research and Innovation in Building and Construction, CIB w78 Conference 2002
- IWHBD (2008). Integrated Whole Building Design Guildelines .New Zealand Government, Ministry for the Environment, www.mfe.govt.nz
- Jassawalla A.R. and Sashittal H.C. (1998) An Examination of Collaboration in High-Technology New Product Development Processes. *Journal of Product Innovation Management*, 15 (3), 237-253
- Koufteros X., Vonderembse M. & Doll W. (2001). Concurrent engineering and its consequences. *Journal of Operations Management*, 19, 97–115
- Kovacic I., Achammer C., Müller C., Seibel H, Wiegand D., Sreckovic M., Glöggler J., Kösegy S. & Filzmoser M. (2012) Leitfaden für Integrierte Planung für Public Policy, Planer und Bauherren, Technical report, Reserach Project Co_Be, Neue Energien 2020
- LEED (2009), LEED® 2009 for New Construction & Major Renovations v3.0, available at: www.usgbc.org/leed , accessed June 2013
- Love, P., Davis, P., Chevis, R., and Edwards, D. (2011). "Risk/Reward Compensation Model for Civil Engineering Infrastructure Alliance Projects." *J. Constr. Eng. Manage.*, 137(2), 127–136.
- McGraw Hill (2010) SmartMarket Report. The Business value of BIM in Europe
- Owen R., Amor R., Palmer M., Dickinson J., Tatum C.b., Kazi A.s, Prins M., Kiviniemi A., East B. (2010) Challenges for Integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, 6, 227-231 232-240
- Pennell, J.P. & Winner, R.I. (1989). Concurrent engineering: practices and prospects. in: Global Telecommunications Conference, 1989, and Exhibition. Communications Technology for the 1990s and Beyond. GLOBECOM '89, IEEE. 1, 647 – 655
- Prasad B., Wang & F. Jiati Denget J. (1998) A Concurrent Workflow Management Process or Integrated Product Development. *Journal of Engineering Design*, 9 (2), 121-135
- Prins M. and Owen R., (2010) Integrated Design and Delivery Solutions, *Architectural Engineering and Design Management*, 6, 227-231
- Prowler D. (2007) Whole Building Design. <http://www.wbdg.org/>
- Sohlenius G. (1992) Concurrent Engineering. *CIRP Annals - Manufacturing Technology*, 41(2), 645-655
- TQB (2013), Total Quality Building, Österreichische Gesellschaft für nachhaltiges Bauen, <https://www.oegnb.net/tqb.htm>, last accessed June 2013
- Valle S. & Vazquez-Bustelo D. (2009) Concurrent engineering performance: Incremental versus radical innovation. *Int. J. Production Economics*, 119, 136-148
- Wang L., Shen W., Xie H., Neelamkavil J., Pardasani A. (2002) Collaborative conceptual design – state of the art and future trends, *Computer-Aided Design*, 34, 981-996

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Designing the planning process for sustainable buildings: from experiment towards implementation

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Designing the planning process for sustainable buildings: from experiment towards implementation

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Buildings play a crucial role in the achievement of sustainability aims, due to the large energy consumption for operation and the related CO₂ production rate. Generally prescriptive-normative strategies are being used for the increase of building performance in terms of energy efficiency. The focus is mainly upon the development and implementation of new technologies for energy-efficient building services and hull together with the improvement of calculation methods. Little effort has been invested into the rethinking of the design and planning process for sustainable buildings which are still planned in a traditional manner, where planning tasks are broken down into sequenced, highly specialized disciplines. The practitioners are aware of the need for a paradigm change in the planning culture and are asking for methods towards a more integrated, collaborative planning practice. We argue that for the achievement of sustainability aims more than energy-efficient technologies coupled with a prescriptive strategy are necessary, and we advocate a shift towards people (the planning-process-stakeholders) as carriers of sustainability. This paper focuses on the development of a holistic, life-cycle oriented planning strategy, which enables knowledge transfer from phase to phase, as well as the creation of common new knowledge. Critical herewith is the collaboration of all planning-process stakeholders (planners, users, managers) from the early planning phases on, since those are crucial for the latter building performance. In order to identify and evaluate the advantages of the integrated planning practice, we have conducted a role-playing experiment simulating integrated and sequential planning processes for an energy-efficient structure. The experiment was part of a research project Co_Be (Cost Benefits of Integrated Planning) at the Vienna University of Technology. The experiment identified efficiency, team- and process-satisfaction, as well as more balanced stress and conflict levels of the integrated planning teams as significant advantages of this treatment. The results of the experiment were verified within the stakeholder feedback-workshop with practitioners. There the need for the development of mechanisms supporting the design of interdisciplinary communication and knowledge creation as well as knowledge management within the integrated planning processes, was identified.

Keywords: Energy-efficient buildings, exploratory research, integrated planning, knowledge transfer, project organizations.

Introduction

Buildings consume 40% of the total energy within the EU for heating and cooling, and are responsible for about 30% of the energy-related CO₂ emissions (Balaras *et al.*, 2007). As such, buildings offer a major potential for the achievement of the EU 20-20-20 aims: reduction of greenhouse emissions by 20%, 20% of renewable energies in total energy

consumption, and the rising of energy efficiency by 20% until 2020, compared to the 1990 levels (EC, 2010). The new European Energy Performance of Buildings Directive (EPBD, 2010) prescribes that by 31 December 2020, all new buildings are ‘nearly zero-energy buildings’. Moreover, the development of new technologies based on renewable energy such as solar, geothermal and wind energy, allows the design and construction of buildings that even produce

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energy: buildings as ‘power plants’, which are, next to the smart grid and energy storage, the main elements of the European ‘post-carbon-society’ (Carvalho *et al.*, 2011).

The current climate protection policy, based on the prescriptive approach in combination with a technology-push is still failing to achieve the actual overall minimization of energy consumption (Marsh *et al.*, 2010; Oreszczyn and Lowe, 2010). In terms of sustainable buildings, the focus in Central Europe has largely been upon the development of energy-efficient HVAC (heating, ventilation, air-conditioning), improvement of building hull technologies and on the increase of thermal insulation mostly through polystyrene-core-based ETICS. This approach is reaching its limits—numerous rebound effects have been observed as well as difficulties with operation and management of such buildings (mold, increased electricity consumption, etc.) (Renders, 2012). The need for a change of the way in which buildings are designed, constructed and operated has increasingly been reported by the planning practice and research. An improved planning process where interdisciplinary work and knowledge bundling in the early planning phases, together with the involvement of users and the know-how transfer from the planning into the operation phase, would enable the development of customized, more sustainable solutions.

Little effort has yet been invested into the optimization of the design-, planning- and operation-management process for sustainable buildings on part of the public policy.

The Central European planning practice, based on the long tradition of high engineering and technological skills, is reflected in a very high quality of architectural detailing and implemented HVAC technologies. However ‘Nearly-zero-energy’ buildings are still designed and planned in a traditional, sequential manner where architects, engineers and project managers often consider themselves as enemies, instead of team members. Therefore, a change in the planning culture towards more participative and collaborative planning practices in order to meet the challenges of not only designing, but actually obtaining and maintaining a sustainable built environment is necessary.

The achievement of sustainability aims requires a shift from the technology- and norm-based increase of energy efficiency, towards people as the carriers of sustainability. Thereby people—the planning-process-stakeholders—are considered to be designers, engineers and constructors, but also users and managers of energy-efficient, sustainable buildings. The collaboration of stakeholders from the early design stages onwards not only contributes to the balance between economic, ecological, social and institutional dimensions of sustainability (Spangenberg and Bonniot,

1998) which are reflected in different interests of the stakeholders (Bal *et al.*, 2012), but also to the appropriate and motivated use of innovative technology and change towards a more sustainable life style.

In this paper, we argue that successful sustainable buildings can only be realized through more integrated and life-cycle oriented design and planning processes. We also argue, that one of the major problems of current planning practices is the problem of efficient knowledge transfer and knowledge management in multidisciplinary project teams (e.g. architects, clients, HVAC engineers, energy consultants), especially due to the fact that on the one hand, knowledge is accumulated and embedded in the processes of the organizations itself and on the other hand in the individual capabilities of the people working in these projects. Therefore, strategies for an efficient interdisciplinary knowledge transfer and communication design within the integrated planning process are necessary. Based on previous findings, we argue in this paper that the integrated planning method supporting the continuous use of social (Javernick-Will and Levitt, 2010) or high-information-rich knowledge-transfer mechanisms (Lim and Benbasat, 2000; Buchel and Raub, 2001; Sexton *et al.*, 2003; Vickery *et al.*, 2004) is more suitable for the transfer of complex, respectively, tacit knowledge which is difficult to codify, as it is in the case of quantitative and qualitative planning aims for sustainability.

To evaluate the effects of the integrated design and planning methodology and to compare them to those of a traditionally sequential planning process, we designed and conducted a role-playing laboratory experiment. This exploratory study was carried out within the research project ‘Co_Be’ (Cost Benefits of Integrated Planning) at the Vienna University of Technology and funded by the Austrian Climate and Energy Funds within the programme ‘New Energies 2020’. The cooperation of the project partners from three different faculties (Civil Engineering, Architecture and Mechanical Engineering), reflects three main professions involved in the planning process (architecture, structural and mechanical engineering) and it brings different professional views on the building design. The different perspectives were found to be helpful in the latter design of the role-playing experiment, which was based on a planning-process simulation, involving 160 students. After the qualitative (student feedback-workshop) and the quantitative (measurement of efficiency and productivity, satisfaction, stress and conflict levels) evaluation of the experiment, the results were presented and discussed in a feedback-workshop, involving 17 professionals (architects, clients, HVAC engineers, energy consultants). The feedback-workshop identified the need for a methodical design of the communication-processes and the organization of integrated

planning teams (defining who does what and when) as well as the necessity for efficient knowledge transfer and knowledge creation methods as being major issues towards a paradigm change of the planning practice.

The paper is organized as follows: We start by outlining the problems and the challenges of the current planning practice; we continue by reviewing and discussing the relevant literature, followed by the empirical research (experiment design, treatments, research methods and data gathering) and the presentation of the evaluation and the experiment-results. We continue with the discussion of the results and finish with the conclusion and implications for future research.

Points of departure

The issue of increased complexity in planning and construction has already been identified by researchers in the 1980s and 1990s. (Baccarini, 1996; Doyle and Hughes, 2000). The introduction of energy- and resources-efficient buildings, the increase in related regulations and norms, the sharpening of building codes, as well as the rising demand for building certificates such as LEED, BREEAM or DGNB are some of the factors adding to the complexity of the planning process, as reported by the planning practice. Further on, a large number of planning-process participants as well as the employment of different professional languages and new tools contribute to the rising complexity of the design, planning, construction and operation of buildings.

In comparison to construction and construction management, which have experienced large progress since the Second World War through the development of different procurement models—such as design and build, built-operate-transfer, design-operate-build (Mills and Glass, 2009), and cost monitoring methods, as well as of new materials (thermal and insulation, vapour sealants) and HVAC technologies, the design process is experiencing a very slow change (König *et al.*, 2009). Even though the expectations on building performance have significantly risen, the buildings are still planned in the traditional, sequential planning method. The specialized disciplines work in a series of consequent steps, mostly starting with architectural design, followed by structural calculation and finally the HVAC engineering reacting to the already pre-defined setting.

Due to the historic separation of disciplines (architecture, structural design, HVAC engineering, project management) and the fragmentation of the planning process into singular problem-solving tasks, a holistic view of the building as an entity is lacking, as well as the common understanding of the planning aim. The importance of the early planning stage has often been

stressed in the literature (Pena and Parshall, 2001; Mendler *et al.*, 2006), as the stage where planning aims and vision statements are set and crucial design-decisions which will be influencing the latter life-cycle building performance are met.

Especially important are the early planning phases for the life-cyclic performance of energy-efficient buildings, since here the crucial parameters determining the life-cycle costs and energy consumption, such as building orientation and form of building hull are set. Currently, the disciplines having actual knowledge on these parameters such as HVAC engineering and facility management are predominantly absent from the early planning phases and can, therefore, only react instead proactively contribute to the building-optimization. In order to provide, share and exchange knowledge, but also in terms of cost-efficiency, all planning-process-stakeholders should be involved in a collaborative manner in the early planning stage (Figure 1). The buildings do not perform in the way that they were designed; there are large differences between planned and measured energy consumptions (Torcellini *et al.*, 2006). It would be advisable to actually involve a participant familiar with the building-operation and operation-monitoring from the pre-design stage on. Users are seldom part of the planning process and mainly poorly informed about the proper use of the building (Crosbie and Baker, 2010; Gupta and Chandiwala, 2010). The mentioned issues also imply a massive loss of knowledge due to the sequential process as well as gaps in knowledge transfer among planners, which is even more prevalent when going from the planning into the operation phase.

The integrated planning method has been advocated as the more suitable method for the design and planning

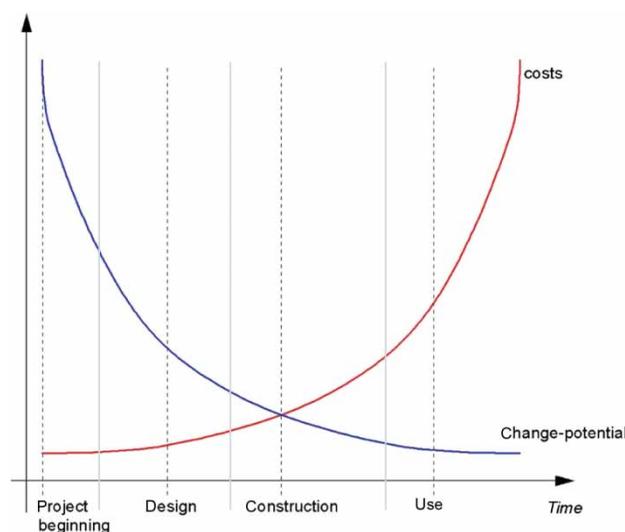
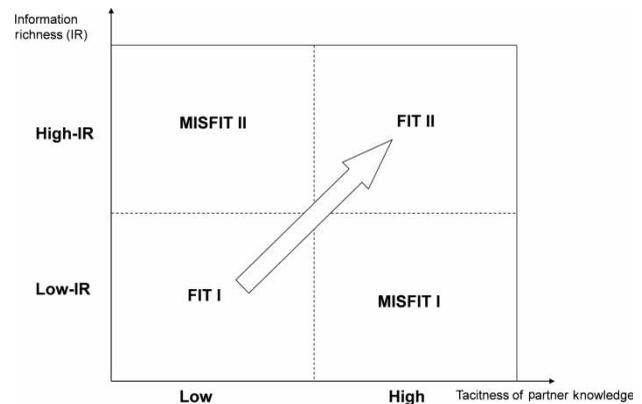


Figure 1 Interdependency of change possibility and cost development in time

of sustainable buildings (van Aken, 2003; von Both and Zentner, 2004). It empowers the collaboration of the largest possible number of stakeholders from the early design stages and it enables the knowledge transfer and new knowledge creation from the design into the operation phase.

A significant amount of research already exists concerning the tools for the support of integrated planning, such as building information modelling (BIM), LCA (life-cycle assessment) and LCC (life-cycle costing) tools. The BIM technology has the largest potential to crucially revolutionize the planning practice through its intrinsic integrative character; however it requires a high level of technical expertise and the reorganization of planning networks and organizations (Prins and Owen, 2010). The research shows, that the relatively slow BIM-adoption in practice is not exclusively bound to the issue of technology and software-interoperability, but much more to the necessity for redefinition of work procedures and the roles of the planning participants in the planning process, involving BIM technology (Kiviniemi *et al.*, 2008). It can be concluded, that the main emphasis concerning the design of sustainable buildings was on the development of technology, as well as optimization- and calculation-methods and tools; however gaining the knowledge about the design of integrated planning processes was largely neglected.

Integrated planning methods involve multidisciplinary project teams, who are simultaneously collaborating in all phases of the planning process. It is, therefore, necessary to look at the process of knowledge transfer between team members and in a further step at the creation of new knowledge as well, because the collaborative nature of multidisciplinary project teams proves to be essential in creating new knowledge (Fong, 2003). The already mentioned complexity in the planning and construction process of energy-efficient buildings requires social knowledge-transfer mechanisms (Javernick-Will and Levitt, 2010) or high-information-rich transfer mechanisms (Daft and Lengel, 1984; Vickery *et al.*, 2004) because they are more suitable for the transfer of knowledge which is complex and thus tacit, like in the case of quantitative and qualitative planning aims for sustainability. Referring to the knowledge-based view (Nonaka, 1994; Grant, 1996; Zach, 1999), the use of high or low information knowledge-transfer mechanisms is determined by the degree of tacitness of the partner-specific knowledge (Figure 2; Srećković and Windsperger, 2011, p. 303). ‘Tacit knowledge is extremely difficult to transfer without... teaching, demonstration and participation’ (Teece, 1985, p. 229). Starting with the information richness (IR) theory in the 1980s (Daft and Macintosh, 1981; Daft and Lengel, 1984, 1986; Daft *et al.*, 1987; Trevino *et al.*, 1987; Russ *et al.*, 1990; Sheer and Chen, 2004) and the recent



LOW-IR: Postal mailings, documents, fax, email, intranet, chat, online forum, newsgroups
HIGH-IR: Seminars, workshops, committees, meetings, video conferences

Figure 2 Relationship between knowledge transfer mechanisms and knowledge attributes

studies on new electronic communication media (Lim and Benbasat, 2000; Buchel and Raub, 2001; Sexton *et al.*, 2003; Vickery *et al.*, 2004), effective information and knowledge transfer requires a fit between task ambiguity/equivocality and ‘richness’ of the communication media. According to the mentioned research, four attributes of the communication mechanism—feedback capability, availability of multiple cues (voice, body, gestures, words), language variety and personal focus (emotions, feelings)—define IR. Explicit and thus codifiable knowledge is easily transferred with written documents or low IR-mechanisms, such as manuals, reports, databases, written instructions and electronic media. Tacit knowledge needs communication media with a relatively higher degree of IR, meaning face-to-face interactions and team-based mechanisms, such as meetings, trainings, seminars, workshops, visits, video conferencing.

Javernick-Will and Levitt (2010) examine the methods firms engaged in international projects use to transfer institutional knowledge. They define two primary types of knowledge transfer methods: formal (project databases, reports, procedures and processes, Intranet) and social (meetings, teleconferences, reviews, personnel transfer, personal discussions). Transfer methods are classified as formal when the processes rely on codified, explicit knowledge, and as social when they require personal interaction to transfer the knowledge. They state that the frequency of use of social methods decreases with more explicit and more easily codified knowledge.

Experiment design

The integrated planning practice in construction has been the subject of research in several comparative studies based on a workshop-setting. Zeiler and

Savanovic (2007) have started a workshop-series with practitioners in order to test the so-called morphological overviews—methods for the support of idea generation and evaluation within interdisciplinary teams—in various treatments. However, not the influence of the treatment on the design outcome was evaluated, but the number of generated alternative solutions. Kolarevic *et al.* (2000) tested the synchronous *vs.* asynchronous design cooperation using a specialized software (Virtual Design Studio), however within mono-disciplinary teams of students of architecture.

Ramalingam and Mahalingam (2011) designed an experiment involving geographically distributed students from India and USA, who collaborated in a virtual environment in order to create a design- and organizational-model of a construction project in the USA. The study implies the necessity of both technical as well as cultural (social) bounding elements (face-to-face communication) for project success and effective team performance. Dossick and Neff (2011) observed the collaboration of several teams on three real projects using a BIM-technology-supported design process. They concluded that technology can even hinder the innovation of the design process through a too rigid corset of workflow and knowledge exchange, hindering the exchange of tacit, informal knowledge. Their concept of ‘messy talk’—the informal, unstructured information exchange as often practised in architecture and construction engineering is tested within a student experiment, where geographically distributed teams work on a project in a virtual environment. They conclude that ‘... messy talk requires both the flexible, active and informal setting described in the 2011 study as well as mutual discovery, critical engagement, knowledge exchange, and synthesis’ (Dossick *et al.*, 2012).

Further examples of process-evaluation as a practical case study research are to be found in the research of the BIM-supported planning process and integrated project delivery (IPD). Rekola *et al.* (2010) carried out a case study of BIM and IPD implementation in the planning process for an university building, where an evaluation-framework of technology-, process- and people-bound problems and benefits was developed. The process is described by workflows, timing, procurement, contracts; people are related to competences, skills, knowledge and communication, and technology to software (tools). Their findings imply that the slow implementation of BIM and IPD in the planning practice originates in the lack of the development interplay of technology, people and processes, whereas singular aspects are well researched and developed. ‘Utilizing BIM efficiency requires tight integration of the project network to the project right from the beginning’ (Rekola *et al.*, 2010, p. 276).

In our presented research in this paper, we will primarily focus on the influence of the sequential and integrated planning practice on the process- and people-bound problems and the benefits arising within interdisciplinary planning teams.

