BIM process facilitator for energy efficient design management

Tarja Mäkeläinen¹, Krzysztof Klobut², Mari Hukkalainen³, Juha Hyvärinen⁴

1) Senior Scientist, VTT Technology Research Centre of Finland Ltd. Email: tarja.makelainen@vtt.fi
2) Senior Scientist, VTT Technology Research Centre of Finland Ltd. Email: krzysztof.klobut@vtt.fi
3) Senior Scientist, VTT Technology Research Centre of Finland Ltd. Email: mari.hukkalainen@vtt.fi
4) Senior Scientist, VTT Technology Research Centre of Finland Ltd. Email: juha.hyvarinen@vtt.fi

Abstract:
This paper discusses approaches for guiding and training professionals in the field of energy-efficient (EE) building design. Designers are facing new competence demands in practicing their profession. Their skills are to be trained with the help of guidelines provided by authorities or client. Here, the focus is on new competences on the fields of Building Information Modelling (BIM), performance based process and specific design competence for managing holistic energy performance of buildings. Traditionally, guidelines are focused separately on building information modelling as a systemic change leading to more integrated design processes, or to specific analysis methods or performance targets for the building, such as cost efficiency, indoor air quality, energy performance, or usability of the spaces. We show examples of the developed guidelines, which combine these focus areas to the same framework. The developed approach offers a smooth way for design professionals to adapt new competence, without frustrations typical for today’s working life: “Yet again another guideline…”. Instead, the approach supports individual understanding and enables to plan the collaborative BIM based work flows and data flows as a part of the design group management.

Keywords: BIM, Building design, Design management, Energy efficiency, Guidelines.

1. INTRODUCTION

Designing of buildings and retrofit processes is facing the need for increasing energy efficiency due to the climate change mitigation and CO₂ emission reduction targets (EU, Energy Strategy 2030; EU, Energy Roadmap 2050). Also, the increased use of renewable and local energy resources is expected. In the building code, the target values for energy performance of buildings are aiming to nearly zero energy buildings (Annunziata, 2013). In the process level, designers’ collaboration is required as the targets can be reached with many different design solutions. Therefore, the design teams should focus more on the energy performance design supported by principals of performance based design and continuous commissioning (NIST 2014; Vainio, 2015), as well as BIM (Building Information Modelling) based energy simulations.

BIM enables better ways for the management and informed decision making in performance based collaborative design process, which is needed in a process targeting to nearly zero energy buildings. However, building design is struggling with this socio-technical change (Sackey, 2014). New design tools are available to capture the geometry and detailed information of design solutions. In order to get benefits out of using these tools and collaborative processes, designers’ need to adjust their mind-sets. Design managers or chief designers are primarily responsible for communicating these kinds of new processes, which are more focused on producing information and visualisation and supporting decision making. The change has to be systemic as the whole design team, as well as other stakeholders involved, need to adapt the new skills and the mind-set. For better understand the new process, its workflow and data flow, several types of description notations are used for research purposes and in guidelines (Figure 1). They usually serve a certain management area and aim to visualize, among others, integrated processes, BIM use case, dependencies and needed collaboration with integration points for different stakeholders.

The authors argue that collaboration and co-design in integrated information management processes can be further developed and the collaborative design team can be supported with co-design activities targeting to a more holistic design solutions, high level performance and innovation. Supportive methods and tools for the team collaboration, in connection to the substance and situated awareness to a specific design challenge are needed. Furthermore, it seems that the existing BIM guidelines as documents do not support these approaches fully. Therefore, more interactive guidelines and training environments are needed, in direct connection to process task flow, guidance and support.

This paper is structured as follows. First a background for the BIM guidelines and recognized development needs from earlier research is summarised. Section 2 summarises the foundation for developing process guidelines for collaboration based on social BIM framework and diffusion model as well as the needs defined in research concerning design collaboration and skills. Section 3 introduces the main models and examples developed for process guidelines for collaboration.
The paper is based on findings from an EU project called Design4Energy, which developed an integrated evolutionary design methodology targeting to highly energy efficient building energy performance throughout the whole life cycle, from planning and design to operation, maintenance and retrofitting. The examples are developed to support the Design4Energy methodology.

1.1 BIM Guidelines

Many BIM standards have been developed, consisting of classification of data, data transfer specification and the guidelines. Guidelines explain the model ownership, the relations with other disciplines, model uses and define the level of detail and the level of development in the most important model publishing events during the process. International survey is on-going to study the characteristics of the individual guidelines (BS BIM GUIDES). The existing guidelines highlight the importance of collaboration and design or project management, as follows:

“The successful management and coordination of an information model project requires that the project-based building information modelling tasks and procedures are planned in advance.” (COBIM, 2012, Series 11, pg. 6).

