The Engineering Project Organization Journal, 2013
Vol. 3, No. 1, 51–63, http://dx.doi.org/10.1080/21573727.2012.760155

Taylor & Francis
Taylor & Francis Group

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

IVA KOVACIC[1]* and MARIJANA SRECKOVIC[2]

[1]*Department of Industrial Building and Interdisciplinary Planning, Faculty of Civil Engineering, Vienna University of Technology, Karlsplatz 13/e234-2, Vienna 1040, Austria*
[2]*Department of Real Estate Development and Project Management, Faculty of Architecture and Planning, Vienna University of Technology, Gusshausstrasse 30/E260-P, Vienna 1040, Austria*

Received 30 April 2012; accepted 15 December 2012

Buildings play a crucial role in the achievement of sustainability aims, due to the large energy consumption for operation and the related CO_2 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 CO_2 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

*Author for correspondence. E-mail: iva.kovacic@tuwien.ac.at

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

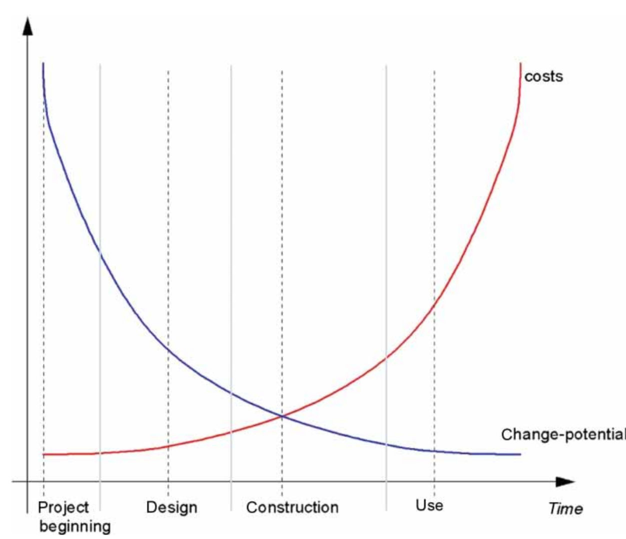

Figure 1 Interdependency of change possibility and cost development in time

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 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.

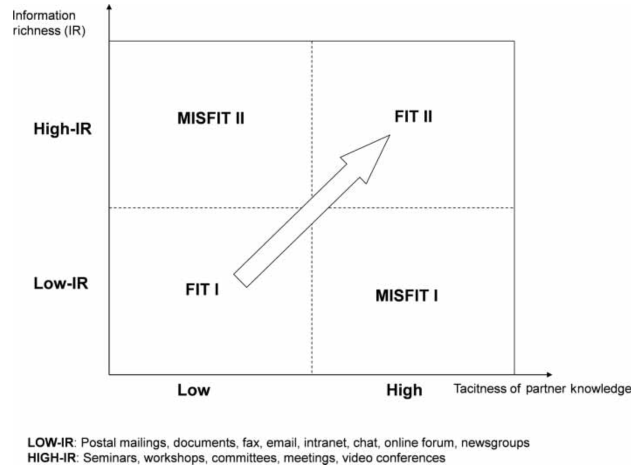

Figure 2 Relationship between knowledge transfer mechanisms and knowledge attributes

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

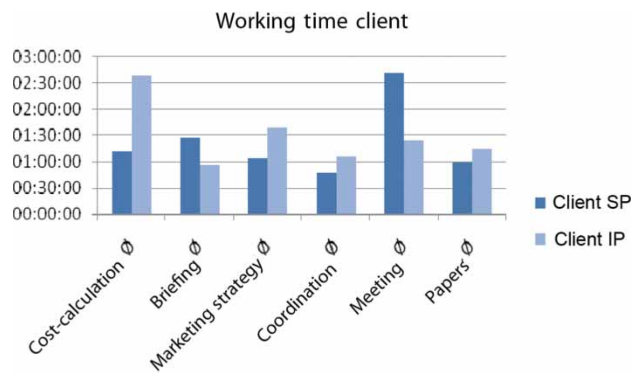

Figure 3 Evaluation of productive working time for client

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.