Treatments

The role-playing experiment simulated two treatments—the sequential (SP)- and integrated (IP) planning—for a sustainable, energy-efficient structure. We decided to conduct a laboratory experiment with student participants to gather large amounts of data in controlled conditions, so that significances and differences can be assigned directly to the treatment (planning methodology). The experiment was set up as a student competition within the university course ‘Building Process Management’ for students of the fourth semester of civil engineering, and students of architecture in higher semesters. In this way, the students were motivated to participate by both credits and with monetary rewards (prizes) for the competition-winners in each treatment.

The students were assigned to design a self-sustained, energy-efficient, temporary smoothie-bar, built out of renewable materials (wood) in interdisciplinary teams. The interdisciplinary teams included four roles: (i) client, (ii) architect, (iii) engineer for structure and HVAC and (iv) the business consultant. A total of 160 students were distributed into one of the two treatments (each consisting of 80 participants) according to the subsequently described control-procedure. Within each treatment, the students were assigned randomly to one of the 20 teams and one of the four roles.

To ensure the comparability of all the results, two interventions were undertaken. Firstly, in order to ensure equal competences and social skills of the teams, the distribution of students into the two treatments was based on the information collected with a pre-questionnaire. The inquiry included information about their demographics (age, gender), education (polytechnic graduation, semester of studies) and professional experience in months defined with a full-time equivalent. We identified participants with the highest similar characteristics in these measures and then assigned one of them to the IP and the other one to the SP-treatment randomly by a coin toss. (Kovacic *et al.*, 2011) Secondly, to provide the same level of information for all the teams and prohibit the use of Internet and electronic devices, all the teams participating in the experiment were provided with the following handouts: product information sheets, tables for the dimensioning of structure, tables for the calculation of solar gains and energy consumption of devices, calculation sheets for the business plan and return of investment (ROI)

calculation. The assignments were also turned in on the provided standardized and pre-formatted sheets—a project map.

The laboratory experiment took place at the University for one whole day from 8.00am until 5.00pm. After a general briefing in the morning, the teams were split into two treatments: sequential planners (SPS) and integrated planners (IPS). The tasks of each role were defined as follows:

- (1) Client: briefing of the team in IP-treatment, or briefing of the architect in SP-treatment; coordination, cost calculation, advertising strategy, responsible for turning in the assignment
- (2) Architect: design of the smoothie-bar, compilation of drawings (floor-layout, sections, typical façade, axonometric drawing, construction drawing)
- (3) Engineer: dimensioning and calculation of structure, energy-concept, calculation of energy demand and solar earnings
- (4) Business Consultant: business plan, ROI

The IPS were grouped together in working booths, working on their given assignment simultaneously in the team setting.

In the SP-treatment, the assigned roles were grouped together in separated rooms (e.g. all architects), working on their assignments in a consecutive manner, based on a temporal scenario: the client briefs the architect, the structural and HVAC engineering concept may follow only after the architectural concept is approved by the client, the business consultant may be contacted only after the complete structure is approved by the architect. In this consecutive work setting, the intervention of the business consultant would probably require a redesign, through the input of completely new information about the business process, which the rest of the team was lacking. In conclusion, in the SP-treatment only two disciplines (roles) were allowed to communicate/meet simultaneously at all times to guarantee a sequential cooperation of the SP teams.

Since the total overall time was kept equal for all teams (7 h) in order to measure and compare the task-related productivity times, the students of both treatments were given the additional task of reading and reviewing scientific papers which had to be done in the non-productive times (when waiting for the design or after the project completion).

Research methods and data gathering

The experiment primarily aimed at answering the question of influence of the treatment on the design quality which was defined by the following pre-set criteria: formal design (aesthetics), construction- and

cost-efficiency, implementation of renewable energies and business plan. We also assumed that due to the support of high-information-rich or social mechanisms for knowledge transfer (Javernick-Will and Levitt, 2010) which were applied (meetings, personal discussions), and the fact that IPS were grouped together in working booths and worked on their given assignment simultaneously (which meant immediate communication and interdisciplinary knowledge transfer during the whole experiment) that the integrated treatment would have a significant impact on the design of a sustainable built structure. Further on, productivity and efficiency of the roles and teams depending on the treatment, conflict and stress levels, (self-reflective) satisfaction with the process results, collaboration and team functionality were measured.

The compilation and evaluation of the collected data was carried out within the framework of the Master-Thesis of C. Brauner and B. Kallinger (Brauner and Kallinger, 2011) at the Vienna University of Technology. The scope of the gathered data and the employed methods of evaluation were as follows:

- Evaluation of the jury-rating of the student competition, impact of the design quality
- Measurement of productivity
- Measurement of stress and conflict levels
- Measurement of process-, result-, collaboration-satisfaction and team functionality

The assignments, which were turned in on standardized project-maps were rated by an impartial jury (experts from the practice) with points from 1 to 10 for each ranging category: *design, construction, energy efficiency, cost-efficiency, overall impression*. The assignments were anonymized for the jury-rating by the means of a hash-code in order to prevent prejudice against a treatment. The advantage of this method lies upon the multi-subjectivity, which eliminates or minimizes the personal preferences or subjectivity. The aim of the competition was also gaining more insight into the impact of treatments on the design-performance in ranging-categories, as well as on the overall design-performance.

Productivity was measured through timesheets where each role (participant) was recording own workflows as the time spent for the role-related tasks. This enabled the comparison of treatments depending on the *productivity for each role*, as well as the *productivity-comparison of roles within each treatment*. For the evaluation of timesheets and the workflow analysis, the ANOVA method (group means according to treatment) was used. The hypothesis states, that the choice of the planning method influences the role's task-distribution within the team. Further on, productivity was analysed through the measurement of the productive time

against the total-time pro quarter. The hypothesis is that the choice of the planning method has an influence on the productivity of the roles within the team.

A crucial question aimed answering was which treatment was faster in completing the assignment (in terms of efficiency). The timesheets with the coordinate system for the measurement of perceived *stress and conflict levels* (scale from 0 to 9) were filled out by all participants, and enabled an exact allocation of stress and conflict to the time of the day, but also the comparison of stress levels within the team.

For the evaluation of conflict and stress levels, the statistic method of the Pearson-correlation coefficient was used. The hypothesis states that the planning method impacts the stress level, especially in the beginning and in the end phase. Further on, an impact of the treatment on the conflict level should be identified. Analysis of levelled stress within the teams should be compiled (high levelling is positive, low levelling within a team is negative).

Through (self-reflective) post-questionnaires, the participants were asked to reflect on constructs in categories *process-, result-, collaboration-satisfaction and team functionality* for the comparison of the overall satisfaction between the two treatments.

For the evaluation of satisfaction and team functionality, the ANOVA method was applied. Each construct was measured with four items on a Likert scale from 1 (very bad) to 5 (very good).

Evaluation and results

The evaluation of the jury-rating of the student competition shows that the impact of the treatment has not been significantly proved with the competition results. The strongest difference-tendency (between SP and IP) was found in the criterion of cost-efficiency, slightly benefiting the SP, however statistically irrelevant. In all other categories, there is no statistical relevance that would identify the treatment-impact on the category of design, construction, energy efficiency or overall impression.

The evaluation of productivity was carried out allocating working times for role-related tasks for each role depending on the treatment, as well as for the productivity of roles within the treatment.

The IP-Clients (Figure 3) saved time on meetings and used this gain predominantly for cost calculation (+1.38 h compared to SP) and the marketing strategy concept (+0.42 h). It was confirmed, that there is a significant influence of the treatment on productivity—the SP-Clients used more than 2.5 h on meetings and communication; whereas IP only 1.75 h. IP-Clients had explicitly more time to dedicate themselves to

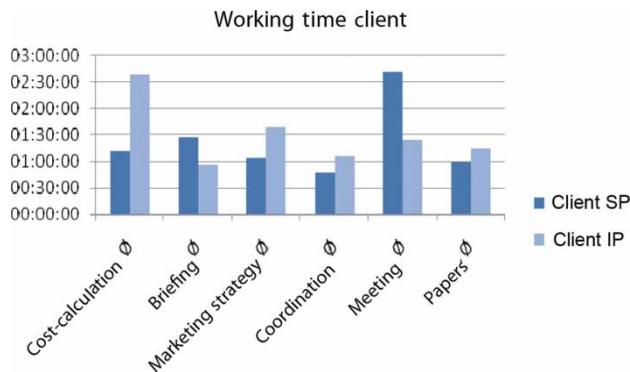


Figure 3 Evaluation of productive working time for client

assignment-relevant tasks, such as cost calculation and the marketing strategy development.

For the roles of the architects, the most significant difference between the treatments is visible again in the time used for meetings and discussions, benefiting the IP-Architects, who used this time for design and drawing (Figure 4).

The SP-architects needed on average 73 min more for meetings and discussions, whereas the IP-architects have used this time predominantly on drawing (+0:52) and some of it on design. A direct correlation of treatment-impact on time spent for the design-task could not be established.

The productive-time-treatment-related differences of Engineers (Figure 5) are not as striking as for the roles of Clients and Architects. The amount of time used for the structural concept differs insignificantly, however much more so for the time used for the compilation of the energy-concept. The category of the energy-concept and the calculation of demand and earnings are the only categories where significance can be allotted to the IP-treatment.

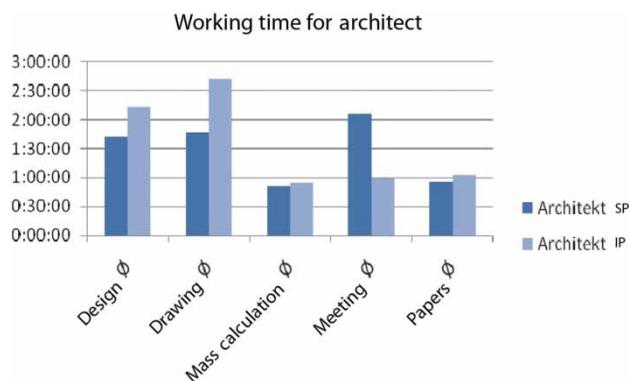


Figure 4 Evaluation of productive working time for architect

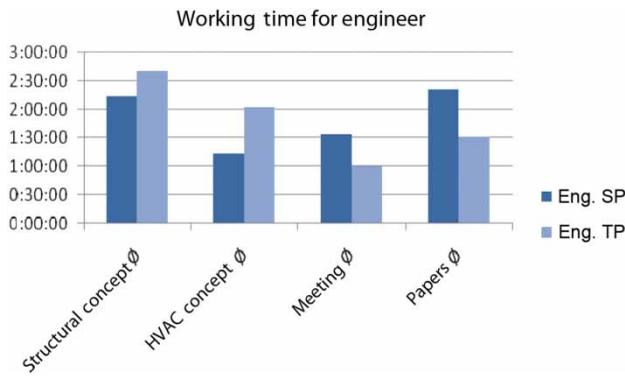


Figure 5 Evaluation of productive working time for engineer

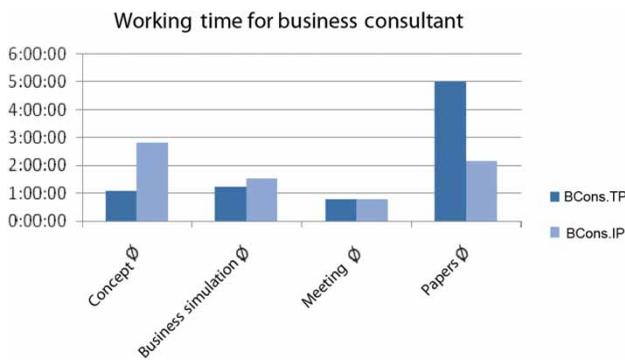


Figure 6 Evaluation of productive working time for business consultant

The treatment-impact on the role of the Business Consultant (Figure 6) was explicit. Whereas in the IP-treatment, this role was present from the start and could proactively collaborate on the assignment, in the

SP-treatment, he was often consulted towards the end of the experiment, after being occupied with the paper reviewing and not assignment-relevant tasks for 5 h (of the total 7 h).

It can be concluded, that the time that a Business Consultant was able to use for the compilation of a business plan highly depended on the treatment. In the IP-treatment, the compilation occurs in a collaborative process, and in the SP-treatment, it is corrective due to the late involvement which inevitably leads to change management for the process re-designing.

The analysis of the productive-role-related working time within treatments shows, that the highest workloads are attributed to the roles of the Architect and the Client in both treatments, and to the Architect even more so in the integrated planning treatment (Figures 7 and 8).

The analysis of overall productivity showed that the IPS had significantly more productive time than the SPS—23 h vs. 19 h. This originates from the fact that the IP-teams were in possession of more productive time from the start by having the Business Consultant in the team.

SP-teams however, were able to complete the assignment with similar success although having significantly less productive time; which was also confirmed by the competition results. In terms of efficiency, IPS were able to finish the assignment on average 24 min earlier than the SPS.

The hypothesis that the type of treatment has an impact on the conflict and stress level was confirmed. The SP-treatment displays higher conflict levels especially in the end phase (Figure 9).

The stress levels in the SP-treatment are not balanced between the roles, contradictory to the IP-treatment, where there is equal distribution of stress across all roles. Especially affected in the SP-treatment is the

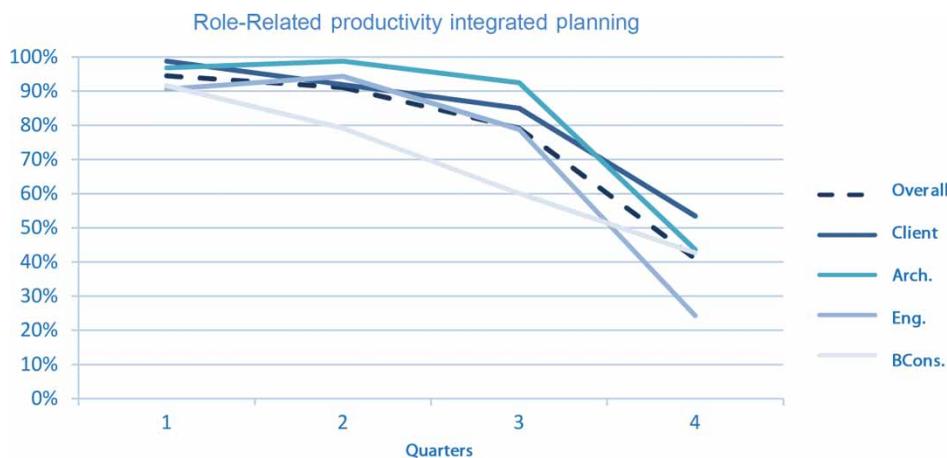


Figure 7 Role-related productivity for IP



Figure 8 Role-related productivity for SP

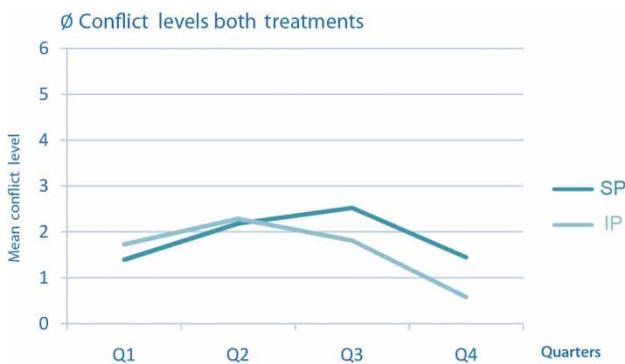


Figure 9 Comparison of conflict levels for SP and IP

role of the Client, whereas in the IP-treatment the Clients' stress levels are in the lowest area.

As Figure 10 shows, in the category 'process-satisfaction' no statistically significant group difference

between the SP- and IP-treatment was proved. The results of the category 'collaboration-satisfaction' show that participants in the IP-treatment were significantly more satisfied with the collaboration than participants of the SP-treatment. This proves that the collaboration-satisfaction is highly dependent on the choice of the planning methodology. The evaluation of the experiment-results demonstrates that especially in the case of Architects and Business Consultants the collaboration-satisfaction is significantly higher in integrated planning.

Similarly, the evaluation-results of the category 'team functionality' show that participants of the IP-treatment were significantly more satisfied than in the SP-treatment. When comparing all four roles, again Architects and Business Consultants showed significantly more satisfaction with the integrated planning practice. In the category 'result-satisfaction', no statistically significant group difference between the SP- and IP-treatment was proved.

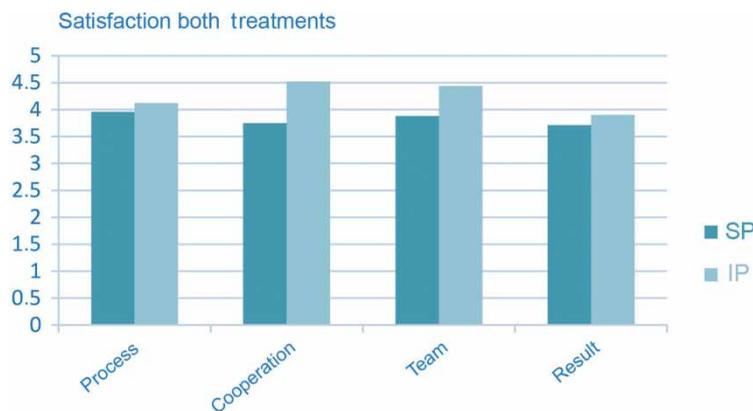


Figure 10 Comparison of process, cooperation, team and result satisfaction for SP and IP

Discussion of results

Initially, the focus of our research was the student competition from which we hoped to gain explicit results in terms of the treatment-impact on the design quality and advantages of the integrated design process for energy-efficient, sustainable buildings. The competition results, despite the granular categorization in four main categories and overall impression, did not show a statistical significance concerning the impact of a specific treatment on quality of design or the energy-efficiency concept. Concluding from these findings, an implication for future research would be a closer data analysis carried out with the aim to identify the factors contributing to the relatively good performance of sequential planners.

The measurement of productivity (time used for tasks) shows the highest treatment-related differences for the roles of the Clients and the Business Consultants, benefitting the IP-treatment. Further on, the IP-teams were able to focus on the assignment-relevant core tasks, such as drawing, cost calculation and the energy-concept, mainly due to the significant time-savings during the communication- and knowledge-transfer process. The IP-treatment, due to the higher productivity, was also more efficient, as the IPS completed the planning task 24 min before the SPS on average, which is a significant time-saving when related to a working day of 8 h. The analysis of the conflict and stress levels confirmed the assumption of the IP-treatment providing lower conflict and more balanced stress-levels, especially towards the end of the planning process. Significantly higher satisfaction was demonstrated in the roles of the Architect and Business Consultant in the categories: collaboration-satisfaction and team functionality.

In conclusion, both treatments achieved similar results, the IP-treatment however faster, with higher satisfaction, lower conflict and stress levels. Generally, it can be said that this treatment features more balanced results. This stability implies a resilience of the process against, for example, clients' changing requirements, moving of planning targets, the budget situation and promises of a more adaptive process.

The results of the experiment and competition were presented in the practitioners' feedback-workshop for verification. Seventeen involved practitioners, including architects, clients, HVAC engineers and energy consultants worked in a moderated round-table setting on answering the questions shown in Table 1.

The practitioners' workshop has confirmed the need for further and deeper exploration of the issues related to the stakeholders and their relationships within the planning process for a sustainable built environment. The responses are to a great extent related to the need

Table 1 Feedback-workshop—questions and answers

Questions	Collective answers
• Identification of the benefits of integrated planning	Communication: better understanding, easier decision-making, trust Error avoidance Process quality—higher satisfaction Long-term advantages Stability Complexity more manageable
• Particularly useful results	Confirmation from practitioners that IP or simultaneous planning has benefits—shorter decision paths; generating high-quality decisions
• Immediate use of results in practice	The transfer of tacit complex knowledge is supported in IP, through face-to-face communication Creation of new knowledge is enabled through simultaneous collaborative multidisciplinary project-team work
• Possible obstacles for implementation	Human being as a 'Creature of Habit' Changes cause resistance Impulse-givers necessary Absence of social capabilities How to motivate the planners to really plan integrally?
• Future steps	Responsibility-allocation (who carries collective responsibility within integrated team?) Education and training of integrated planners (experts or generalists?) Group think—development of counter steering control mechanisms Social competences needed in IP

for better education, improvement of social skills and understanding among disciplines and in general to the development of a public policy supporting the integrated planning practice (contracts, model of shared responsibilities). The collected feedback implies that the people- and process-issues have largely been

neglected in comparison to the efforts invested in the problem-solving of ecological issues. Concerning the inquired benefits of the integrated planning practice, the experts have confirmed the assumptions that simultaneous collaborative multidisciplinary project-team work with its shorter decision paths and face-to-face communication, generates high-quality decisions and new knowledge and further makes planning and construction complexity more manageable.

In this context, the conducted exploratory research represents an important milestone, showing that the integrated planning brings higher satisfaction, lower stress levels and general time-savings, which implies benefits for the work-life-balance. There is also large potential for the optimization of both the building performance and the planning-team performance, not by addressing the technological issues, but even more so the social ones, through mechanisms which support the design of collaboration and communication methods, the creation of new knowledge and knowledge management for both planners and users.