“The content of a BIM Execution Plan includes the following: Project information; BIM goal & uses; Each project member’s roles, staffing and competency; BIM process and strategy; BIM exchange protocol and submittal format; BIM data requirement; Collaboration procedures and method to handle shared Models; Quality control; and Technology infrastructure & software.” (Singapore, BIM Guide, 2012, Section 1.1, p. 2)

“The success of a BIM enabled project delivery process is highly dependent upon the level at which the entire design/construction team can collaboratively produce and manage information for the duration of the project.” (Hong Kong: CIC BIM Standards, section 2.3, pg. 46)

“A BIM Coordination room shall be provided during design and during construction for facilitating BIM design review and clash detection/coordination where all the team members can meet to discuss technical discipline coordination issues using the BIM models. Alternatively, collaboration meetings using web conferencing (webinar) is acceptable for facilitating these meetings.” (USA: VA BIM Guide, 2010, Section 6.2)

1.2 National BIM Guide for owners

National BIM Guide for owners describes the owner responsibilities widely in the BIM process. One of the main tasks that the client needs to make is to require for BIM based design. An example of a guideline based on recently launched National BIM Guide for Owners (NIST, 2017) shows the principle how the project requirements are matched by the planned BIM use. The principle is that “Once the Owner’s project BIM goals are defined, the Project BIM Team should also ensure that these BIM goals can be met with current technology practices and required team competencies. The project BIM goals should lead to the choice of BIM Uses and additional BIM requirements.” (NIST, 2017)

Design management in BIM based project is a critical factor. BIM based process brings value to the decision making points, which are happening in many levels. Here we focus on the levels of design management (chief designer view) and project steering and management (client’s or project manager’s view). The planning of all model uses has to be done beforehand in order to serve the project targets.

1.3 Recognized development needs

Arif et al. (2009) introduced four levels of knowledge retention maturity. Knowledge management is an integral part of BIM capability and subsequent maturity. The matrix thus incorporates these levels: (i) knowledge is shared between employees, (ii) shared knowledge is documented (transferred from tacit to explicit), (iii) documented knowledge is stored and (iv) stored knowledge is accessible and easily retrievable (Arif, et al., 2009). Resent research has been made by Elmualim et al. (2014) to understand the close relationship of Design Management (DM) and innovation: relationship between design management, innovation and the role of BIM in advancing collaboration in response to the required change. Their survey resulted that today most organisations attempt to manage design projects by applying systematic planning, communication techniques and decision making protocols. “Mainstream architectural design practises are changing. Collaborative processes in the design stage are taking new forms particularly where emerging technologies are used” (Elmualim et al., 2014).
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Figure 1. Current wide range of process notations used
To meet these changes and challenges, architectural design management skills need to be re-evaluated to advance new and innovative design strategies.

The concept of IDDS (Integrated Design and Delivery Solutions) brings together developments of new concepts, tools and technologies in three different areas: 1) Integrated procurement and project delivery; 2) Integrated IT applications, covering all phases of project development, design, construction and use, especially including the further development of the BIM concept; and 3) Skill enhancement for people working in the building and construction sector (Owen et al., 2013). In addition, target 4 in IDDS roadmap is pointing out the cultural change knowledge management and dissemination (Owen et al., 2013). In the knowledge management area of IDDS, the development needs are defined as: a) need for many experts to solve challenges and find most useful solutions; b) need for tools/methods to support professional dialogue; and c) new mind-set for a more collaborative design work. “The culture within the construction sector is generally one of distrust; we need to develop team mental models to improve project collaboration of distributed project teams combined with computer supported collaborative working” (CIB IDDS Core Team, 2012).

It is essential that we capture knowledge and re-use in both in practice and education, so that we can foster improvement at the pace of the fastest, rather than at the pace of the slower maturity. Knowledge capture and re-use within projects is helped greatly by using BIM, unless a new model is created at each stage of the process and embedded data, information and knowledge is lost in doing so. (Owen et al., 2013)

### 2. FRAMEWORK FOR DEVELOPING PROCESS GUIDELINES FOR COLLABORATION

The main framework used in this study was developed by Succar & Kassem (2015), who described a model showing the areas of Technology, Process and Policy, in three maturity steps: Modelling, Collaboration and Integration. Our focus stays in the area of process: modelling processes, collaboration process and integration processes – and how to support these activities with guidelines and training. The other frameworks used as a starting point for this study are based on the model of “Seven Pillars of integrated Project Delivery” by Spata (2010) and “Social BIM framework” by Adamu et al. (2015). Seven pillars needed for Integrated Project Delivery introduced in 2010 saw BIM as optional technology, while more support for procurement and project quality was encouraged: multi-party agreement, shared risk and reward, relational contracting, shared project objectives, zero change orders and shared unitary fund.