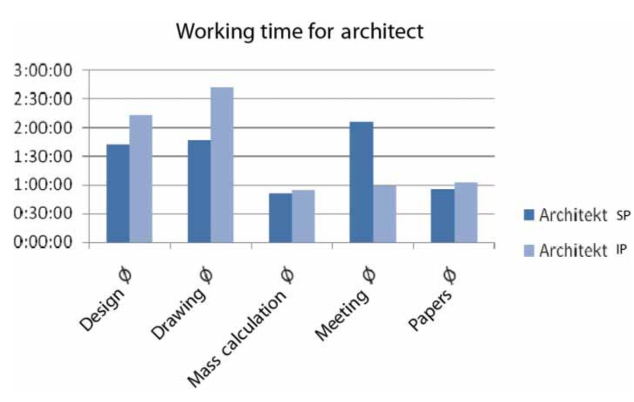

Figure 4 Evaluation of productive working time for architect

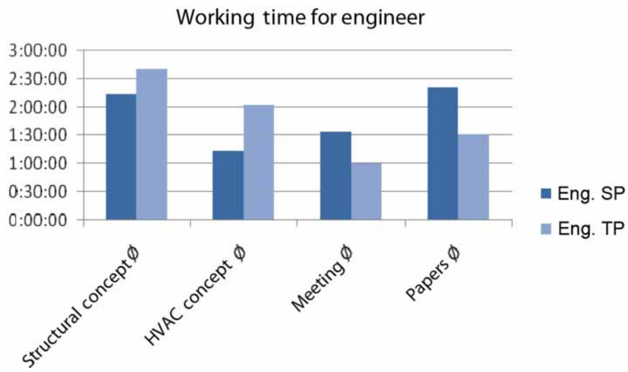

Figure 5 Evaluation of productive working time for engineer

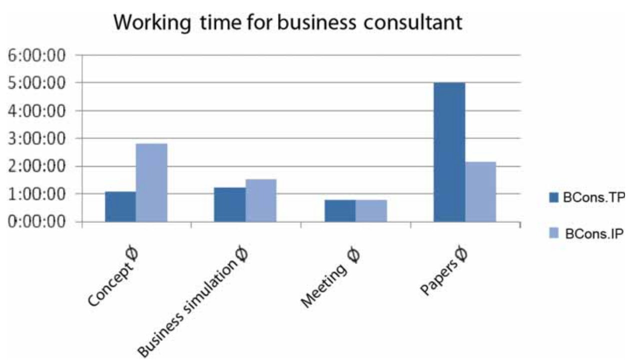

Figure 6 Evaluation of productive working time for business consultant

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

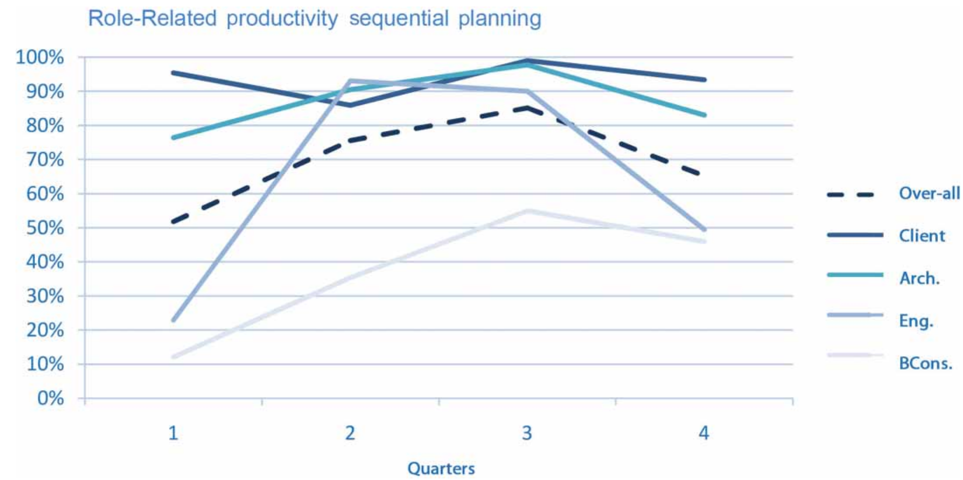

Figure 8 Role-related productivity for SP

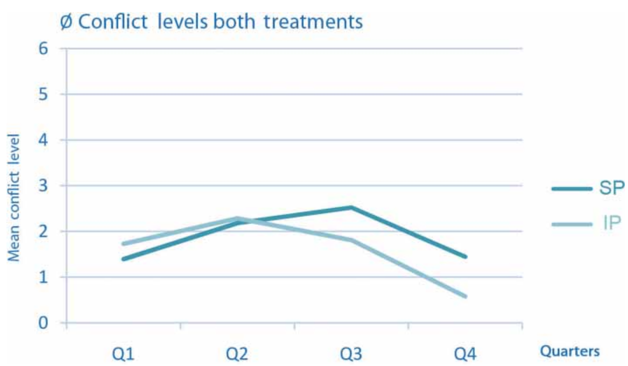

Figure 9 Comparison of conflict levels for SP and IP

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.

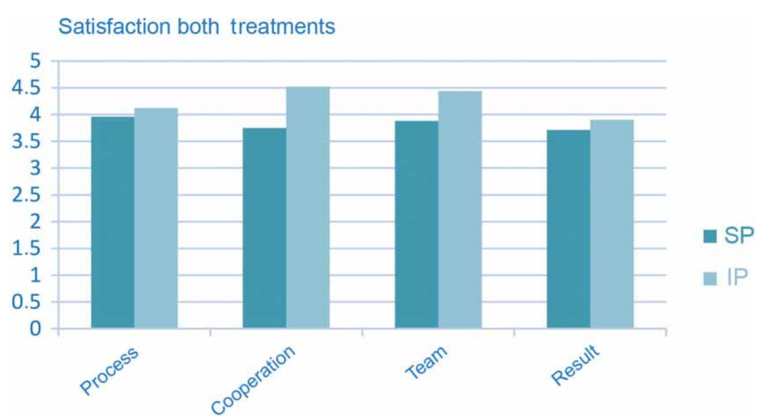

Figure 10 Comparison of process, cooperation, team and result satisfaction for SP and IP

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.

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

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 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.

Acknowledgements

This project is funded by the Austrian Climate and Energy Funds and carried out at the Vienna University of Technology. The authors gratefully acknowledge the support of Prof. Christoph Achammer. The exploratory research - experiment - was carried out in cooperation with the Institute of Management Science, Dr. Michael Filzmoser and Prof. Sabine Kösegi and the Department for Real Estate Development, Prof. Dietmar Wiegand, who we gratefully acknowledge.

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., Kreißig, 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.