Conclusion

In this paper, we explore the paradigm shift in the current planning practice from the traditional, sequential planning process towards a more integrated planning practice. We argue that for the achievement of a sustainable built environment, where one of the major aims is reaching the maximum level of energy and resources efficiency, a bundled knowledge of various disciplines is necessary from the early planning stages on, since these stages determine the future life-cycle performance of the building. In this sense, a shift from a technology-driven towards a people- and process-driven sustainability approach is necessary, where communication, knowledge-transfer and the creation of new common knowledge play a crucial role, not only in the life-cycle phases but also in the project organization itself.

To test our thesis, we conducted a role-playing experiment simulating a traditional and an integrated planning practice for the design of a sustainable structure, and we verified the results in the practitioners' workshop. The role-playing experiment confirmed better performance of the integrated planning practice in terms of productivity and efficiency, but more over in terms of higher satisfaction, less conflict and more balanced stress-levels. The practitioners' workshop confirmed the need to further explore the people- and process bound issues such as social skills, allocation of responsibilities and commitment of planning teams.

The integrated planning practice requires collaborative interaction from experts with different professional

backgrounds. These multidisciplinary teams face the problem of knowledge-sharing, knowledge creation and subsequently knowledge management. Fong (2003, p. 481) regards knowledge-sharing in multidisciplinary project teams 'as a multitude of processes taking place directly without language (socialisation) and with language (externalisation).' He argues that socialization is a valuable mode of sharing knowledge in teams without language through imitation, observation and sharing experiences face-to-face. Further, the collaborative nature of multidisciplinary project teams is essential in creating new knowledge and sharing knowledge between experts with differing interests and knowledge domains.

The integrated planning treatment showed that all the roles were generally more satisfied with the planning process, leading to the assumption that social or high-information-rich knowledge-transfer methods which in the IP-treatment were personal discussions and a continuous communication during the whole planning phase, were more successful in reaching an overall goal of better communication, satisfaction and teamwork. These results imply that interpersonal or face-to-face communication has a crucial effect on the efficient transfer of knowledge, which is complex, tacit and difficult to codify.

What are the implications for future research? As already stated, design and planning processes, and especially so the ones for sustainable buildings, are complex and require a high degree of knowledge transfer between project partners. Taking this research further, would be exploring knowledge transfer mechanisms and knowledge management in the case of integrated planning models for a sustainable, energy- and resources-efficient structure. This would include the exploration of knowledge creation and knowledge transformation in integrated planning processes as well.

Our assumptions for further research would be (1) that knowledge, which is complex, tacit and difficult to codify, as it is in the case of sustainable architectural design and engineering, will more likely be transferred successfully in the integrated, life-cycle-oriented design and planning processes and (2) that integrated design and planning processes lead to a broader common base of knowledge for project organizations and thus are more suitable for realization of sustainable built environment.

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References

- van Aken, J.E. (2003) *On the Design of Design Processes in Architecture and Engineering: Technological Rules and the Principle of Minimal Specification*, Eindhoven Centre for Innovation Studies, Eindhoven University of Technology.
- Baccarini, D. (1996) The concept of project complexity—a review. *International Journal of Project Management*, **14**(4), 201–4.
- Bal, M., Bryde, D., Fearon, D. and Ochieng, E. (2012) The influence of stakeholder engagement in construction sustainability, in Hajdu, M. and Skibniewski, J.M. (eds.) *Proceedings of Creative Construction Conference 2012*, Budapest, 30 June–3 July.
- Balaras, C., Gaglia, A., Elena Georgopoulou, E., Mirasgedis, E., Sarafidis, Y. and Lalas, D. (2007) European residential buildings and empirical assessment of the Hellenic building stock, energy consumption, emissions and potential energy savings. *Building and Environment*, **42**(3), 1298–314.
- Brauner, C. and Kallinger, B. (2011) Vergleich von integralen und sequenziellen Planungsmethoden, Master thesis, Vienna University of Technology.
- Buchel, B. and Raub, S. (2001) Media choice and organizational learning, in Dierkes, M., Berthoin Antal, A., Child, J. and Nonaka, I. (eds.) *Handbook of Organizational Learning and Knowledge*, Oxford University Press, New York, pp. 518–34.
- Carvalho, M., Matteo Bonifacio, M. and Dechamps, P. (2011) Building a low carbon society. *Energy*, **36**(4), 1842–7.
- Crosbie, T. and Baker, K. (2010) Energy-efficiency interventions in housing: learning from the inhabitants. *Building Research & Information*, **38**(1), 70–9.
- Daft, R.L. and Lengel, R.H. (1984) Information richness: a new approach to managerial behavior and organizational design, in Cummings, L.L. and Staw, B.M. (eds.) *Research in Organizational Behavior*, JAI Press, Homewood, IL, pp. 191–233.
- Daft, R.L. and Lengel, R.H. (1986) Organizational information requirements, media richness and structural design. *Management Science*, **32**(5), 554–71.
- Daft, R.L. and Macintosh, N.B. (1981) A tentative exploration into the amount and equivocality of information processing in organizational work units. *Administrative Science Quarterly*, **26**(2), 207–24.
- Daft, R.L., Lengel, R.H. and Trevino, L.K. (1987) Message equivocality, media selection, and manager performance: implications for information systems. *MIS Quarterly*, **11**(3), 355–66.
- Dossick, C.S. and Neff, G. (2011) Messy talk and clean technology: communication, problem-solving and collaboration using building information modelling. *Engineering Project Organization Journal*, **1**(2), 83–93.
- Dossick, C., Anderson, A., Iorio, J., Neff, G. and Taylor, J. (2012) Messy talk and mutual discovery: exploring the necessary conditions for synthesis in virtual teams, in *Working Paper Proceedings, Engineering Project Organizations Conference*, Rheden, The Netherlands, 10–12 July.
- Doyle, A. and Hughes, W. (2000) The influence of project complexity on estimating accuracy, in Akintoye, A. (ed.), *16th Annual ARCOM Conference*, Glasgow Caledonian University, Association of Researchers in Construction Management, 6–8 September, 2, 623–34.
- EC (2010) European Commission, Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage, available at <http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0265:FIN:EN:PDF> (accessed 20 January 2013).
- EPBD (2010) Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.
- Fong, P.S.W. (2003) Knowledge creation in multidisciplinary project teams: an empirical study of the processes and their dynamic interrelationships. *International Journal of Project Management*, **21**(7), 479–86.
- Grant, R.M. (1996) Toward a knowledge-based theory of the firm. *Strategic Management Journal*, **17**(Winter Special Issue), 109–22.
- Gupta, R. and Chandiwala, S. (2010) Understanding occupants: feedback techniques for large-scale low-carbon domestic refurbishments. *Building Research & Information*, **38**(5), 530–48.
- Javernick-Will, A.N. and Levitt, R.E. (2010) Mobilizing institutional knowledge for international projects. *Journal of Construction Engineering and Management*, **136**(4), 430–41.
- Kiviniemi, A., Tarandi, V., Karlshøj, J., Bell, B. and Karud, O.J. (2008) Review of the development and implementation of IFC compatible BIM. Erabuild, available at http://www.eracobuild.eu/fileadmin/documents/Erabuild_BIM_Report_January_2008_-_Executive_Summary.pdf (accessed 20 January 2013).
- Kolarevic, B., Schmitt, G., Hirschberg, U., Kurmann, D. and Johnson, B. (2000) An experiment in design collaboration. *Automation in Construction*, **9**(1), 73–81.
- König, H., Kohler, N., Kreifßig, J. and Lützkendorf, T. (2009) *Lebenszyklusanalyse in der Gebäudeplanung*, Detail Green Books, Munich.
- Kovacic, I., Faatz, S., Koesegi, S. and Filzmoser, M. (2011) Research project cost benefits of integrated planning: first experiment-results. *OTMC An International Journal*, **1**(3), 254–63.
- Lim, K.H. and Benbasat, I. (2000) The effect of multimedia on perceived equivocality and perceived usefulness of information systems. *MIS Quarterly*, **24**(3), 449–71.
- Marsh, R., Grupe Larsen, V. and Kragh, M. (2010) Housing and energy in Denmark: past, present, and future challenges. *Building Research & Information*, **38**(1), 92–106.
- Mendler, S., Odell, W. and Lazarus, M.A. (2006) *The HOK Guidebook to Sustainable Design*, Wiley, Hoboken, NJ.

- Mills, F. and Glass, J. (2009) The construction design manager's role in delivering sustainable buildings. *Architectural Engineering and Design Management*, 5(1–2), 75–90.
- Nonaka, I. (1994) A dynamic theory of organizational knowledge creation. *Organization Science*, 5(1), 14–37.
- Oreszczyn, T. and Lowe, R. (2010) Challenges for energy and buildings research: objectives, methods and funding mechanisms. *Building Research & Information*, 38(1), 107–22.
- Pena, W. and Parshall, S. (2001) *Problem Seeking: An Architectural Programming Primer*, Wiley, Hoboken, NJ.
- Prins, M. and Owen, R. (2010) Integrated design and delivery solutions. *Architectural Engineering and Design Management*, 6, 227–31.
- Ramalingam, S. and Mahalingam, A. (2011) Enabling conditions for the emergence and effective performance of technical and cultural boundary spanners in global virtual teams. *Engineering Project Organization Journal*, 1(2), 121–41.
- Rekola, M., Kojima, J. and Mäkeläinen, T. (2010) Towards integrated design and delivery solutions: Pinpointed challenges of process change. *Architectural Engineering and Design Management*, 6(4), 264–78.
- Renders, N. (2012) Realistic saving potentials? The correlation of calculated and actual measured energy use, in *Flemish Institute of Technological Research (VITO)—Belgium, Intelligent Energy Europe Tabula—Expert Workshop*, 29 February, Wels, Austria.
- Russ, G.S., Daft, R.L. and Lengel, R.H. (1990) Media selection and managerial characteristics in organizational communications. *Management Communication Quarterly*, 4(2), 151–75.
- Sexton, M., Ingirige, B. and Betts, M. (2003) *Information Technology-Enabled Knowledge Sharing in Multinational Strategic Alliances: Media Richness—Task Relevance Fit*, Working paper, available at http://usir.salford.ac.uk/19482/1/CIB_78_-_New_Zealand_2003_Final.pdf (accessed 20 January 2013).
- Sheer, V.C. and Chen, L. (2004) Improving media richness theory: a study of interaction goals, message valence, and task complexity in manager-subordinate communication. *Management Communication Quarterly*, 11(1), 76–93.
- Spangenberg, J. and Bonniot, O. (1998) *Sustainability Indicators: A Compass on the Road Towards Sustainability*, Wuppertal Paper Nr. 81, February.
- Srećković, M. and Windsperger, J. (2011) Organization of knowledge transfer in clusters: a knowledge-based view, in Tuunanen, M., Windsperger, J., Cliquet, G. and Hendrikse, G. (eds.) *New Developments in the Theory of Networks, Franchising, Alliances and Cooperatives*, Springer Verlag, Berlin, pp. 299–315.
- Teece, D.J. (1985) Multinational enterprise, internal governance and industrial organization. *American Economic Review*, 75(2), 233–8.
- Torcellini, P., Pless, S., Deru, M., Griffith, B., Long, N. and Judkoff, R. (2006) *Lessons Learned from Case Studies of Six High-Performance Buildings*, Technical Report, National Renewable Energy Laboratory, Golden, CO.
- Trevino, L.K., Lengel, R.K. and Daft, R.L. (1987) Media symbolism, media richness and media choice in organizations. *Communication Research*, 14(5), 553–74.
- Vickery, S.K., Droge, C., Stank, T.P., Goldsby, T.J. and Markland, R.E. (2004) The performance implications of media richness in a business-to-business service environment: direct versus indirect effects. *Management Science*, 50(8), 1106–19.
- von Both, P. and Zentner, F. (2004) *LUZIE. Lebenszyklusbezogene Einbindung der Zielplanung und des Zielcontrolling in den Integralen Planungsprozess*, Technical Report, FIA Projekt, Bundesministerium für Wirtschaft und Arbeit, Bundesministerium für Bildung und Forschung.
- Zach, Michael H. (1999) Developing a knowledge strategy. *California Management Review*, 41(3), 125–45.
- Zeiler, W. and Savanovic, P. (2007) *Morphological Overview in Integral Building Design: Prescriptive Reflection International Association of Design Research*, the Hong Kong Polytechnic University.

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Key success factors of collaborative planning processes

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Key success factors of collaborative planning processes

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Building design and planning is a typical instance of coordination and collaboration processes, where experts work together in fulfilling their own distinct planning tasks that build the basis for the realization of the joint building project. Increasing requirements on building performance, like resources and energy efficiency, resulting in growing project complexity call for a holistic view of the project rather than a fragmented one, as strengths in one domain cannot easily offset weaknesses in others. Traditional sequential planning processes fall short in fulfilling this requirement. This study compares sequential and integrated building design in a large laboratory experiment with student participants. The focus of the study was to examine the impact of personality traits on team performance in different planning procedures in a building planning experiment. We identified that the success of design processes relies on both skills and the personality traits of the team members. In the integrated planning treatment groups with higher level of conscientiousness achieve worse results, whereas groups with higher level of conflict and workload achieve better results. We conclude that, when choosing or designing the optimal planning procedure for a team, personality traits should be taken into account since they significantly influence results.

Keywords: Experiment, integrated building design, integrated planning, personality traits, sequential planning.

Introduction

Integrated building design is based on collaborative planning and has been recommended as the method for the realization of a sustainable built environment (Rohracher, 2001; Alshuwaikhat and Abubakar, 2008; IWHBD, 2008; Heiselberg *et al.*, 2009; Russell-Smith *et al.*, 2014). The fragmented nature of the architecture, engineering and construction (AEC) industry is still the greatest obstacle for the achievement of better building performance in terms of energy- and resource efficiency, for which increased integration and coordination of the different disciplines involved in design and construction process are necessary (Faniran *et al.*, 2001). The principles of integrated building design originate in concurrent engineering (CE), which was first introduced in the automotive and aeronautical industry. CE is based on principles such as the use of cross-functional multidisciplinary teams, the use of software tools and digital models, sharing of information, communication and coordination (Anumba *et al.*,

2002). However, several authors criticize the direct transfer of the CE methods from the manufacturing industries to the AEC industry—a customized process is needed to meet the specific requirements of the construction industry (Faniran *et al.*, 2001). Khalfan *et al.* (2001) argue that the lack of realization of the full potentials of CE—concerning cost and time reduction and increases of effectiveness and efficiency—might originate in the insufficient planning and implementation of CE. Therefore, deeper knowledge of the actual design of the integrated design process is crucial. In recent years especially integrated project delivery (Prins and Owen, 2010; Lahdenperä, 2012), collaborative planning in the AEC industry (Sturts Dossick and Neff, 2011; Dewulf and Kadefors, 2012) and project-organizations engaged in collaborative practice (Love *et al.*, 2010; Hartmann and Bresnen, 2011) are upcoming topics in the context of CE that have increasingly been discussed in literature.

The identified advantages of CE originate in the integration of the concept–design–production phases

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and overlapping of activities, resulting in a reduction of changes, rework and consequently of the number of possible errors. Constraints and conflicts can be detected in the early design stages, where alterations can be carried out at low cost, the number of design alternatives is multiplied through early collaboration of all constituents and requirements of suppliers and users can be better grasped by early collaboration to improve the overall product quality (Wang *et al.*, 2002). The importance of early phases, like conceptual design, plays a crucial role for future product performance: Design decisions account for 75% of product cost (Hsu and Liu, 2000). The research community has generally advocated CE as a successful method for improvement of lead time, cost reduction and product quality (Pennell and Winner, 1989; Smith and Eppinger, 1998).

Concerning the transferability of insights from CE to the AEC industry, attention has to be paid to specific characteristics of this industry. CE is basically developed for the introduction of serial products, whereas building design and related design and construction remain the domain of prototyping, because of unique characteristics such as the building site, building orientation, varying needs of users and investors, varying planning teams and rare in-house planning.

CE in industry and integrated planning in architecture and construction differ through project organization: In industrial design the whole team (designers, builders and testers) are known from the beginning and are mostly in the same company—this is not the case in the Central European AEC industry. One team carries out the project development and feasibility study; another (competition winning) team carries out the actual design; the contractor is known after the bidding process, where design is already done. The architecture and construction projects are multi-party projects, where there is no unity of ownership, command and culture, which is the case with in-house industrial design (van Aken, 2003).

These differences of the industries lead to specialities in integrated planning that make it distinct from standard CE and call for additional research. AEC practice reports the need for the change of the traditional design process, which is arranged in a sequential manner, with little communication between constituents of different phases: ‘There seems to be thinking out there that there’s got to be a better way to do this than the way we’ve been doing it?’ (AIA, 2009, p. 5). The practitioners report the lack of early collaboration as especially deficient; as such the needs of users can hardly be considered; moreover, the lack of knowledge transfer from planning to the operational phase is problematic (Kovacic and Müller, 2011).

Despite this development the success factors of the different planning processes are yet not well

understood. We lack solid empirical foundations to judge if and under which conditions integrated planning is superior to sequential planning. The research question of this paper therefore is: What are the key success factors of collaborative planning processes. In an attempt to take the first steps towards answering this research question, we conducted an explorative laboratory experiment with undergraduate participants. We collected data about possible success factors and analysed their effects on team performance through a regression analysis.

The remainder of this paper is structured as follows: After this brief motivation the second section discusses potential success factors for collaborative planning and formulates hypotheses for our study. The third section describes the experimental study and the data gathered. Results of regression analyses of the collected data are presented in the fourth section. The fifth section summarizes the main results and draws conclusions for research and practice.

Success factors in collaborative planning

The following section deals with potential success factors of collaborative planning, which we subsequently evaluate and analyse in the experimental setting. Literature discusses several factors potentially influencing the performance of a team:

(i) the team potential and the effort they spend on the planning task, (ii) the attitudes towards working in a group, (iii) the planning procedure used during collaborative planning and (iv) personality traits of the group members. We subsequently discuss these factors in detail and formulate hypotheses concerning their assumed influence on team performance. The regression analysis in the fourth section also covers the interaction between these effects, as it can be assumed that the effect of the usage of different planning procedures—i.e. of integrated and sequential planning—is dependent on attitudes towards working in groups and personality traits of the team.

Qualification and effort

As in any task, also in collaborative design, the qualification of the participants is based on education and experience. However, it not only matters whether the group possesses these qualifications, but also to which extent the group uses them in the planning process. We therefore formulate the following hypotheses:

H1a: Higher team qualification positively influences the team performance.

H1b: Higher team effort positively influences the team performance.

These two aspects are relevant in individual as well as in group tasks; however, group tasks additionally feature the problem of collaborating in a team which is not relevant in individual tasks.

Group work

Jassawalla and Sashittal (1998) claim that participants' cooperation, openness and willingness to cooperate as well as trust are fundamentals of high-level integration in teams, which could be endangered by personal attitude such as disinterest towards the collaborative process. Productive joint work in groups covers several relevant aspects, including the team members' general attitudes towards working in groups, how proficient they are in communicating with others and coordinating joint activities. We therefore formulate the following hypotheses:

H2a: Better attitudes towards team work positively influence the team performance.

H2b: Better cooperation skills positively influence the team performance.

H2c: Better communication skills positively influence the team performance.

Besides these attitudes and capabilities of working in groups the planning procedure applied to do so is argued to influence the team performance.

Planning procedure

Building design and planning are typical instances of coordination processes. Hereby, numerous experts (architect, structural and HVAC engineers, project manager, facility manager)—usually associated with different and legally independent firms—work together in fulfilling their own distinct planning tasks that together build the basis for the realization of the joint building project. Their tasks are highly specialized and at the same time highly interdependent. The success of a building design relies on optimized overall results, so that weaknesses in one area cannot be offset by strengths in others. This is even more true for the augmented requirements on building performance and increased complexity of the planning process posed by sustainability and energy efficiency (Nofera and Korkmaz, 2010).

In this newly evolving design field, the traditional planning process that follows a sequential workflow, where each expert performs her/his task on the basis of the previous expert's output, falls short of fulfilling sustainability goals in complex situations. The reciprocal interdependencies between tasks call for an integrated

rather than sequential planning process (Thompson, 1967). We therefore formulate the following hypothesis:

H3: The integrated planning procedure will positively influence the team performance compared to the sequential planning procedure.

Personality traits

Collaboration with other team members and team performance to a large extent depends on the personality traits of the team members. This was found, for example, in the field of product development by Kichuk and Wiesner (1997). Personality traits are enduring characteristics of individuals, which cannot be changed easily. An established system for classifying and evaluating personality traits includes the, so-called, 'Big Five': extraversion, agreeableness, conscientiousness, openness to experience and neuroticism (e.g. Costa and McCrae, 1992). Although, to the knowledge of the authors, no studies yet have analysed the effect of personality traits on team performance in building planning tasks, existing literature on team performance in other domains suggests that personality traits of the team influence outcomes (Driskell *et al.*, 1987). Kichuk and Wiesner (1997), for example, found that successful product development teams are characterized by higher extraversion and higher agreeableness, while showing a lower level of neuroticism. The effects of personality traits on team performance, found in existing empirical studies, differ considerably with group size, group task or the domain of the study. Subsequently, we briefly describe the above-mentioned personality traits and formulate hypotheses concerning their influence on team performance in accordance with the majority of the existing literature (Driskell *et al.*, 1987; Kichuk and Wiesner, 1997).