These models capture the main elements of inter-organisational integrated design projects: focusing on collaboration, shared situational awareness, collaborative decisions with risk management and design leadership, as well as BIM coordination. Our research methodology follows the steps of expert system prototyping as a development method (O’Leary, 1988), based on above introduced frameworks and models as point of departure. The research aim was to develop a Design methodology and process guidelines for collaboration throughout the entire lifecycle of energy efficient building design.

### 3. RESULTS

#### 3.1 The developed Design4Energy methodology

The developed design methodology is holistic, evolutionary and energy efficiency oriented, which targets to balanced holistic building performance. Key building blocks of the developed design methodology are illustrated in Figure 2.

The main principle of the criteria for holistic design methodology is that design solutions, in all levels of development, are based on neighbourhood studies and alternatives have been analysed taken into account neighbourhood energy efficiency (EE) potentialities, especially the use of RES (renewable energy sources) in the energy source mix. Holistic EE design means here the design in connection to neighbourhood. The main principle of criteria of evolutionary is that design solutions are analysed to serve both the first users and the users in the future (during the life time of the facility in its different usages) by balancing the adaptability and flexibility of EE solutions. The main principle of criteria of energy efficient oriented is that design solutions are estimated, designed, built, and optimised as well as operated, monitored and renovated for best possible user-centred energy efficiency in their neighbourhood content. The defined design methodology focuses on information management and good data-flow chain.

The methodology is adaptable to any design approaches and methods, procurement strategies or any building type and serving the decision making process with information using key processes: BIM with EE simulations and analyses and advanced visualisation,
Performance-based design process, and Collaborative design process. Design management (executed by chief designer) ensures that relevant information is presented to the client at the right time and in right way for the decision making. This can be developed as a service, which provides analysed solution alternatives for decision making and relying to three key processes.

The first key process is BIM with EE simulations and analyses and advanced visualisation. The principle is that design process takes advantage of modelling with configurable catalogue components, integrated to model checking, EE simulations and analyses and key performance indicator (KPI) assessment with relevant visualisation. The second key process is Performance-based design process where design solutions are assessed by KPIs, which are set by the client in the feasibility study, enabling to reach the targets for the whole building. Design process aims for improved energy efficiency of the end products (facilities connected to their neighbourhoods) including consumption, trading and production of energy. Performance-based approach breaks the project target into indicators, sets targets to each of them and adjusts their target levels as metrics. Indicators belong to the following criteria areas: performance in use, economical performance, environmental performance and impact to neighbourhood. The third key process is Collaborative design process. The main principle is that design process takes advantage of good collaboration and co-design to reach targets (best EE solution to fulfill KPIs) as part of other lean process characteristics. As a new technology cannot result into good benefits in an old process, there has to be process re-engineering. Needed competences for the design team are: team building and virtual collaboration, co-creation and integrated communication management, and design team leadership (Design4Energy, D2.3).

3.2 Example: Overall design advisory for holistic EE buildings
Holistic EE design consists of challenging problem solving and development of design alternatives, and the collaboration of disciplines will be done as integrated design group work. A platform developed in the Design4 Energy project supports the collaboration with functionalities to share design content and collaborative decision making with dashboards (as a design review tool). Collaborative review and presentation of the design to the client will be done before decision making. Both internal design group meetings and review meetings with the client need to be planned in advance to ensure effectiveness and progressive holistic and evolutionary EE design. The structure of the meeting and its agenda vary based on the scope of the building project. Overall EE design advisory can also be used as a basic principle during every internal design group meetings and reviews and presentations to the client. The main principle of the overall design advisory for holistic EE buildings is that, in co-operation and utilizing co-design events, the design group aims to find and solve design problems.