Extraversion paraphrases traits such as sociability, activeness, assertiveness, etc. A high level of extraversion within a team should lead to results that integrate the perspectives and ideas of all involved; we therefore assume a positive relationship between extraversion and team performance, which was also found in the majority of existing studies.

H4a: A higher level of extraversion in the team positively influences the team performance.

Agreeableness includes traits such as courteousness, trust, cooperativeness, tolerance, etc. Empirical studies show mixed results concerning this personality trait. Highly agreeable work groups clearly might improve the working climate and the possibility to overcome conflicts; besides, they could also lead to compromises or the avoidance of productive conflict and the

collaborative search for integrative solutions. In general, we assume that the positive effects of high agreeableness in a team surmount its disadvantages and formulate; hence the following hypothesis:

H4b: A higher level of agreeableness in the team positively influences the team performance.

Conscientiousness describes persons who are dependable, careful, thorough, organized, hard-working and achievement-oriented. These qualities can be assumed to be beneficial for team performance in general. However, the increased productivity of conscientious teams might lead to lower creativity in creative tasks like building design. We nevertheless formulate our hypothesis in accordance with the majority of the results of empirical studies which find a positive relationship.

H4c: A higher level of conscientiousness in the team positively influences the team performance.

Traits connected to openness to experience include imagination, curiosity, originality, broad-mindedness, intelligence, etc. Previous studies came to no conclusive results concerning the effects of openness to experience. Its positive effects on the innovative potential of groups could be outperformed by lower efficiency; we argue that for the creative task of building planning openness to experience can be seen as a desirable characteristic of a planning team.

H4d: A higher level of openness in the team to experience positively influences the team performance.

Neuroticism may be perceived as an emotional instability and describes traits like anxiety, depression, anger, emotionality or insecurity. One could hypothesize that neuroticism negatively affects team performance as it might hinder effective collaboration in teams and fuel conflicts. However, in our study we had to exclude this factor of the 'Big Five' due to data collection problems. Pre-tests of the pre-experiment questionnaire indicated that participants were reluctant to answer the questions that measure the neuroticism scale, which could harm truthful information revelation or participation in the experiment.

Method and data

After the discussion of potential success factors and the derivation of hypotheses regarding how they influence the performance of teams, this section will describe the experiment and the questionnaires used to gather the necessary data for our analyses.

Experiment

To investigate the key success factors of collaborative planning procedures, we conducted a laboratory experiment with undergraduate participants from the curricula civil engineering and architecture at the Vienna University of Technology in Fall 2011. The experimental study was part of the research project 'Costs and benefits of integrated planning'.

Previous research on work groups suggests that the type of the task, the size of the work group, the project length and available resources as well as the environment influence the group performance (Cummings, 2004). To gain reliable insights into the effect of the planning procedure—i.e. integrated versus sequential planning—and the effects of personality traits, it is necessary to control for these aspects which is possible in laboratory experiments.

All planning groups consisted of four members, representing roles in the design process (client, architect, engineer, business consultant) with distinct tasks and deliverables. The group task was identical for all groups: the design of a temporary, self-sustained smoothie bar in the surroundings of the Vienna University of Technology main building, the target customer group being students, to ensure that the work groups have sufficient and equal knowledge of the location and the target group. Deliverables for each role included an architectural design drawings and cost calculation for the architect, structural design drawings and calculation as well as the energy-system design drawings and calculation of solar gains for the engineer, cost and benefit calculations for the business expert, and marketing strategy description for the client. The resources were identical (standardized sheets for the drawings, calculation tables and forms, catalogues with equipment) and also the project time was fixed with eight hours (the experiment was scheduled for one whole day).

To ensure equal capabilities in both treatments, information about the participants' professional experience, the progress in their study, drawing skills, etc. were collected—together with other information as described in the subsequent section—by a pre-experiment online questionnaire. Based on this information, pairs of participants with experience as equal as possible were identified and randomly assigned to one of the two experimental treatments (sequential planning or integral planning). Afterwards, within the two treatments, groups of students were created, assigning an architecture student to the architect role of one group at random and three civil engineering students to the remaining three roles (client, engineer and business consultant) at random.

On the experiment day, the participants were split up according to the treatment they were assigned to, and

accordingly briefed by the experimenters. Afterwards, the groups (in the integrated planning procedure) or the participants with equal roles (in the sequential planning procedure) congregated in their rooms and started to work on their tasks to perform their deliverables.

The only difference between the work groups was the planning procedure they had to use, which constituted the two treatments of the laboratory experiment. In the integrated planning treatment all four group members sit and work together during the whole experiment—from the initial design until the handing in of the results—discussing and deciding jointly on design solutions. On the other hand, in the sequential planning treatment the different disciplines were situated in different rooms and only allowed to meet in a one-on-one fashion. Communication was restricted to face-to-face meetings and discussions, so that the experimenters who supervised the participants in the different rooms could ensure that the experimental conditions were not violated. The experimental condition was induced by separate briefings of the two sets of work groups, so they did not know about the distinct planning procedures until a debriefing event, where also first results were presented to interested participants.

These two predetermined procedures are argued to best represent the essentials of sequential and integrated planning, respectively. One-on-one meetings require redo-loops in case of additional information, feedback or problems from other professions concerning an accomplished task, as it is the case in sequential planning. If the work group members interact during the whole process, this information can be provided or requested timely and redo-loops can be avoided and joint decision-making will be supported.

The standardization of all available resources, such as the available planning time, materials and human resources, shifts the attention towards the outcomes of the building design process, which was a jury evaluation of the results of the work groups in this study. This is in contrast to the main part of the literature as mentioned in the introduction, which, especially in the domain of CE, focuses on process efficiency such as reductions in planning costs through reduction in number of changes or in planning time.

Questionnaires

For the analyses of key success factors, we gathered significant amounts of information on the participants, the planning process of the work groups and their outcomes. The pre-questionnaire elicited demographic data about the participants (age and gender), which we used as control variables in the analyses, as well as information about their experience: full-time equivalent of relevant professional experience, how many

semesters they have studied and a self-evaluation of their drawing skills on a four-point scale (from one being very bad to four being very good). Furthermore, the pre-experiment questionnaire surveyed personality traits of the participants including the four relevant traits of the Big Five: extraversion, agreeableness, conscientiousness and openness to new experiences (Costa and McCrae, 1992).

Extraversion (PEI), agreeableness (PAG), conscientiousness (PCO) and openness to experience (POE) were surveyed by standard 10-item scales. Attitudes towards working in groups were elicited from the participants' attitudes towards team work (STW, 9-item scale), attitudes towards cooperation (SCO, 10-item scale) and attitudes towards communication (SCO, 6-item scale). The participants had to answer these questions on a 5-point Likert scale ranging from 1 (by no means at all) to 5 (totally true). Based on the answers of the participants the scales were checked for consistency and reached satisfactory Cronbach's alphas.

During the experiment, the participants continuously self-documented the tasks they were performing as well as the perceived level of workload and conflict within the group (each on a 10-point scale, at least every 30 minutes). The experimenters took care that this information was indicated and reminded the participants if necessary. After the experiment the participants had to fill in a brief post-experiment questionnaire indicating their satisfaction with (i) the procedure, (ii) their result, (iii) the functionality of the team and (iv) the collaboration in the team. Furthermore, they could communicate suggestions or problems. All deliverables were handed over to a jury of five experts from the industry and the academy. The jury members individually evaluated all 40 groups (without knowledge of group participants or planning treatment) concerning four specific criteria (architectural design, structural design, energy efficiency, life-cycle costs and benefits) and also provided a holistic evaluation (each evaluation was done on a scale from 1 to 10, the higher the better).

Results

A total of 160 students participated in the laboratory experiment, a quarter of whom were architecture students. 80 participants were assigned to 20 groups that followed a sequential planning procedure (work group members communicated exclusively in one-on-one meetings—as described in the previous section); the remainder 80 participants were assigned to 20 groups that followed an integrated planning procedure (work group members were placed together in one room—as described in the previous section).

The average holistic evaluation of the jury served as the dependent variable in our analyses as an approximation of the quality of planning groups' outputs. We argue that in building design the process effectiveness is of much higher relevance compared to process efficiency, as planning time and planning cost are negligible compared to the resulting building's life-cycle time and cost. However, our research also included evaluation of efficiency, first analyses on the data gathered in the laboratory experiment found a higher time efficiency of integrated planning teams and a higher satisfaction of the work groups with the integrated planning process (Kovacic and Sreckovic, 2012).

The independent variables gathered on an individual basis were aggregated to group-level variables by the common approach of calculating the averages (Cummings, 2004). Table 1 provides descriptive statistics of the independent and dependent variables at the level of analysis (i.e. the group level). Note, however, that the averages at the individual level are equal to the averages at the group level as all group sizes are equal.

From Table 1 one can observe that the participants on average were about 23 years old, in their fifth to sixth semester and already possessing around eight months of professional experience. About 30% of the participants were female.

Table 2 presents the correlations of the independent variables. Not surprisingly, age, the semester of study and the months of professional experience are positively correlated. Moreover, the strong correlation of the personality threats: agreeableness and the attitudes towards team work is comprehensible. Interesting is the striking positive correlation between group averages of self-

documented level of perceived workload and the level of perceived conflict, indicating that workload, work distribution and conflict go hand in hand during the planning processes.

Regression analyses were started with a base model (model 0 in Table 3) that considers the effects of the planning procedure as a dummy variable (0 for sequential 1 for integrated planning) and the control variables. Consistently with initial and previous univariate analyses, we found no direct effect of the planning procedure on the outcome quality of the design process (Kovacic *et al.*, 2011). Also control variables, i.e. the average age and the portion of female group members, have no impact on the outcome.

Model 1 considers the effect of skills and experience and finds weakly ($p < .1$) significant contribution of the average drawing skills and the average study progress. These first two models (model 0 and model 1) did not fit, however, model 2 keeping drawing skills and study progress as explanatory variables and adding the four general personality traits—as well as their interaction with the planning procedure used by the group—leads to the first reasonably fitting model 2, with adjusted multiple R^2 of 0.27, F -statistic 2.329, significant at $p < .05$.

In model 2, average drawing skills lead to higher evaluation ($p < .05$); furthermore, groups with higher values for conscientiousness (PCO) reached significantly inferior results ($p < .01$) in integrated planning procedures, while in general high conscientiousness of the group has no such effect. Adding the planning specific personality traits, such as attitudes towards team work, cooperation and communication (and

Table 1 Descriptive statistics for dependent and independent variables at the group level

	Mean (SD)	Min	1. Q	Median	3. Q	Max
Age (years)	22.870 (2.102)	20.500	21.690	22.500	23.000	29.750
Female	0.294 (0.203)	0.000	0.250	0.250	0.500	0.750
Study (semesters)	5.650 (2.558)	3.250	4.188	5.000	6.000	16.500
Drawing skills	3.131 (0.420)	2.250	3.000	3.000	3.312	4.000
Experience (months FTE)	7.888 (7.746)	0.000	3.438	4.500	10.542	27.500
Extraversion PEI	3.331 (0.262)	2.725	3.194	3.362	3.506	3.775
Agreeableness PAG	3.826 (0.240)	3.200	3.700	3.900	3.956	4.275
Conscientiousness PCO	3.746 (0.235)	3.200	3.544	3.800	3.931	4.175
Openness POE	3.650 (0.207)	3.275	3.450	3.663	3.775	4.100
Team work STW	3.789 (0.243)	3.333	3.604	3.806	3.917	4.472
Communication SCM	3.982 (0.222)	3.625	3.833	3.958	4.135	4.417
Cooperation SCP	3.328 (0.204)	2.625	3.219	3.312	3.500	3.675
Workload	4.031 (0.532)	2.061	3.652	4.143	4.382	4.849
Conflict	4.034 (0.533)	2.030	3.674	4.157	4.392	4.854
Jury	6.255 (1.161)	3.800	5.550	6.500	7.200	8.200

Note: FTE, full time equivalent.

Table 2 Correlation of independent variables

	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	-0.07	0.78***	0.21	0.58***	0.18	-0.20	-0.07	0.09	-0.20	-0.03	-0.12	0.04	0.04
2. Female		-0.05	-0.13	0.04	-0.06	0.19	-0.23	-0.03	0.12	-0.33*	-0.12	0.01	0.02
3. Study			-0.05	0.59***	0.18	-0.07	-0.07	0.14	-0.19	-0.14	-0.06	-0.07	-0.07
4. Drawskill				0.36*	0.07	-0.13	0.15	0.12	0.14	0.19	0.15	0.24	0.24
5. Experience					0.34	-0.23	-0.12	-0.02	-0.07	-0.15	-0.12	-0.01	0.00
6. PEI						0.36*	0.27	0.34*	0.37*	0.15	-0.20	-0.20	-0.22
7. PAG							0.46**	0.30	0.63***	0.38*	-0.15	0.05	0.04
8. PCO								0.46**	0.35*	0.50**	0.22	-0.13	-0.13
9. POE									0.17	0.39*	-0.24	-0.01	-0.01
10. STW										0.40*	-0.15	-0.09	-0.09
11. SCM											0.01	0.08	0.09
12. SCP												-0.07	-0.06
13. Workload													0.99***
14. Conflict													

Significance levels:

* $p < .05$.** $p < .01$.*** $p < .001$.

Table 3 Overview of the regression analyses

	Model 0	Model 1	Model 2	Model 3
Intercept	3.520 (-1.672)	2.704 (1.644)	-7.645 (-1.204)	-9.102 (-2.057)*
Procedure	0.198 (-0.54)		10.618 (1.208)	6.750 (0.995)
Age	0.128 (1.449)			
Female	-1.034 (-1.138)			
Drawing skill		0.931 (1.907)	0.947 (2.078)*	0.917 (2.362)*
Study		0.181 (1.955)	0.113 (1.588)	0.092 (1.483)
Experience		-0.049 (-1.510)		
POE			1.551 (1.150)	2.083 (2.394)*
PCO			1.949 (1.492)	0.971 (1.010)
PEI			0.556 (0.505)	
PAG			-1.144 (-0.971)	
Procedure * POE			2.438 (1.259)	
Procedure * PCO			-5.580 (-3.233)**	-4.018 (-3.002)**
Procedure * PEI			-2.362 (-1.404)	
Procedure * PAG			2.313 (0.228)	
Conflict				0.238 (0.693)
Procedure * conflict				1.838 (2.073)*
Mult. R^2 (adj.)	0.09 (0.02)	0.14 (0.06)	0.48 (0.27)	0.51 (0.38)
F -statistic	1.243	1.864	2.329	3.997
DF	36	36	28	31
p -Value	.308	.153	.035	.002
AIC	130.494	128.661	124.449	116.086

* $p < .05$.** $p < .01$.*** $p < .001$.

their interaction with the planning procedure) did not lead to a better model and therefore is not reported, however, adding perceived level of conflict did lead to our final model 4. Given the high positive correlation of perceived workload and perceived conflict should be included in one model.

With the insights from the previous models, systematic variation led to the final model 3, which best fits the

data and explains the reasons for good performance evaluation by the jury, with adjusted multiple R^2 of 0.38, F -statistic 3.997, significant at $p < .01$ and lowest with 116,086 as lowest Akaike information criterion (AIC) of all models—see Table 3.

The average drawing skills are in all models of importance ($p < .05$), the average progress in the study contributes insignificantly ($p \sim .15$) but according to

adjusted lower R^2 and higher AIC in a model without this explaining variable should be kept in the model. Furthermore, a high group value for openness to experience leads to better results.

The planning procedure, the conscientiousness of the group and its perceived level of conflict for themselves have no influence on the outcome for them alone. Only in specific planning procedures, do this personality trait and the conflict level influence the outcome, as can be derived from the significant interaction effects in model 3. Highly conscientious groups perform worse in integrative planning, which indicates that this planning procedure is adverse to their working habits. On the other hand, high conflict level leads to better results in integrated planning. This procedure seems to be able to better handle conflict and transform it into valuable outcomes.

Discussion and conclusion

The laboratory experiment reported in this paper was motivated by interest to identify the factors that influence performance in collaborative building planning. However, the analyses of the accomplished experiment did not support this general link; so we investigated the key success factors of the collaborative planning process in more detail in this paper.

Consistent with our hypothesis H1a, we found significant positive effects of group qualification—progress in the study, drawing skill and professional experience were not relevant. Attitudes towards working in groups and the planning procedure were not influential, which leads us to reject hypotheses H2 and H3. The through literature assumed direct link between integrated planning and high performance—through integration and coordination of various disciplines throughout the project (Faniran *et al.*, 2001); the involvement of the whole project team in initial design, joint decision-making and holistic thinking (IWHBD, 2008), therefore, was not found. This is also consistent with preliminary analyses (Kovacic and Sreckovic, 2012) which also found no direct positive influence of integrated planning on the outcomes reached with this planning procedure. In accordance with literature and our hypothesis H4d, a high level of openness to experience is beneficial to group performance as it enables more creative and novel outcomes. The other three personality traits, extraversion, agreeableness and conscientiousness, did not show a direct positive influence on team performance as hypothesized. Previous studies on the influence of personality traits on team performance revealed that this relation is highly task dependent. The creative task of building design seems to hinder the exploitation of positive effects like extroversion,

agreeableness and conscientiousness as already mentioned in the second section.

One interesting result is the significant interaction effects with the planning procedure we found in our regression analysis. On the one hand, groups with high conscientiousness reach worse results with the integrated planning procedure; on the other hand, groups that perceive a high level of conflict—or workload as these two measures were highly correlated as shown in Table 2—reach better results with the integrated planning procedure. What can be the reasons for these findings and what is their relevance for theory and practice? Integrated planning could be interrupting for the accomplishment of tasks in a manner in which the highly conscientious group members prefer and therefore lead to inferior results. Furthermore, group think phenomenon might undermine the identification of the participants with, and the feeling of responsibility for, the results achieved in the work group. It is therefore necessary to adjust the planning procedure to individual personality traits to avoid such effects, for example, by the use of IT (like building information modelling) in the group coordination, so that the different professions can work together in some phases of the planning process, but in others can focus on their own subtasks.

Concerning conflict and workload, both are not by themselves negative to a work group result; by contrast, if handled correctly a high workload can lead to a lot of work done and conflicts, if settled successfully, lead to an integration of different perspectives and thereby probably better results. This seems to be the case when high perceived conflict and workload are dealt with by integrated planning procedures. The easier interaction makes it easier to reallocate and coordinate workload in the group and also to exchange information and discuss different perspectives. Both can result in positive impulses for the resulting output.

Based on the results, we can derive some recommendations for AEC practice. Before engaging in a design process, a personality trait analysis of team members could be briefly assessed. Based on the assessment, a careful design of the design process can be outlined—for example, as a succession of interactive workshops, and individual, concentrated problem-solving or modelling phases. Further on, a moderator should be employed in the initial team-forming phase, in order to initiate the team forming, to design the communication and to give necessary space for expressing the ideas to the more introverted team members. This could be especially encouraging for the engineers, who often prefer to work within the restrictions of a given design, due to their professional culture. However, bringing in new ideas based on the specific e

professional expertise and contribution, leads to better results in an adequate planning procedure. Furthermore, establishment of a culture of positive conflict is necessary, for which again a moderator could be employed, as supervisor and process facilitator.

In planning projects where experts represent firms in inter-firm collaboration, the personality of the group members from different firms still has a significant impact on group functioning; however, organizational culture might be an influencing factor as well in such constellations. The existence and strength of this relation calls for future research.

The presented analyses focus on aggregate work group characteristics (average values of all members as a measure for the whole group). Diversity might be a critical point in this regard. For group composition it is an interesting question whether the diversity among group members in demographics, background, experience, etc. is beneficial or harmful to the success of the work group and whether different planning procedures can help to realize or avoid these positive or negative effects.

Moreover, the presented study faces several limitations, which should be addressed in future research to deepen our understanding of the influence of personality traits and planning procedures on outcome quality. Though the experiment shows a satisfying sample size it is based on only one planning project; therefore it should be replicated with tasks of various sizes and complexities to enforce confidence in the obtained results. Furthermore, as students took over the roles in the planning teams, generalizability of the results to the professional sector might be a critical issue. The use of undergraduate participants in laboratory experiments often is the only way to accomplish studies that focus on process design, as an intervention in real planning processes could cause harmful and expensive outcomes and additionally cannot be observed and analysed easily. However, experiments with expert participants, for example, as part of postgraduate programmes, could allow validating the findings of this study. As professionals are typically not available very easily these studies would normally have fewer participants, which makes statistical analyses hard but allows for detailed case studies on planning processes, which explicitly take into account personality traits and planning procedures and their effect on outcomes.

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References

- AIA (2009) *Experiences in Collaboration: On the Path to IPD*, American Institute of Architects California Council, p. 5.
- van Aken, J. (2003) *On the Design of Design Process in Architecture and Engineering: Technological Rules and the Principle of Minimal Specification*, Working Paper, Eindhoven Centre for Innovation Studies.
- Alshuwaihat, H.M. and Abubakar, I. (2008) An integrated approach to achieving campus sustainability: assessment of the current campus environmental management practices. *Journal of Cleaner Production*, **16**(16), 1777–1785.
- Anumba, C.J., Baugh, C. and Khalfan, M.M.A. (2002) Organisational structures to support concurrent engineering in construction. *Industrial Management & Data Systems*, **102**(5), 260–270.
- Costa, P.T., Jr. and McCrae, R.R. (1992) *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) Manual*, Psychological Assessment Resources, Odessa, FL.
- Cummings, J.N. (2004) Work groups, structural diversity, and knowledge sharing in a global organization. *Management Science*, **50**(3), 352–364.
- Dewulf, G. and Kadefors, A. (2012) Collaboration in public construction—contractual incentives, partnering schemes and trust. *Engineering Project Organization Journal*, **2**(4), 240–250.
- Driskell, J.E., Hogan, R. and Salas, E. (1987) Personality and group performance, in Hendrick, C. (ed.) *Group Process and Intergroup Relations, Review of Personality and Social Psychology*, Vol. 9, Sage Publications, Thousand Oaks, CA, pp. 91–113.
- Faniran, O.O., Love, P.E.D., Treloar, G. and Anumba, C.J. (2001) Methodological issues in design-construction integration. *Logistics Information Management*, **14**(5/6), 421–428.
- Hartmann, A. and Bresnen, M. (2011) The emergence of partnering in construction practice: an activity theory perspective. *Engineering Project Organization Journal*, **1**(1), 41–52.
- Heiselberg, P., Brohus, H., Hesselholt, A., Rasmussen, H., Seinre, E. and Thomas, S. (2009) Application of sensitivity analysis in design of sustainable buildings. *Renewable Energy*, **34**(9), 2030–2036.
- Hsu, W. and Liu, B. (2000) Conceptual design: issues and challenges. *Computer-Aided Design*, **32**(14), 849–850.
- IWHBD (2008) *Integrated Whole Building Design Guidelines*, New Zealand Government, Ministry for the Environment,

- available at www.mfe.govt.nz (accessed 26 November 2013).
- Jassawalla, A.R. and Sashittal, H.C. (1998) An examination of collaboration in high-technology new product development processes. *Journal of Product Innovation Management*, **15**(3), 237–254.
- Khalfan, M.M.A., Anumba, C.J., Siemieniuch, C.E. and Sinclair, M.A. (2001) Readiness assessment of the construction supply chain for concurrent engineering. *European Journal of Purchasing & Supply Management*, **7**(2), 141–153.
- Kichuk, S.L. and Wiesner, W.H. (1997) The Big Five personality factors and team performance: implications for selecting successful product design teams. *Journal of Engineering and Technology Management*, **14**(3–4), 195–221.
- Kovacic, I. and Müller, C. (2011) Collaborative planning practice for sustainable buildings—a case study research, in *People, Buildings and Environment, Conference Proceedings*, Vol. 2, Lednice, Czech Republic, 7–9 November 2012.
- Kovacic, I. and Sreckovic, M. (2012) Designing the planning processes for sustainable buildings: from experiment towards implementation. *Engineering Project Organization Journal*, **3**(1), 51–63.
- Kovacic, I., Filzmoser, M., Faatz, S. and Koeszegi, S.T. (2011) Costs and benefits of integrated planning: first experiment results. *Organization, Technology and Management in Construction*, **3**(1), 254–263.
- Lahdenperä, P. (2012) Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery. *Construction Management and Economics*, **30**(1), 57–79.
- Love, P.E.D., Mistry, D. and Davis, P.R. (2010) Price competitive alliance projects: identification of success factors for public clients. *Journal of Construction Engineering and Management*, **136**(9), 947–956.
- Nofera, W. and Korkmaz, S. (2010) Design process integration for sustainable, high performance buildings, in *Working Paper Proceedings Engineering Project Organizations Conference*, South Lake Tahoe, CA, 4–7 November 2010.
- Pennell, J.P. and Winner, R.I. (1989) Concurrent engineering: practices and prospects, in *Global Telecommunications Conference, 1989, and Exhibition. Communications Technology for the 1990s and Beyond*, GLOBECOM '89, IEEE, Vol. 1, pp. 647–655.
- Prins, M. and Owen, R. (2010) Integrated design and delivery solutions. *Architectural Engineering and Design Management*, **6**(4), 227–231.
- Rohracher, H. (2001) Managing the technological transition to sustainable construction of buildings: a socio-technical perspective. *Technology Analysis & Strategic Management*, **13**(1), 137–150.
- Russell-Smith, S.V., Lepech, M.D., Fruchter, R. and Meyer, Y.B. (2014) Sustainable target value design: integrating life cycle assessment and target value design to improve building energy and environmental performance. *Journal of Cleaner Production*, available at <http://dx.doi.org/10.1016/j.jclepro.2014.03.025>
- Smith, R.P. and Eppinger, S.D. (1998) Deciding between sequential and concurrent tasks in engineering design. *CE (Concurrent Engineering): Research and Application*, **6**(1), 15–25.
- Sturts Dossick, C. and Neff, G. (2011) Messy talk and clean technology: communication, problem-solving and collaboration using building information modelling. *Engineering Project Organization Journal*, **1**(2), 83–93.
- Thompson, J.D. (1967) *Organizations in Action*, McGraw-Hill, New York.
- Wang, L., Shen, W., Xie, H., Neelamkavil, J. and Pardasani, A. (2002) Collaborative conceptual design—state of the art and future trends. *Computer-Aided Design*, **34**(13), 981–996.

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RESEARCH ARTICLE

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The “BIM-sustain” experiment – simulation of BIM-supported multi-disciplinary design

Iva Kovacic*, Lars Oberwinter†, Christoph Müller† and Christoph Achammer

Abstract

Background: The AEC practice using BIM technology in Central European (CE) context is still very young; the previous experiences demonstrated a number of upcoming 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 and in general lack of experience and knowledge on integrated practice).

The optimal data management, transfer and synchronization within inhomogeneous software context, as is often the case within inter-firm construction projects, require enormous organization, coordination and communication effort in the earliest design-phases. The BIM implementation implies therefore necessity of fundamental rethinking of the conventional design process, which in CE context is still predominantly based on sequential, segmented practice.

Methods: At the Vienna University of Technology a BIM-supported multi-disciplinary planning process with students of architecture, structural engineering and building physics, using several BIM-software tools was simulated. From the qualitative and quantitative evaluation of this BIM-supported multi-disciplinary collaboration will enable the compilation of guidelines for efficient use of BIM in design and planning process for the planners and standardization bodies.

Results: First insights on process-quality, such as team-, process- and technology satisfaction, as well as conflict- and stress levels will be presented in this paper. We were able to identify numerous technical problems related to the data transfer and inconsistencies in translation, which resulted in participant dissatisfaction and significant increasing of work-loads.

Conclusion: The first results imply at the importance of process-organization techniques such as face-to face communication, coordination and work-load allocation between the team-members in order to conduct the efficient BIM-supported process; as well as at urgent need for advancement of the tools in terms of data transfer and exchange. In the next step, using mandatory protocols and timesheets, a detailed statistical analysis of the people-process-technology issues will be conducted, as well as comparison of „Open-Platform-BIM“ to „One-Platform-BIM“ model.

Keywords: BIM; Collaboration; Integrated Planning; Exploratory Research; Experiment

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Background

The consolidations for realization of sustainable built environment result in increasing complexity of planning and construction process. The increasing number of partaking disciplines uses wide spectrum of specialised visualisation, simulation or calculation tools. The practice calls for more integrated design and planning process, which would enhance simultaneous collaboration of various disciplines for sharing and creation of new common knowledge. Building Information Modelling (BIM) is believed to bear large potential for inducing a shift from the conventional, fragmented practice, which still largely dominates the AEC (architecture, engineering and construction) industry (Fellows and Liu 2012), towards more integrated design practice (Prins and Owen 2010). BIM as method is supportive of collaborative planning, facilitating communication and information exchange among various planning process participants (Rizal and van Berlo 2010). However, Rekkola et al. (2010) argue that “integrated design” is still handled rather loosely in the practice – often is the creation of BIM model 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 of design process), than about what (building model and its properties).

This paper will focus on introduction of BIM-supported planning in the CE and particularly Austrian AEC (architecture, engineering and construction) market, where the application of this technology is still novel, as well as the integrated planning approach. Austrian market is characterised by a large number of very small planning offices (average size of architectural office of 2,7 employees (Forlati et al. 2006)) as well as construction companies largely coming from the small- or medium size sector. The traditional design and planning process is carried out by small scaled, highly segmented large number of experts working in sequential manner, using various kinds of tools and software. Therefore the standards, but also the knowledge for BIM-supported planning process is largely lacking.

The further problem that most of the Austrian offices are facing is the high fluctuation of the employees and of the related know-how loss; which is a common characteristic of the most of the small project-oriented firms. Owen et al. (2010) point out the need for enhancement of skills of project members, which are often highly specialised in their own fields of expertise, but seldom trained to work in integrated project environment. The organizations also seldom support this kind of professional development. The introduction of the new BIM-tools therefore mostly means more than simple CAD-tools shift, since the adoption is mostly related to the reorganization of the processes and management strategy of the project-based organization.

Seen in this light, in the practical BIM operation and use a number of problems on different levels can be

met. On the technological level, the questions of the interfaces in the data transfer of the multi-disciplinary models arises, as well as of the heterogeneous data-structure of the different software, and of management of ever larger data-volumes. On the semantical 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, over reduced slab models for structural engineering for earthquake simulation, to complete spatial representation of architectural models in the full geometric complexity.

The optimal management, filtering and reliable synchronisation of such highly differentiated information in the context of in the AEC industry, still dominated by the heterogeneous software-structure, requires high effort in organisation, administration interdisciplinary communication and know-how; especially in a market that lacks a tradition and knowledge of integrated planning practice. A standard solution offering the complete software package for this large spectrum does not yet exist, and it is questionable if such solution is viable, due to the prototypic nature of construction projects.

The BIM-based software-packages that would fully support and enhance the integrated, interdisciplinary planning practice and life-cycle data integration are still rather seldom. The one-stop-shop tools for modelling of architecture, structural and MEP (mechanical and electrical) engineering, energy simulation, life cycle costing and assessment are still not available according to the requirements of planning practice and building policy. The intra-firm project-constellation and mostly changing project-stakeholders with each new project, represent challenges for interoperability of new software-tools combinations with each new project. A pre-requisite for a successful implementation of life-cycle oriented planning and management is therefore a smooth and efficient data exchange without information losses.

If the early BIM research was mainly focused on the problem-solving of the software-interoperability and efficient data exchange, the current research efforts are focusing on the change of the planning practice towards integrated design and delivery, which is not only related to the handling of technical, but even more over so to the process-related issues (Succar 2009; Penttilä and Elger 2008; Gu and London 2010). The process-reorganization addresses both the intra- and inter-firm project organization and standardization of the workflows, role descriptions and related responsibilities of the stakeholders, as well as the general commitment towards collaborative planning attitude. Rekkola et al. (2010) argue, that the actual BIM-benefit lies in the domain of

workflow and business practices therefore process-knowledge, beyond the technological issues. Within a case study of university building, they identified problems and benefits of BIM-supported integrated process by creating categories: people (competence or knowledge problem), process (work-flows, timing, contracts, roles) and technology (software). They argue that a) for enhanced integrative practice a participative process is necessary and b) 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 especially within markets still dominated by sequential design and planning method, either for holistic concepts such as Building Life-cycle Management (BLCM) (von Both 2011) or Integrated Design and Delivery Solutions (IDDS) Modell (Prins and Owen 2010), remain with the people (planning process stakeholder) and process – the process of model building of an integrated, interdisciplinary building model requires close cooperation and coordination of the planners, contractors, industry and facility managers, a highly skilled project team as well as detailed conventions on an inter-organizational level (et al. 2010, Plume and Mitchell 2007; Arayici et al. 2011).

Methods

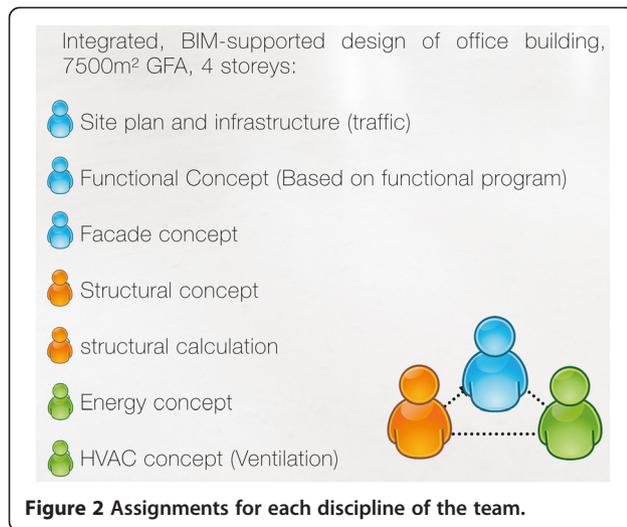
Although a large bulk of literature is implying on the benefits of BIM (Azhar 2011; McGraw-Hill Construction 2010; Becerik-Gerber and Rice 2010; Gilligan and Kunz 2007), the over-all measurement of BIM-related benefits for planning networks and practice is still difficult to justify, due to the high level of complexity of employed tools and of the process, but also due to the lack of a

standardized measuring methodology (Jung and Joo 2011; Barlish and Sullivan 2012). The issue of how to measure BIM benefits is especially important in the emerging markets, such as Austrian is, in order to enhance the adoption of the technology and more over the process in the industry. For the adoption in the AEC market the closer research of interrelations within the triangle: technology (operability) – people - process is necessary, in order to create a guideline for BIM adoption, assessment, usability, risks, and evaluation (Gu and Kerry London 2010).

In order to evaluate BIM-performance within an integrated planning process in relation to the technology-people-process triangle, we conducted an experiment with students, simulating a multi-disciplinary planning process for sustainable building within a design-studio class in the winter semester of 2012/13. The experiment is a part of an on-going research project “BIM-Sustain: Process Optimisation for BIM-supported Sustainable Design” involving cooperation of university research and BIM-software vendors and developers. This interdisciplinary collaboration of academy and industry enables development of customised strategic concepts for the individual BIM-settings within multi-disciplinary planning context. The final aim of the project is compilation of guidelines for BIM-supported design and planning. The guidelines will include the conventions for efficient data-exchange and a road-map for the standardization process at Austrian Standardisation Institute (standardization body), recommendations for the planners for the inter- and intra-firm organization of BIM-supported design process, and finally proposals for improvement of interoperability for the software-vendors; based on experiment-findings. Similar guidelines were

	Architect	Structural Engineer		Building Science (Simulation in TAS)	
	CAD	CAD	FEM	CAD	Calculation
1	Allplan	Allplan	Scia Engineer	Allplan	Allplan
2	Autodesk Revit Architecture	Autodesk Revit Structure	SOFISTIK	Autodesk Revit MEP	PLANCAL Software for Gebäudetechnik
3	GRAPHISOFT ARCHICAD 16	TEKLA	Dlubal	PLANCAL Software for Gebäudetechnik	PLANCAL Software for Gebäudetechnik
4	GRAPHISOFT ARCHICAD 16	Allplan	Dlubal	PLANCAL Software for Gebäudetechnik	PLANCAL Software for Gebäudetechnik
5	Autodesk Revit Architecture	Allplan	Scia Engineer	PLANCAL Software for Gebäudetechnik	PLANCAL Software for Gebäudetechnik
6	GRAPHISOFT ARCHICAD 16	Allplan	Dlubal	Autodesk Revit MEP	PLANCAL Software for Gebäudetechnik
7	Allplan	TEKLA	SOFISTIK	Autodesk Revit MEP	PLANCAL Software for Gebäudetechnik
8	Autodesk Revit Architecture	TEKLA	Scia Engineer	Allplan	Allplan
9	GRAPHISOFT ARCHICAD 16	Autodesk Revit Structure	Dlubal	PLANCAL Software for Gebäudetechnik	PLANCAL Software for Gebäudetechnik
12	GRAPHISOFT ARCHICAD 16	Allplan, TEKLA	Dlubal	Autodesk Revit MEP	PLANCAL Software for Gebäudetechnik
13	GRAPHISOFT ARCHICAD 16	TEKLA	SOFISTIK	Autodesk Revit MEP	PLANCAL Software for Gebäudetechnik

Figure 1 Software-combinations used by the teams.

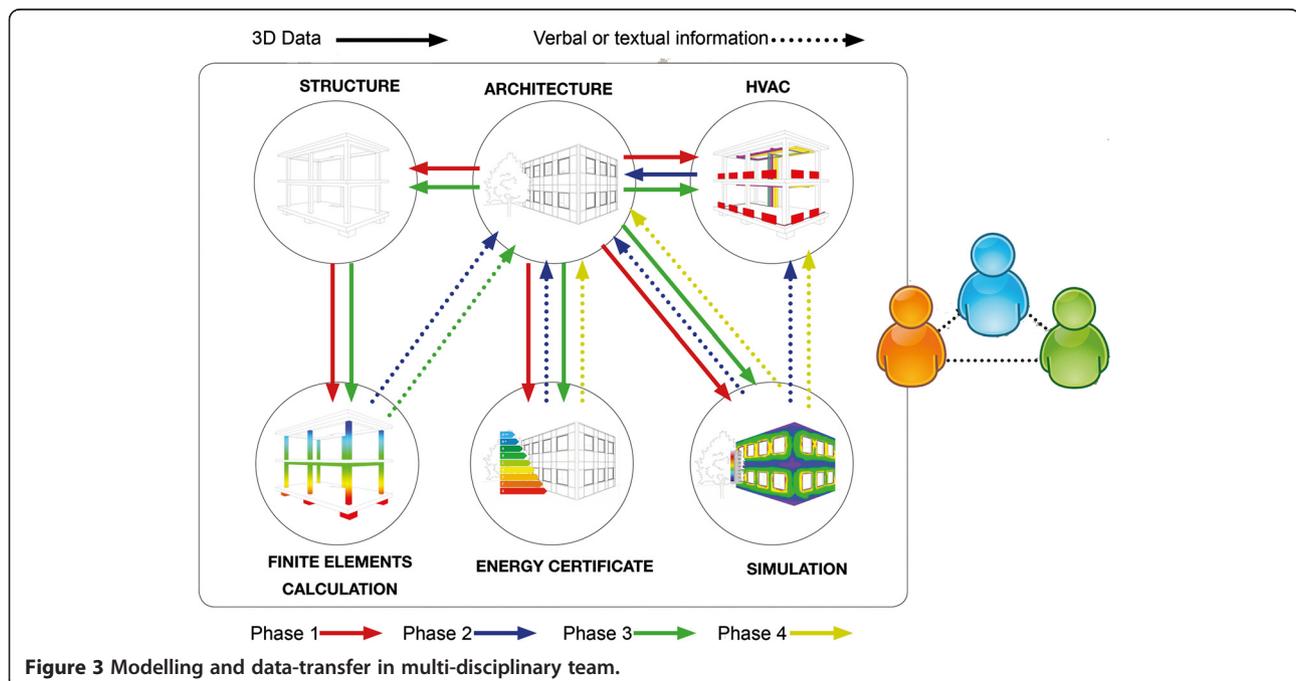


compiled by the Penn State within the Computer Integrated Construction Research Program (2012); or the Integrated Project Delivery For Public and Private Owners (2010).

The empirical research by experiment has often been employed to test of BIM-performance and capabilities. Plume and Mitchell (2007) conducted in 2004 an experiment with 23 students in a design studio setting, testing the IFC-model performance in multi-disciplinary collaboration (architecture, landscape architecture, MEP, statutory planning, sustainability and construction management.) They focused primarily on operational issues, such as building model (representation of a building model in different

tools) and IFC –server data sharing issues. They conclude that the original architectural model needs significant adaptation for the use of other disciplines or their tools. Further issue needing closer attention is model management – tracing of the changes and updates carried out on the common model. Sacks et al. (2010) carried out the “Rosewood experiment”, comparing the BIM-supported versus the traditional 2D CAD the planning and fabrication process of the pre-cast façade. BIM proved to be more efficient by 57%, however IFC proved not mature enough causing data inconsistency in transfer between architectural and engineering system. Losses in translation can be assigned to object-semantic, a similar problem addressed by the Plume and Mitchell (2007).

Sturts Dossick and Neff (2011) observed the collaboration of several teams on three real projects using a BIM-technology supported design process, focusing on people and process issues. They concluded that technology can even hinder the innovation of the design process through a too rigid corset of work-flow and knowledge exchange, hindering the exchange of tacit, informal knowledge. Their concept of “messy talk” – the informal, unstructured information exchange as often practiced in architecture and construction engineering is tested within student experiment, where geographically distributed teams work using BIM on a project in a virtual environment. They conclude that “...messy talk requires both the flexible, active, and informal setting described in the 2011 study as well as mutual discovery, critical engagement, knowledge exchange, and synthesis.” (Dossick et al. 2012).