The holistic EE performance is followed based on the project level key performance indicators, KPIs. The overall energy efficiency and sustainability of a building composes of various design decisions related to energy efficiency and used energy sources. Accordingly, holistic energy solutions are required when targeting to the best possible buildings’ energy design. The holistic energy design of buildings should primarily target to minimise the energy demand without compromising the good quality of using the building. In addition, holistic energy design should include the optimal use of renewable energy sources, as well as minimising the CO₂ emissions and optimising the energy costs. Energy cost is covers investment cost and operational costs. KPI’s may define also life-cycle cost.
3.3 Design checklists and Design Advisories

The design collaboration can be supported by design checklists, which have been developed focusing on the Design4Energy methodology. These checklists combine the elements required for holistic EE design. The design group can use these lists e.g. in their internal review meetings. Below, as an example, a checklist for design reviews for Architect together with structural, HVAC designer and energy experts (Design4Energy, D2.3):

- **Aim for as simple solutions as possible to increase the solutions’ reliability (PEP, 2007).**
  - Aim for compactness of the house for reduced heat losses and window design for passive solar energy utilisation (PEP, 2007). Check spatial needs and lay-outs. Thermal and moisture technical design and analyses. Consider good indoor climate, Ventilation and Quality
- **Use of renewable energy sources**
  - Identify local available renewable energy sources (solar, wind, geothermal energy, biofuels) and their maximum potential for utilisation. Check the availability of the space and the preliminary plans for on-site renewable energy production from architect and from structural designer (e.g. space for a mounting of solar panels, heat collectors or a wind mill).
- **Energy concept**
  - Preliminary design of energy production needed for the energy demand (district heating, cooling, gas, boiling, etc.) and inform HVAC planner about this energy concept. Respond to energy demand with dimensioning of energy mix using as much renewable energy sources as possible (Geothermal/ Sun power/ Wind/ Biofuels)
- **Analyses and collaboration**
  - Analysing of energy matching and neighbourhood impacts with the indicators from the target setting. Sizing /dimensioning. Co-design with architect and HVAC for technical spaces. Preliminary and detailed design of energy storages if required.

An example is developed for a more detailed substance oriented checklist, which can be called a Design advisory. One of them, evolutionary analyse, supports the design group collaboratively agree on evolutionary design targets, and to ensure that the building is resistance for future changes. A structured set of questions was defined to analyse any potential what-if situations in the future. Seven areas to consider were introduced and provided with more detailed advisories. Consider changes of energy pricing demographical changes in community and changes in people behaviour, Consider changes in the usage profiles of spaces, in local energy production and in neighbourhood. Consider climate change, regulatory changes and changes in technology.

3.4 Process facilitator

In the level of Design management (DM), it is important to identify how the domain based modelling and for analysing are used, and tasks and also scheduling these activities to the total process work flow. Design management (chief designer view) and project steering and management (client’s/ project manager’s view) need to be supported by BIM process planning tools. A one result of the D4E methodology, we introduce a process description map with symbols and a process execution facilitator tool as a planning tool for the design management. The symbol language consists of domain models and model uses like analyses, simulations and visualization (Figure 3).

The structure of the interactive guideline includes domain based to do -lists and links to checklists/ design advisories to be used as guide in design group’s collaboration meetings. Visual process map serves as a facilitator tool/ enabler that could support the design work management during the process. The best benefits are gained when the process map is used in the planning of the integrated design work and choosing the most useful model uses (analyses) for the design project. The BIM models are pin-pointed to the description of data flow.

![Figure 3: Developed symbols on the orange background for covering domain models and model uses.](image-url)
4. CONCLUSIONS

In this paper we have introduced a development results for a tool supporting BIM process planning. The tool is visualized a conceptual prototype linking the energy design intelligence (with check lists and design advisories and guidelines) to the detailed modelling process workflow (to-do-activities) with needed collaboration. The guidance system still gives room for designers as professionals on their specific fields as actors in co-creation - and relying to each other’s expertise for achieving the project targets. Further development steps cover collecting user feedback and up-dating the conceptual prototype to be a BIM process planning tool with dial-up choices, where each symbols can be picked from a library. The developed guideline prototypes (modeling guidelines, check lists and design advisories) are in line with IDDS research roadmap and Knowledge management (Owen et al, 2013). The developed method can be used as a documented know-how and are possible to use in next projects in order to support the new culture within the construction sector and team mental models. In order to improve collaboration between stakeholders and co-design between the design group, a set of check lists and design advisories for a certain model uses (e.G. analyse for evolutionary design solutions) is drafted. The concept should be flexible for adding advisories, guidelines and check lists which support specific project targets. The guidelines are based on situational awareness by pin-pointing the interventions to geometrical location.

Adapting BIM as sociotechnical change, the collaborative process needs to be supported with meaningful guidelines suitable for planning the common activities in the design process and also supporting design management in following the process. Making the design intelligence transparent and having well organised meetings brings benefits for the project. The content of design advisories can be used in the next generation of tools, as they are taking steps towards multi-objective approaches (Diakaki, 2008) including parametric / generative design tools to integrate design and energy modelling (Hetherington, 2013) and augmented artificial environments. For reaching these scenarios, to standardize all relevant BIM based processes as IDMs (Informaton delivery manuals) is a good start.

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