Peterson et al. (2011) conducted a simulation of integrated project management within two classes at Stanford and TU Twente, using pre-made BIM models in Revit, Tekla and AutoCAD 2006 and 2007 (which in our understanding cannot be considered as BIM models due to the lacking of parametric characteristics), the models were imported in the various cost and scheduling software such as Primavera or Vico.

The formerly mentioned experiments and research of BIM-supported planning practice focus on evaluation of singular issues - some primarily focus on the technology performance (interoperability, building model semantics), such as Plume and Mitchell (2007) experiment and Sacks et al. (2010). Sturts Dossick and Neff (2011) on the other hand focus mainly on the process issues. The student classes carried out at Stanford and TU Twente apply the holistic evaluation, however examine the BIM-supported project management, which in terms of data exchange displays lower complexity than multi-disciplinary design, involving structural and thermal simulation, which both are based on exact transfer of geometry.

In our research, we have addressed the triangulation of the technology, people and process parameters, in order to identify how they are correlated. Therefore, through the experiment the data on a) BIM-performance in terms of data-transferability in different software-

constellations will be collected through protocols and revision of delivered models and b) the team performance using different BIM-tools will be assessed through protocols and recorded feedback workshop. The executed experiment is the first one to have a holistic approach on the evaluation of people-process-technology triangle, testing a large number of software tools (all together thirteen) and software combinations on the transfer of complex geometrical data, but also on usability.

Through exploratory research – an experiment within an interdisciplinary design class involving 40 students, the collaborative, multi-disciplinary BIM-supported planning for an energy-efficient office building is simulated. The multi-disciplinary teams consisting of: architect, structural engineer, building physicist (BS) were formed by the means of a pre-questionnaire, which questioned skill-level, experience and preference of the software. Upon the results of the questionnaire a matrix of software-combinations used by each team was compiled (Figure 1).

In the course of the experiment (design class) basically two work-flow models can be identified: One-Platform BIM (proprietary) and Open-Platform BIM (using IFC exchange format). The experiment began in September 2012, the latest available software versions were used. The Open-Platform BIM teams (Figure 1, Teams 3–13) use different, for each discipline typical (custom)

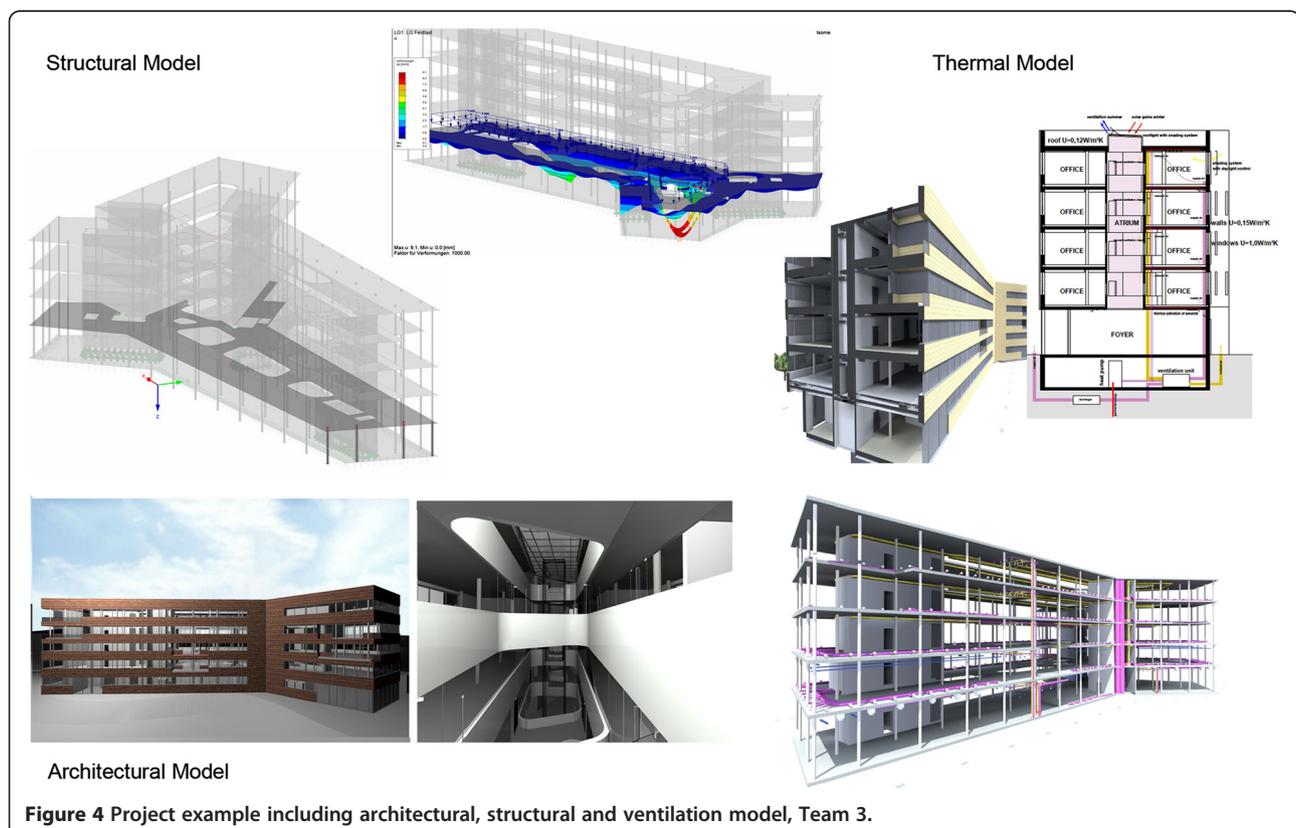


Figure 4 Project example including architectural, structural and ventilation model, Team 3.

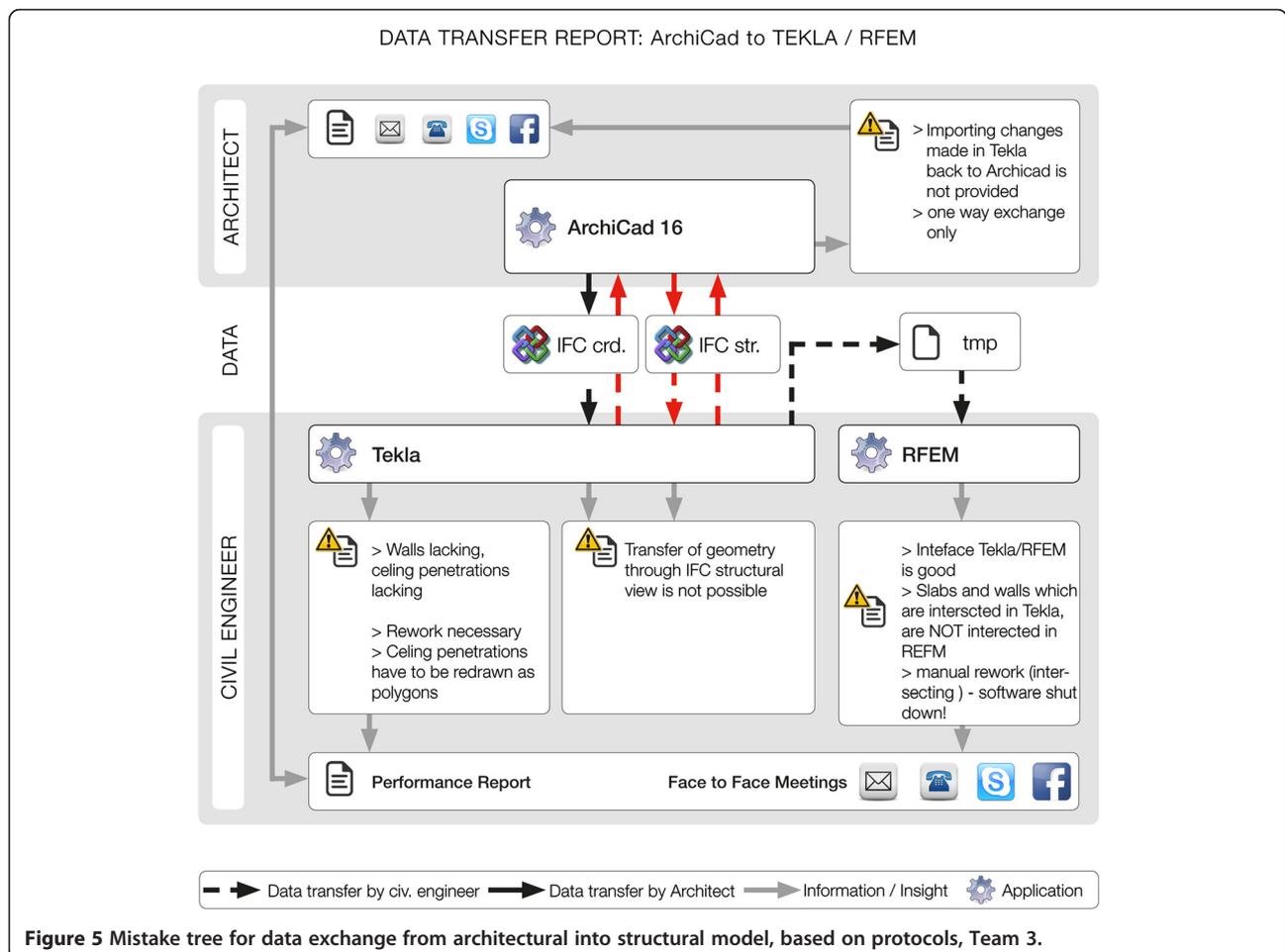
software, and work with central architectural model, exchanging the data using the IFC. By central architectural model we mean the physical, architectural model as the point of origin for the further transfer into a) structural, analytical software or b) into the thermal analysis software. The One-Platform BIM teams (Figure 1, Teams 1 and 2) work with one software family Nemetschek Allplan (2012) or Autodesk Revit (2012) using proprietary standards, again starting with architectural model.

The teams are assigned with compilation of the architectural (in Allplan 2012, Revit Architecture 2012 or ArchiCAD16 2012), structural (Simulation in Dlubal RFEM 2012; Sofistik 2012 or Scia 2012, drawings in Tekla Structures 2012; Revit Structure 2012 or Allplan 2012), and ventilation (in Plancal 2102 or Revit MEP 2012) models, as well as the light simulation and energy certificate (Figure 2). For the thermal simulation TAS 9.2 (2012) is used, for light simulation Dialux 4.9 and for energy certificate Archiphysik 10. Planning documentation was handed out, consisting of a functional programme, site-plan with orientation and set origin, layer-structure and colour scheme for latter room-stamps.

The time-schedule of the design-class is strictly organized; the experiment is taking place in the period of one semester. We have organised three presentations, where in the first one the architectural model is presented, in the second presentation the structural and thermal and in the final presentation the optimised, full model containing all the information (Figure 3). Between the presentations the reviews with teachers as well as tutorials provided by software vendors are taking place.

Figure 4 presents the final model as delivered by one of the student-teams (Team 3) at the final presentation, including architectural model with visualization, model of loadbearing structure and maximal slab deformation under load, model of ventilation and energy and HVAC concept (Figure 5).

On the level of technology, the experiment is examining the fitness of various software constellations for data transfer, import and export, documenting the data loss and needed rework if data-loss has occurred. In terms of process, the efficiency and efficacy of multi-disciplinary teams working with BIM: efficiency of the employed BIM methods for data-exchange, communication effort, and work-allocation (work-flows); and on people-level



satisfaction and conflict levels are assessed. Through the mandatory protocols and time-sheets the problems related to the technology (data-transfer inconsistencies or losses, semantics) but also to the process-people related problems (conflicts, communicational difficulties, lack of work-flow definitions or responsibilities etc.) can be tracked (Figure 4). Additionally, an e-learning platform has been set up, with a forum for tutor feedback as well as for student-communication, scheduling and posting of tasks is taking place.

Results and discussion

People-related problems

The first data on satisfaction was gathered at the point close to the second presentation of structural and thermal models – basically one data exchange step has taken place – export from architectural model towards FEM (Finite Element Method) Software and thermal simulation software. In the student workshop through rough questionnaire answered by 19 students (three architects, two engineers, 14 BS), a) satisfaction with BIM-technology, b) satisfaction with teamwork, c) satisfaction with process (work-flows), d) conflict-level and e) stress-levels were questioned on the scale ranging from 0 (low) to 6 (high) (Table 1).

The general BIM-technology dissatisfaction resulted from data transfer problems, as reported especially by the BS students using TAS simulation software, where data exchange uses gbXML standard. Mostly all of the architectural models had to be newly drawn in TAS, due to the data loss or wrong interpretation by TAS. It was reported by the students that the time effort for the adaptation of the imported model was equal to the time effort for creation of the new model (two days).

Technology-related problems

When passing architectural geometry into structural analysis software two types of IFC-Files are used: Coordination View and Structural Analysis View (Building Smart 2013). Software for Finite Element Method (FEM) calculation requires the Structural Analysis View of an IFC-File. But only a few CAD-Programs support the export of this type (Table 2). Additionally, not every FEM-Software

Table 1 Results of the first questionnaire

Question	Mean value	Median value
Satisfaction with BIM	1,89	2
Satisfaction with teamwork	3,84	4
Satisfaction with process	2,37	2
Stress level	4,16	5
Conflict Level	1,37	1

Table 2 Compatibility with IFC – Structural Analysis View

CAD		FEM	
ArchiCAD		Dlubal RFM	↔
Allplan		Scia Engineering	↔
Revit	↔	Sofistik	↔
Tekla	↔		

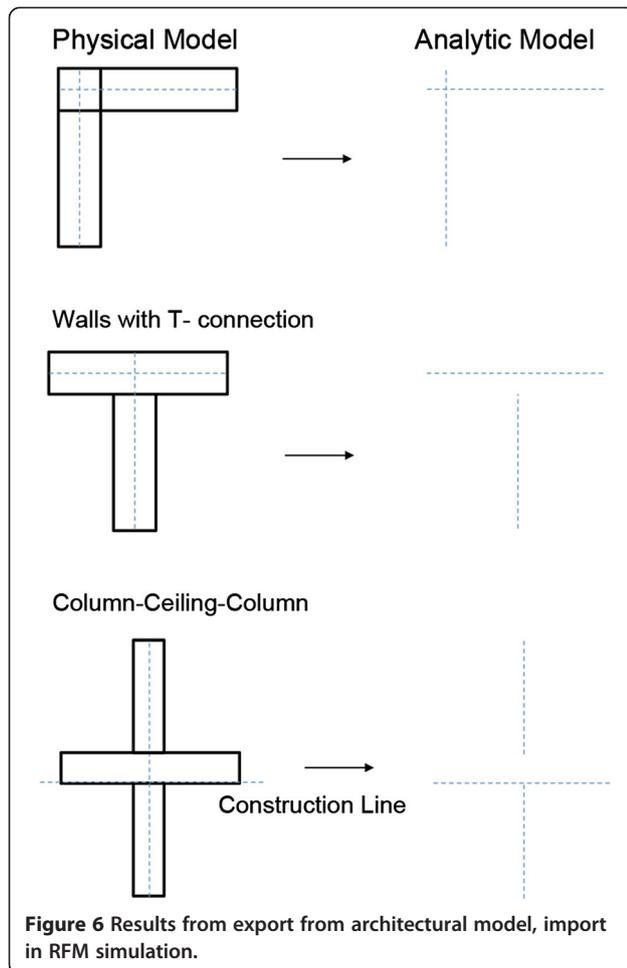
supports the import of the physical model (Coordination View –Table 3). As a consequence, an intermediate step is needed to transfer the model from architecture to structural model: an import into a program which can import and export both types of files, a step which goes along with a loss of information (Figure 6). Figure 5 displays a few typical problems when importing from physical (architectural) model into analytic model (structural engineering) – the construction line of intersecting walls is not intersected in the analytic view, which requires remodelling after the import of physical model. This problem originates in the semantics of modelling, namely that architectural models are a set of spaces which require closed elements, whereas structural engineers model a building as a set of loadbearing elements, slabs, columns and plates. Due to this incompatibility it was i.e. not possible to import an Allplan-Model as an IFC-File into the FEM-Software Sofistik, because both programs support the type which cannot be read by the other one.

The IFC 2x3 (structural analysis view standard) still leads to variety of problems: especially more complex geometry such as sloped or rounded walls, roof elements and openings are very likely to cause problems or even disappear when being imported.

For example, problems were the identified with Tekla Structures: stairs become boxes, openings disappear, and round elements become rectangles. Findings from data transfer from Allplan to Scia: when round walls are used, the model takes long period of time to get imported in Scia (hours). To illustrate further problems, we assembled a scene containing several pertinent elements, exported an IFC file and imported this into different structural analysis programs. Figure 7 illustrates the architectural model; Figures 8 and 9 the interpretations by different FEM software - a completely different result when importing the exact same IFC file.

Table 3 Compatibility with IFC – Coordination View

CAD		FEM	
ArchiCAD	↔	Dlubal RFM	←
Allplan	↔	Scia Engineering	↔
Revit	↔	Sofistik	
Tekla	↔		



Considering the data transfer from architectural model to thermal simulation as the main problem appeared the incompatibility of TAS software with the IFC standard. TAS can only import the proprietary gbxm interface, which again can only be produced by Revit. When working with ArchiCad, Encina plug in for creation of gbxm can be used. In any case – using direct transfer via gbxm or via Encina, numerous problems related to the geometry were

identified: walls are not transferred correctly, and were reworked in TAS instead of Revit; missing windows, etc.

Conclusion

This paper presented the first results of an experiment: simulation of BIM-supported multi-disciplinary design for energy-efficient office building, using various BIM-tools for architectural, structural, energy and ventilation modelling, and thermal simulation. For both structural engineering and thermal simulation, the data transition becomes difficult as soon as there is complex geometry involved, such as round walls, which have caused problems in all software-combinations. A problem of semantics of building models is a constant issue – architects use different room-stamps than BS, the pillars are drawn from slab to slab whereas structural engineers work with one continuous pillar from top to bottom slab. Further difficulties originate from incompatible software-combinations such as Allplan to Sofistik, or ArchiCAD to Sofistik (see Tables 2 and 3). For building physics this applies to the Allplan to TAS, since TAS does not support IFC standard, and Allplan does not have plug in or possibility of producing a gbxm file. Such constellations can lead to significant problems in the current BIM-supported planning practice, if e.g. an architectural office using ArchiCAD has to work with the structural engineers using Sofistik, since the data transfer will not be possible and purchase of additional software or of additional “BIM-services” will lead to increase of the planning costs.

In terms of comparison of One-Platform BIM versus Open-Platform BIM, it can be concluded that One-Platform BIM constellation, as closed system, does not exist on the market yet. The One-Platform BIM Software (Nemetschek Allplan and Autodesk Revit) both leave the original platform in order to conduct structural calculation and simulation; however offer proprietary interface to these software or even plug-ins (Revit to Sofistik). Even with proprietary interfaces the complex geometry causes problems in transfer through very long

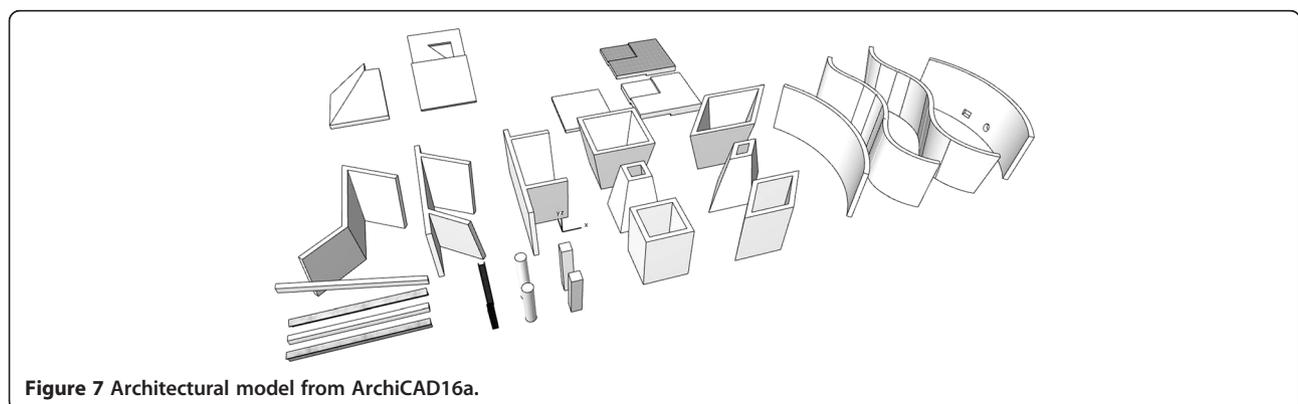


Figure 7 Architectural model from ArchiCAD16a.

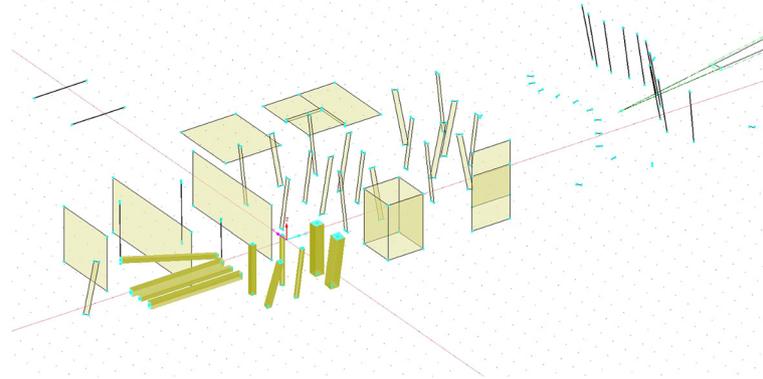


Figure 8 Import in Dlubal REFEM.

transfer-time (Allplan to Scia). The Open-Platform BIM, using IFC interface has proved as time-efficient and exact in transfer, if there is a standardised setting used for IFC transfer from architectural in the structural model and under condition that simple geometry is involved.

Our findings in comparison to the student experiment executed in 2004/05 by Plume and Mitchell (2007) show that ArchiCAD has made significant progress (at that time it was very limited in exporting an IFC file, today it is the software with the best functioning IFC translator); however the question of the building-model semantics for different disciplines and the difference in the grade of required detailing for each model has not been solved yet. Our findings basically confirm the findings of the Rosewood experiment – we experience similar data losses and wrong interpretations at export and import of IFC; Rosewood experiment works with the same version of IFC. Further development of IFC is urgently necessary, since software-side interfaces are still underdeveloped, as well standards IFC 2×3 and 2×4

are still lacking many information (e.g. surface materials (announced for 2×4), real window frame geometry, 3D wall/slab layers.)

The satisfaction with the BIM-technology at intermediate stage of the design class has been reported as low, due to the very difficult data-transfer, inconsistency and data losses, especially so for the thermal simulation, where models had to be redrawn.

Processes-satisfaction has been found as weak: workflows are poorly organised among team-members, there are many problems in allocation of responsibilities. In many teams it is expected from the architect to undertake all of the major adaptations of the architectural model in order to make it fit for the transfer (the consultants are not ready to adopt the imported models). Teams often report that some team members are often not available.

On the level of people-related problems, despite the reported low conflict level team-satisfaction is only average. We were able to observe a lack of team affiliation

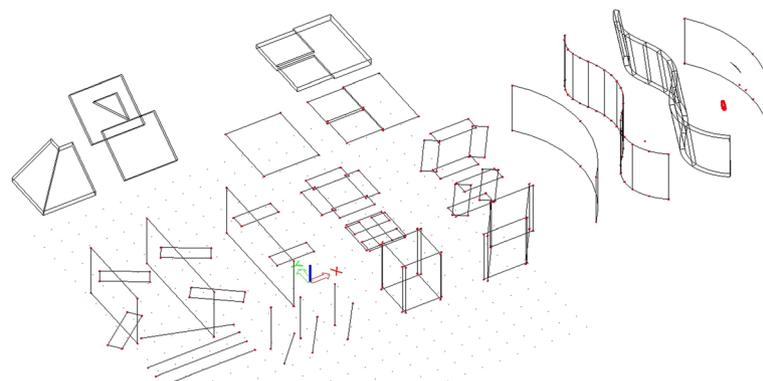


Figure 9 Import in Scia.

with most of the teams, often a bonding between two disciplines can be observed and the third one is not playing along. This phenomenon might be referred to the lack of an organised kick off meeting. Some of the problems originate in the lack of professional knowledge (e.g. design of an office building or energy efficient facade) and in general to the lack of experience and knowledge in collaborative planning. In some cases the lacking of the team-building/bonding, and following the aim to „just finish the project“ led even to an increase of fragmentation of the design process (architect defines everything, the consultants only optimise in following steps), which is exactly the opposite of the expected BIM-effect. We can confirm the argument by Sturts Dossick and Neff (2011) – BIM-technology is advantageous for exchange and presentation of explicit knowledge, but does not support the tacit knowledge of how the buildings are designed. Our first findings also imply that BIM-technology does not support integrated practice by itself, for the support of the collaboration other means are necessary such as well organised formal (kick-off meeting) and opportunities for informal communication (von Both and Zentner 2004).

Finally, BIM as presently used, hardly changes the work-flow between architects and structural engineers, not only due to technical interface limitations but even more so due to a logical contradiction. FEM models require a far lower level of detail than the architectural model delivers, so any automatically converted model necessarily needs to be post-processed manually by the engineer in order to simplify the model for reasonable meshing and resulting calculation times. When importing a coordination view IFC into calculation software, the discretization of architectural models into FEM-suitable meshes is carried out within the import and is hence forced to accept the model geometry “as it is”. For example, a small rounded wall opening, let’s say for a drainage pipe, will produce a complex mesh in the FEM model when being imported. For the structural system however, this opening is irrelevant, but still causes enormous effort in calculation and will hence be deleted by the engineer. Once simplified, such a wall element cannot be re-exported into the central model, because otherwise the opening would be missing. Vice versa, once the architectural model changes and is re-imported, the opening is back. The possible solution is either the radical improvement of FEM-software performance concerning calculation time for meshing; or enabling of the FEM software to directly manage the referential architectural model. The problem of bi-directional model-management remains one of the greatest challenges, not only because of the technical issues, but mostly because of the process issues:

definition of the rights (who may change what and when?) related to the change management.

As possible solution of the bi-directional model management the model server architecture is proposed (Kiviniemi et al. 2005). Jørgensen et al. (2008) develop different scenarios for the use of separate models, separate models with aggregate model and one shared model, where rights, accessibility and ownership is exactly defined, however with the limitation of the model server using ArchiCad, as the only software properly handling the IFC import and export.

As first future step, detailed statistical analysis of the mandatory protocols and time-sheets will be carried out in order to gain more knowledge on performance of One-Platform BIM versus Open-Platform BIM, as well as of communication effort, work-allocation, satisfaction and conflict levels. The recorded feed back workshop (interviews) will be coded and analysed, to gain qualitative information on process efficacy, not only efficiency.

In September of 2013 the second experiment will be conducted, in the framework of second multi-disciplinary design class, where we will be able to use the first findings and propose a framework for data-exchange procedures as well as for careful design of communication, including a kick-off workshop for team building. Finally we will compare the results of the two experiments, evaluate the benefits and compile the guidelines for the planning practice and standardization bodies.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

IK organized the experiment, carried out the survey, evaluated the results and drafted the manuscript. LO and CM carried out the experiment, compiled and evaluated the data. CA supported the experiment-design. All authors read and approved the final manuscript.

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References

- Allplan. (2012). <http://www.nemetschek-allplan.at/software/architektur/allplan-architektur.html>, last access December 2013.
- Arayici, Y, Coates, P, Kiviniemi, A, Koskela, L, & Kagioglou, M. (2011). *BIM implementation and Adoption Process for an Architectural Practice*. USA: FIATECH Conference.
- ArchiCAD16. (2012). <http://a-null.com/ARCHICAD16.php>, last access August 2013.
- Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership Management Engineering*, 11(3), 241–252.

- Barlish, K, & Sullivan, K. (2012). How to measure the benefits of BIM — A case study approach. *Automation in Construction*, 24, 149–159.
- Bazjanac, V, & Kiviniemi, A. (2007). *Reduction, Simplification, Translation and Interpretation in Exchange of Model Data*. Maribor: CIB W78.
- Becerik-Gerber, B, & Rice, S. (2010). The perceived value of Building Information Modelling in the U.S. Building Industry. *Journal of Information Technology in Construction*. ISSN 1874–4753, at <http://www.itcon.org/2010/15>.
- Building Smart. (2013). <http://www.buildingsmart-tech.org/specifications/ifc-overview>, last accessed August 2013.
- Computer Integrated Construction Research Program. (2012). *BIM Planning Guide for Facility Owners, Version 1.01, May*. University Park, PA, USA: The Pennsylvania State University. <http://bim.psu.edu>.
- Dlupal REFM. (2012). <http://www.dlupal.de>, last access August 2013.
- Dossick, C, Anderson, A, Iorio, J, Neff, G, & Taylor, J. (2012). Messy Talk and Mutual Discovery: Exploring the Necessary Conditions for Synthesis in Virtual Teams. In *Working Paper Proceedings*. The Netherlands: Engineering Project Organizations Conference Rheden.
- Fellows, R, & Liu, AMM. (2012). Managing organizational interfaces in engineering construction projects: addressing fragmentation and boundary issues across multiple interfaces. *Construction Management and Economics*, 30(8), 653–671.
- Forlati, S, et al. (2006). *Getting Started*. Wonderland Association, Platform for Architecture.
- Gilligan, B, & Kunz, J. (2007). *VDC Use in 2007: Significant Value, Dramatic Growth, and Apparent Business Opportunity*. Stanford University: CIFE Technical Report #TR171.
- Gu, N, & Kerry London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19, 988–999.
- Jørgensen, KA, Skauge, J, Christiansson, P, Svidt, K, Birch Sørensen, K, & Mitchell, J. (2008). Use of IFC Model Servers Modelling Collaboration Possibilities in Practice. In *Aalborg University, Department of Production, Department of Civil Engineering, Aarhus School of Architecture, Department of Building Design*.
- Jung, Y, & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction*, 20, 126–133.
- Kiviniemi, A, Fischer, M, & Bazjanac, V. (2005). Integration of Multiple Product Models: IFC Model Servers as a Potential Solution. In *Proc. of the 22nd CIB-W78*.
- McGraw-Hill Construction. (2010). *The Business Value of BIM in Europe. Smart Market Report*. McGraw-Hill Construction Research and Analysis Aliances.
- Nemetschek Allplan. (2012). <http://www.nemetschek-allplan.at>, last access December 2013.
- Owen, R, et al. (2010). Challenges for integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, 6(4), 232–240.
- Penttilä, H, & Elger, D. (2008). New Professional Profiles for International Collaboration in Design and Construction. In *26th eCAADe Conference Proceedings, Antwerpen (Belgium) 17–20 September 2008* (pp. 333–340).
- Peterson, F, Hartmann, T, Fruchter, R, & Fischer, M. (2011). Teaching construction project management with BIM support: Experience and lessons learned. *Automation in Construction*, 20, 115–125.
- Plume, J, & Mitchell, J. (2007). Collaborative design using a shared IFC building model—Learning from experience. *Automation in Construction*, 16, 28–36.
- Prins, M, & Owen, R. (2010). Integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, 6(4), 227–231.
- Project Delivery For Public and Private Owners. (2010). *NASFA, COAA, APPA, AGC and AIA*. www.aia.org/ipd.
- Rekkola, M, Kojima, J, & Mäkeläinen, T. (2010). Integrated Design and Delivery Solutions. *Architectural Engineering and Design Management*, 6(4), 264–278.
- Autodesk Revit. (2012). <http://www.autodesk.de/products/autodesk-revit-family/overview>, last access December 2013.
- Revit Architecture. (2012). <http://www.autodesk.de/products/autodesk-revit-family/features/architecture>, last access December 2013.
- Revit Structure. (2012). <http://www.autodesk.de/products/autodesk-revit-family/features/structure>, last access December 2013.
- Revit MEP. (2012). <http://www.autodesk.de/products/autodesk-revit-family/features/mep>, last access December 2013.
- Rizal, S, & van Berlo, L. (2010). Tool for Benchmarking BIM Performance of Design, Engineering and Construction Firms in The Netherlands. *Architectural Engineering and Design Management*, 6(4), 254–263.
- Sacks, R, Kaner, I, Eastman, MC, & Jeong, YS. (2010). The Rosewood experiment — Building information modelling and interoperability for architectural precast facades. *Automation in Construction*, 19, 419–432.
- Scia. (2012). <http://www.scia-software.de>, last access August 2013.
- Sofistik. (2012). <http://www.sofistik.de>, last access August 2013.
- Sturts Dossick, C, & Neff, G. (2011). Messy talk and clean technology: communication, problem-solving and collaboration using Building Information Modelling. *Engineering Project Organization Journal*, 1(2), 83–93.
- Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, 18, 357–375.
- TAS. (2012). <http://www.edsl.net/main/Software.aspx>, last access August 2013.
- Tekla Structures. (2012). <http://www.tekla.com/>, last access August 2013.
- von Both, P. (2011). Produktdatenmodellierung - aktuelle Entwicklungen und Möglichkeiten der Vernetzung von Produkt- und Prozessebene. 1. In *Internationaler BBB-Kongress, Dresden 15.09.2011*.
- von Both, P, & Zentner, F. (2004). LUZIE Lebenszyklusbezogene Einbindung der Zielplanung und des Zielcontrolling in den Integralen Planungsprozess. In *Technical report, FIA Projekt, Bundesministerium für Wirtschaft und Arbeit, Bundesministerium für Bildung und Forschung*.

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Designing and evaluation procedures for interdisciplinary building information modelling use—an explorative study

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Building information modelling (BIM) tools are increasingly present in the architecture, engineering and construction industry. This software tool chain requires not only new knowledge on the level of technology, but also people with knowledge related to skills and re-configuration of the process. There is hope that BIM tools will increase the degree of process integration and support the multidisciplinary planning practice. In order to test this assumption and gain first insights in multidisciplinary collaborative planning process using various BIM tools, an experimental study in a university course on multidisciplinary design was carried out. The results of our analyses indicate that BIM software is perceived as highly useful but not interoperable. The lack of interoperability and resulting problems are also the main topic of focus group discussions conducted after the course. Architects are less satisfied with the interdisciplinary planning process. Early coordination, concerning organization and software, proved positive for later collaboration.

Keywords: BIM, interdisciplinary planning, process integration, experiment.

Introduction

The architecture, engineering and construction (AEC) industry faces a need for integrated planning procedures that enable efficient collaboration and knowledge sharing among the disciplines involved. Building information modelling (BIM), that is, the joint usage of digital building models throughout the building life cycle by the involved actors, is argued, in practice and academia, to enable collaborative planning by facilitating communication and information exchange between diverse participants in the planning process. The usage of BIM should improve efficiency and quality significantly, while reducing the planning time simultaneously.

BIM is expected to bear a large potential for the enhancement of design integration, thereby enabling a shift from fragmented design tradition that is still largely dominating the AEC industry (Fellows and Liu, 2012). Advantages of BIM can be identified on

two levels—real and virtual. In real world, through software and model interoperability, project-value is increasing along the fragmented AEC value chain, enabling the communication and collaboration of different tools and stakeholders. On the virtual level, simulation and therefore optimization of construction process is possible in the early design phases, at still low cost (Grilo and Jardim-Goncalves, 2010).

Rekola *et al.* (2010) argue that integrated design is still handled rather loosely in practice—often the creation of single BIM model is sufficient for the project to be referred to as integrated project, regardless of actual interdisciplinary data sharing and model use. Former BIM research has largely focused on solving of technical issues related to the data exchange and creation of functional interfaces. However, current research emphasizes that process-knowledge beyond technological issues, like workflow management and business practice accommodate the actual benefits of BIM. Rekola *et al.* (2010), for example, identify problems and benefits of

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BIM-supported integrated planning processes in the following areas: (i) people (competence or knowledge problem), (ii) process (work-flow, timing, contracts, roles) and (iii) technology (software). They argue that for enhanced integrative practice an interrelation of people, process and technology is compulsive. The lack of knowledge of BIM-supported process and related people-problems in their opinion causes the slow BIM adoption that can currently be observed in practice. Moum (2010) goes even further in her study of five-design team stories using 3D BIM in an interdisciplinary setting, claiming that technology issues are secondary, and non-technological issues are the central problem in BIM-supported design. The nature of architectural design, based on tangible ‘baking bread’ and intangible ‘playing jazz’ capabilities, makes the successful and efficient BIM tools implementation particularly difficult, in which technology usability, user behavior and team interactions are interlaced in multiple ways and require careful balancing across these two processes.

BIM is experiencing a slower rate of implementation in Europe than in the USA, especially in Central Europe (McGraw-Hill Construction, 2010). Given the lack of best practices in the Central European planning tradition (involving architects, planners and contractors), we decided to accomplish an explorative study to explore potentials and deficits of BIM in the multidisciplinary design process within design studio class with student participants. BIM in teaching is already a relatively well-established method, especially in the field of construction management. Peterson *et al.* (2011) focus on teaching project management methods using BIM tools, in single-disciplinary setting, extracting project management relevant data (scheduling, masses for costs) from architectural models and transferring the data in various project-management tools. Hyatt (2011) uses BIM tools for scheduling, LEED certification scheduling and 4D simulation. Both authors, Peterson *et al.* and Hyatt conclude that ‘real’ tools are of significant importance—the work experience in the first case or the field trip experience in the second are the crucial factors for learning or grasping of optimization potential of a project much more than technology. Poerscheke *et al.* (2010) study multidisciplinary design (architecture, landscaping, structural, construction, mechanical and electrical engineering) in which students optimize a given pre-design of an elementary school in collaborative manner for usability, sustainability and so on. The intention of this research is twofold: to test BIM tools for fitness for each discipline on the one hand and the interdisciplinary collaboration on the other. They conclude that BIM and simulation tools are useful for enhancement of analysis and synthesis but do not enhance creativity, the actual driver

for idea-generation is the interdisciplinary collaboration. Plume and Mitchell (2007) test in their course the interoperability of BIM tools via the IFC interface, again using given preliminary projects. Students of various disciplines perform cost estimation, thermal simulation, and acoustic analysis using a common model via an IFC model server. This course dates back to winter term 2004, where the technical possibilities of the main modelling tool, *ArchiCad*—the supported IFC version—were still limited, and many of the addressed problems, such as versioning, have been solved. However, many of the problems of the semantic nature still remain unsolved—for example, the definition of the ‘room’ being different for architects and building physicist. (Kovacic *et al.*, 2013). Dossick *et al.* (2012) focus on the analysis of communication and creation of new knowledge in spatially distributed student teams that collaborate in a virtual environment, compiling 4D scheduling and organizational analysis. In this domain, modelling in real time actually supports the messy talk and thereby increases creativity.

None of the above discussed BIM teaching approaches focuses or actually deals with the process of initial, collaborative building design. These instead apply either prefabricated building models and designs or in later design phases where the architectural design is completed, and architectural model serves as a knowledge base for project management tasks (scheduling, cost management). There is still lack of knowledge about the creation of the initial building design, its simulation and optimization in a collaborative manner using the various BIM tools to support both the improvement of the building quality and the planning process quality.

Research design

In the evaluation of BIM performance in multidisciplinary design process, we primarily aimed at examining the role of BIM in the integrated design process in the earliest stage, in which the architectural model is initially created including structural predesign and energy (HVAC) concept. Further aim was to examine the fitness of BIM tools for requirements of each discipline concerning data-exchange. Thereby, both technical issues, such as usefulness of tools and interoperability in heterogeneous software environment, as well as non-technical issues such as diverging professional languages and semantics, communication and organization, play equally important roles. As framework for the evaluation, the triangle ‘technology–people–process’ was used, as research shows that despite the focus on development of technology in BIM research (software interoperability, advancement of singular

Table 1 BIM tool constellations

Team	Architectural model CAD	Structural model CAD	Engineering FEM	Building science (thermal simulation: TAS; energy performance certificate: Archiphysik; daylight simulation: Dialux)	
				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

models, versioning and model sharing), the actual success of implementation largely depends on people (skills, understanding, capacities) and process (management strategy, process design) (Gu and London, 2010; Arayici *et al.*, 2011; Singh *et al.*, 2011).

For this purpose, we conducted an exploratory study with graduate students in a design studio class: 'Interdisciplinary Design Concepts using BIM'. A total of 39 students from architecture, structural engineering and building science collaborated in 11 multidisciplinary teams, each group used a different BIM software constellations. The design class was organized and supervised by three departments of the Vienna University of Technology: The Department for Industrial Building, Faculty of Civil Engineering, Department for Building Physics, Faculty of Architecture and the Department for Management Sciences, Faculty for Mechanical Engineering which were in charge of the evaluation of the experiment.

The teams were given an assignment of a sustainable office building design, for which they were provided with a functional program, site-plan with orientation and set origin, layer-structure and colour scheme for latter room-stamps. The students were assigned to teams—each featuring a different combination of BIM software for architecture, civil engineering and building science as shown in Table 1—according to their software experience based on a self-evaluation in a pre-experiment questionnaire. Each team used a different combination of BIM-software for the architectural model, the modelling and calculation of load bearing structure and the thermal and daylight simulation, as well as ventilation calculation, simulation and

modelling. The task of the teams was to deliver a preliminary integrated design, comprising architectural and functional designs, load-bearing structure, HVAC (ventilation) concept and energy concept together with a proof of concept (simulation and optimization)—shown exemplarily for one of the groups in Figure 1. The teams had to deliver architectural, structural, thermal and ventilation models, as well as thermal simulation and energy certificate in collaborative manner.

Teams and collaboration

The class involved 13 architects, 11 civil engineers and 15 building physicists, working in 11 teams, each team comprising at least one of every discipline, several groups comprising 2 building scientists and 2 architects.

The time-schedule of the design-class was strictly organized—the course and experiment took one semester. The class was structured as succession of weekly feedback sessions, as well as two intermediate and one final presentation. The two intermediate presentations were at the point in time succeeding the interdisciplinary model exchange. The first presentation included the presentation of digital architectural model and of structural and energy concepts, the second included the architectural and structural models and energy simulation, and the final included the optimized integrated model with thermal simulation results. In between the weekly feedback sessions, the software training crash-courses took place, where supporting software vendors introduced the specific BIM software functionalities and provided data exchange support.

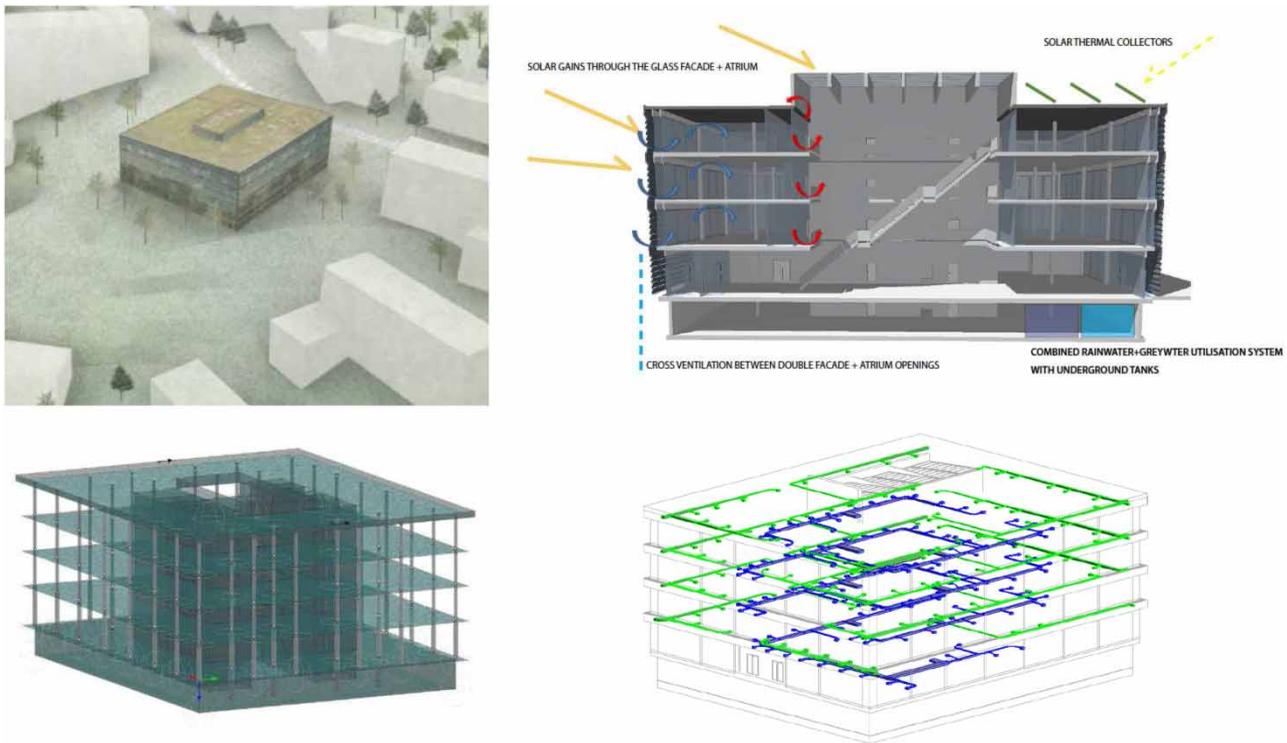


Figure 1 Exemplary resulting models of a student-project: architectural, structural, energy concept, ventilation

Besides to the software training, the students were given an introductory lecture on BIM basics and principles.

After assigning the students to the teams and to the task, the teams were left to themselves in terms of organization and coordination. The only obligatory meeting was the Friday discussion session, where attendance of the complete team was required, as well as the attendance of the two intermediate and one final presentation required.

Results and discussion

Our analyses of the technical and the interpersonal aspects of the multidisciplinary-integrated planning processes in the 11 groups of the experiment were based on the several data collected during and after the course. The experiment was evaluated on the level of people, process and technology, via protocols and time (self-)assessment, post-questionnaires concerning the BIM software and the BIM planning process and outcome, as well as focus group discussions with the representatives of the three disciplines after the experiment. Observations of the course instructors are addressed later in this section.

The students were keeping and delivering time reports not only to determine the efficiency, but also

to allocate temporal resources spent on specific activities (communication, coordination, modelling, technical problems). Additionally, participants kept protocols which allowed not only to uncover problems related to the technology (data exchange, data transfer problems), but also people- and process-related issues (conflicts, communication difficulties, lack of workflow definitions, etc.).

The time reports included the time categories: software training, design (generating ideas, sketches, modelling), technical planning (analysis and calculation, model adaptation, preparation of the presentation), weekly feedback session, technical problems (online support of the vendors, model exchange related problems, model adaptation for import/export, problem solving) and organization (direct and indirect communication, meetings)—see Figure 2 for an exemplary Pareto-diagram of the total work time spent by one of the groups on these activity categories. The results for time assessment vary between groups; however, a consistent observation is that most of the time is used for the technical planning, followed by technical problems.

After the experiment, a questionnaire-based survey was conducted, as well as three focus group discussions, one with which each of the three disciplines architects, civil engineers and building scientists. A focus group is a qualitative research method in which groups of

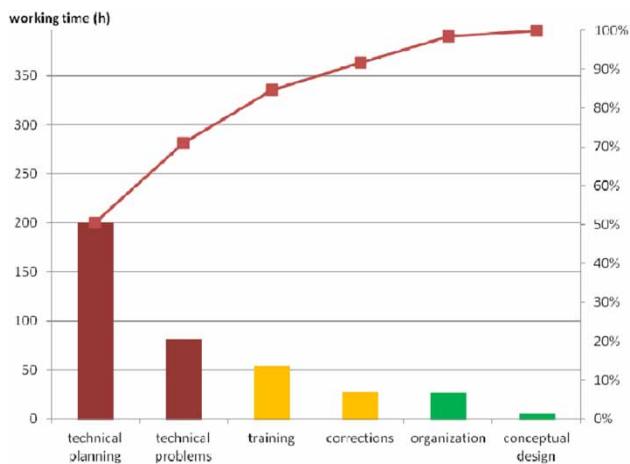


Figure 2 Exemplary Pareto-diagram of time assessment (Group 2)

people are asked about their perception, opinions, beliefs and attitudes towards products, concepts, ideas and so on (Marshall and Rossman, 1999). Questions are asked in an interactive setting and participants can freely talk with each other. The method originates from marketing research, but can also be used for usability engineering of software and web sides (Nielsen, 1993).

The focus group discussions were analysed by means of content analysis (Koeszegi and Srnka, 2007) by two independent coders in a four-step procedure. First the audio records were transcribed, followed by a separation of the whole content into thought units. In a third step, a category scheme was developed based on theoretical considerations (deductively) and the data at hand (inductively) (see Table 2). In a last step, the data is coded. The quality of steps two and four are controlled by statistically measuring the inter-coder unitizing and coding reliability to secure objectivity of the content analysis.

The results of this content analysis procedure are summarized in Figure 3. The focus group discussions showed that issues of interoperability dominated the focus groups. Early coordination (organization and software) proved positive for later collaboration. The positive experiences outweigh the negative, especially for the structural engineers and building science. This is intuitive, as these are the professions that benefit from BIM, even though they do not create the original BIM. Time pressure and stress were noted in later planning phases, which calls for carefully designed time and process management.

The post-questionnaires assessed satisfaction with process ('I have performed my tasks efficiently'), with result ('The aims that I have set have been achieved')

Table 2 Content analysis coding categories

Category	Description	Example
Ease of use	Discussion concerning the ease of use of BIM tools	'So to perform a change in SCIA is super easy'
Usefulness	Discussion concerning the usefulness of BIM tools	'I do not think it is good that it is possible to make a change in SOPHISTIC, or that this is changed automatically'
Interoperability	Discussion concerning the interoperability of BIM tools	'He gives a feedback back in REVIT. It says: 'there is a problem with a building part' you have to have a look at it!'
Training	discussion of BIM and software training	'Training helped, but I would not be able to learn a software, without a project'
Software support	Discussion of software support	'I had a mistake, as I wanted to make an opening in the slab for the core, and the openings were not visible, and I have asked the software support'
Technical discussion	(Detailed) discussion of technical issues	'What FE net size did you set?'
General discussion	General discussion concerning BIM	'BIM is gains increasing importance in practice, because ...'
Negative collaboration	Expression of negative experiences in collaboration with other disciplines	'Problems ... came up (...) with static'
Positive collaboration	Expression of positive experiences in collaboration with other disciplines	'But with the architect it worked very well, so (...)'
Suggestion	Suggestions for general improvements or solution of specific problems	'What could be useful when organizing a project like this would be that architects have already finalized their part'
Confirmation	Filler words and general acceptance	'That is right'
Misc.	Off topic discussions	—

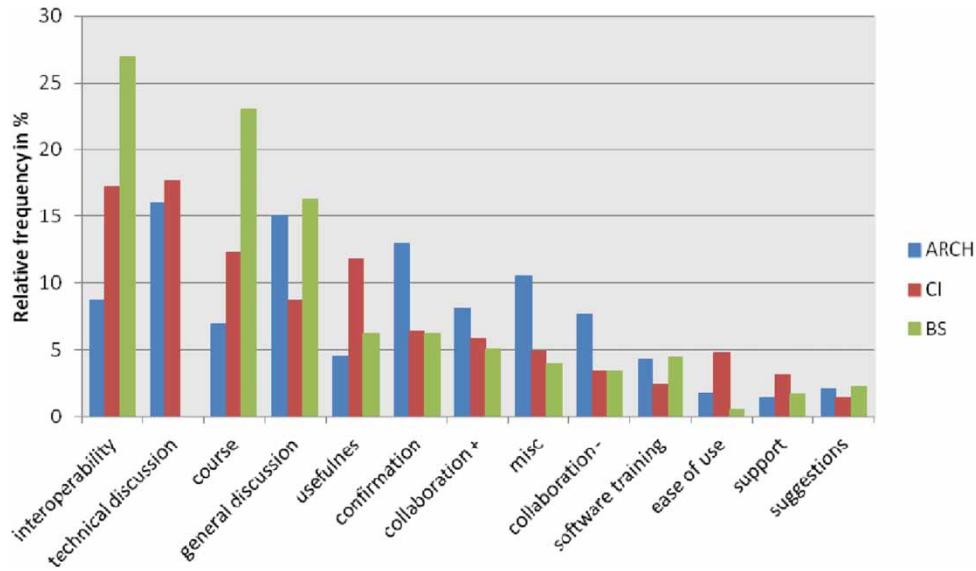


Figure 3 Content analysis of focus group discussions

and cooperation. The software-related questionnaire included questions related to ease of use (“The software increases my productivity”), and usability (“In total I think the software is useful for my tasks”) according to technology-acceptance model (TAM) of Davis (1989) model and additionally interoperability as a BIM specific feature of software applications. These latent constructs were measured by multiple items on a 5-point Likert scale ranging from low/disagree (1) to high/agree (5).

The satisfaction with the process and result is generally relatively high (see Figure 4) in all of the disciplines, however, architects (usually the creators of the original BIM model) are less satisfied with cooperation, which holds true at a lesser extent for the other roles, too. The focus group discussions demonstrated that issues of interoperability dominated the focus groups. Early coordination (organization and software) proved

positive for later collaboration. The hypothesis that exclusively through the use of BIM tools the integrated planning would be enhanced was not affirmed. An integrated design process requires a careful process design involving teaming, design of communication and data-exchange beyond BIM technology in order to fully enhance the process integration.

The results of post-questionnaires concerning software acceptance (Figure 5) show that users assign BIM-software a high-perceived usefulness, lower ease of use and extremely low interoperability of different software solutions. This is especially true for civil engineers and building scientists. Interoperability is of the greatest importance for the structural engineers and building science students, since they extract the data from the original, architectural model, however, is judged as very problematic. Improving especially interoperability would have the strongest positive effect on

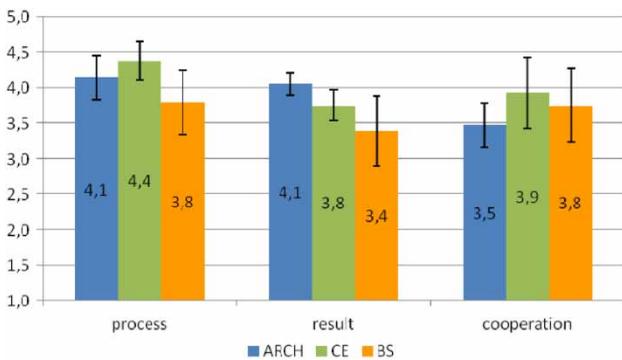


Figure 4 Results of the general questionnaire

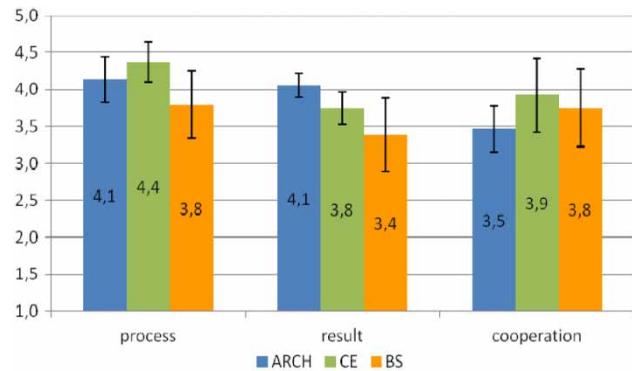


Figure 5 Results of the software questionnaire

the acceptance of BIM-software according to our analyses.

Besides these analyses based on the data gathered from the groups, the course instructors and supervisors observed several aspects concerning the quality of design, workflow- organization and class administration during the weekly feedback discussions and the three presentations, which are discussed subsequently.

The students were primarily concerned with mastering the software, modelling and interdisciplinary data exchange, which resulted in projects of average or even below-average design quality. Due to the numerous difficulties in terms of interoperability and model exchange, many improvements of design were 'sacrificed' in order to minimize the necessary rework. In some cases, the design was not optimized as result of the consensus in the team to prevent additional calculation and simulation effort for the engineer or building scientist in the team. A further problem—though not just BIM-related, but rather related to software usage in general—concerning the outcome quality is the interpretation of results—the students are relying on the results generated by the software tools and often are not able to verify or interpret them. In some cases, manifold over- or under-dimensioning of the load bearing elements or generated heating loads in summer have not been reported as fault at presentations.

The work flow organization turned out as sequential design, despite the instructions and requirements to present integrated projects. In most of the groups, the architects started with the initial design and modelling, counting as model 'owners'. The disciplines that followed were expecting necessary model adaptations for failed data-exchange or design-improvement after the simulation or calculation to be carried out by the architect, as 'model owner/creator', which resulted with numerous conflicts. The 'teams' were not feeling as teams until the final presentation, which required the presentation and delivery of the integrated digital model. At this point in time, finally all of the team members felt working on a joint project, much more than only optimizing the architect's model. We assume that the lack of team-spirit and joint aim setting can be contributed to a required but missing kick-off meeting where teams could be initially formed.

The class involved cooperation of two faculties (civil engineering and architecture) and of three different disciplines (architecture and building science are both master curricula of faculty of architecture), which posed challenges for the involved course supervisors in terms of administration and organization. Numerous constraints on the schedule had to be considered due to the different curricula. The same holds true for the

organization of the class as different course-management-platforms for each discipline were used. The administration of the class in terms of ECTS credits represented the main difficulty, because of the unbalanced reward of credits for each discipline. For the architects the class was offered as elective class rewarding 2 credits, for civil engineers as project class rewarding 4 credits and for building physics students as master project course rewarded 10 credits. The differences in course credits were compensated by additional tasks (reports, further analyses, etc.) but certainly influenced the effort and motivation of the participants. This disproportional reward represented a major issue for balancing of workloads within the teams and was resulting in many conflicts with both team members and faculty.

Conclusion

The assumption that exclusively through the use of BIM tools the integrated planning would be enhanced cannot be supported by the results gathered in the explorative experimental study we presented and discussed in this paper. The participants worked in a sequential manner especially in the first part of the experiment, where the architect was expected to provide an architectural design, as well as to create the architectural BIM. This model then was used by the successive disciplines for their subsequent modelling. Many conflicts and discussions arose on the issue of model management, changes and adaptation of the original model, which are necessary for the proper transfer into the subsequent engineering and thermal simulation. In general, the architect was expected to carry out all of the adaptations, which led to numerous conflicts—who has to do what and when?

The lack of team spirit and joint vision can be attributed to the lack of an organized, moderated kick-off meeting as well as to the lack of time and space for face-to-face student meetings and workshops. The expectation that student teams will be able to organize themselves for collaborative work without support was not affirmed.

The main challenge remains and the improvement of the quality of the projects should follow the maxim 'form follows function' instead of 'form follows tool'. Careful balancing of BIM tools usage and interdisciplinary design workshops involving traditional media such as model building, sketching and mapping could enhance a more creative way for finding innovative solutions, however, the optimization of results largely depends on experience and practical know-how of involved disciplines. In general, our results comply with the findings reported by Poerscheke *et al.* (2010),

and the focus group discussions comply with practitioners focus groups (Gu and London, 2010).

After the pilot experiment in winter term 2012, we ran a second experiment in 2013. Lessons learned from the pilot experiment were incorporated in the design of this experiment: A designed process, including teaming workshop and a variety of integrated, intensive workshop phases and the phases where team members can work by themselves. Furthermore, more credits were assigned to the architectural students (5 credits), due to the reorganization of the studio and more support of the faculty administration. We plan to compare the results of the two instances, to gain more insight on (i) benefits of BIM for enhancement of integrated planning and (ii) on its impact of process-design on planning results (satisfaction, workflow, efficiency) as soon as the collected data is edited and evaluated.

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References

- Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C. and O'Reilly, K. (2011) Technology adoption in the BIM implementation for lean architectural practice. *Automation in Construction*, 20, 189–195.
- Davis, F.D. (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Management Information Systems Quarterly*, 13(3), 319–340.
- Dossick, C., Anderson, A., Iorio, J., Gina Neff, G. and Taylor, J. (2012) Messy talk and mutual discovery: exploring the necessary conditions for synthesis in virtual teams. *Engineering Project Organizations Conference*, Rheden, The Netherlands.
- Fellows, R. and Liu, A.M.M. (2012) Managing organizational interfaces in engineering construction projects: addressing fragmentation and boundary issues across multiple interfaces. *Construction Management and Economics*, 30(8), 653–671.
- Grilo, A. and Jardim-Goncalves, R. (2010) Value proposition on interoperability of BIM and collaborative working environments. *Automation in Construction*, 19, 522–530.
- Gu, N. and London, K. (2010) Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, 19, 988–999.
- Hyatt, A. (2011) A case study integrating lean, green, BIM into an undergraduate construction management scheduling. 47th ASC Annual International Conference Proceedings.
- Koeszegi, S. & Srnka, K. (2007) From words to numbers: How to transform qualitative data into meaningful quantitative results. *Schmalenbach Business Review*, 59, 29–57.
- Kovacic, I., Oberwinter, L., Müller, C. & Achammer, C. (2013) The “BIM-sustain” experiment – simulation of BIM-supported multi-disciplinary design. *Visualization in Engineering*, 1–13, 1–12.
- Marshall, C., and Rossman, G.B. (1999) *Designing Qualitative Research*, 3rd edn, Sage, London.
- McGraw-Hill Construction. (2010) The business value of BIM in Europe. Bernstein, H.M. (ed.), Smart Market Report.
- Moum, A. (2010) Design team stories Exploring interdisciplinary use of 3D object models in practice. *Automation in Construction*, 19, 554–569.
- Nielsen, J. (1993) *Usability Engineering*, Academic Press, Boston.
- Peterson, F., Hartmann, T., Fruchter, R. & Fischer, M. (2011) Teaching construction project management with BIM support: Experience and lessons learned. *Automation in Construction*, 20, 115–125.
- Plume, J. and Mitchell, J. (2007) Collaborative design using a shared IFC building model—Learning from experience. *Automation in Construction*, 16, 28–36.
- Poerscheke, U., Holland, R.J., Messner, J.I. and Philak, M. (2010) “BIM collaboration across disciplines”, Proceedings of the International Conference on Computing in Civil and Building Engineering.
- Rekola M., Kojima, J., and Mäkeläinen, T. (2010) Towards integrated design and delivery solutions: Pinpointed challenges of process change. *Architectural Engineering and Design Management*, 6, 264–278.
- Singh, V., Gu, N., and Xiangyu Wang, X. (2011) A theoretical framework of a BIM-based multi-disciplinary collaboration platform. *Automation in Construction*, 20, 134–144.