Holistic Building Design

An integrated building design methodology based on systems thinking for reaching sustainability

Aliakbar Kamari[1], Poul Henning Kirkegaard[2]
[1,2]Department of Engineering, Aarhus University
[1,2]{ak|phk}@eng.au.dk

This paper introduces a new perspective on methodological requirements in building design related to questions of sustainability, where stakeholders ought to look at design in an integrated way when economy, society, and technical components are embedded in an ecological holistic perspective. To bind these different aspects together and face complexity, while the goal is to reach sustainability, Holistic Building Design (HBD) is drawn on existing concepts of systems thinking (ST), integrated design processes (IDP), and application of innovative technologies through building information modeling (BIM). The main aim of this approach is to involve deeper in all aspects of sustainable building design. The methodology is introduced and empirically practiced in a master's level course, and a general overview besides the first results of this on-going process are presented in this paper. It is observed that the HBD framework could significantly influence the understanding of the design process and enhancing it by iterative decision-making and turning the focus on the early design stage.

Keywords: *Sustainability, Systems thinking, Integrated Design Process, Building Information Modeling, Holistic Building Design, Complexity*

INTRODUCTION

The new vision and tightened sustainability concepts have led to an increased demand for the design of sustainable buildings as well as sustainable development of the built environment (Keeler et al. 2016). In this paper, we do not use space to discuss environmental crises, as it has been being research adequately. We believe the climate change/energy efficiency is not the only environmental concern we face. The rationales for the development of sustainable solutions and so sustainable buildings reach far beyond the singular goal of mitigating energy efficiency or climate change to encompass setting the stage for the future -the sustaining- of our species and aspiring still further to a positive outcome: improving the quality of our lives (Bergman 2012). Sustainable buildings put out economic, cultural, and social advantages to urban communities. Along the way, buildings can benefit from adopting a broader approach to sustainability, which seeks to decrease operation and maintenance costs; reduce environmental impacts; and can increase the building's adaptability, durability, and resilience towards future challenges as well as a preferable, healthier, and more convenient environment to the occupants (Kamari et al. 2017).

The conventional building design approaches treat buildings as objects, as things. Yet each building is, in fact, a system with each part affecting the other parts and, in turn, the building and its surroundings as a whole. Moving towards sustainable development of buildings to include and deal with broader perspectives from sustainability implicates handling enormous *complexity* concerning:

- the understanding of requirements and fulfillment of sustainability objectives and criteria while dealing with its multifaceted challenges,
- integration and involvement of multiple stakeholders (a shift from the "one mind" of the master builder to the many minds of the professionals and specialists) that contribute their expertise to cope with their demands and priorities, and
- identification, creation, evaluation, and application of innovative solutions in the development of sustainable buildings and so built environment.

Given these realizations, sustainable building design requires an overarching and inclusive theoretical framework together with integrated and instrumental concepts, design strategies, tools, and methods (as demonstrated in Figure 1). In doing so, we need to create a shift both in the whole pipeline and picture, to reach sustainability as a globally desired design value, and therefore, in our design methodologies to become more holistic in essence. It is even more important to incorporate the emerging knowledge in the current higher education system, to be practiced by students. This could be the most reliable manner to make sure that the new methodological advances within their ultimate ability are used in the near future by practitioners in the AECO industry.

This paper presents an integrative perspective on methodological requirements in building design towards tackling the above challenges, named Holistic Building Design (HBD). HBD's framework is currently being developed, evolved, and practiced by the lead author since 2016. The main aim of this approach is to involve deeper in all aspects of sustainable building design, and therefore, to deal better with very complex issues in the built environment. The involved design stakeholders, therefore, are enabled to cope with a much bigger complexity and integrate very large amounts of information so as to create innovative sustainable solutions.

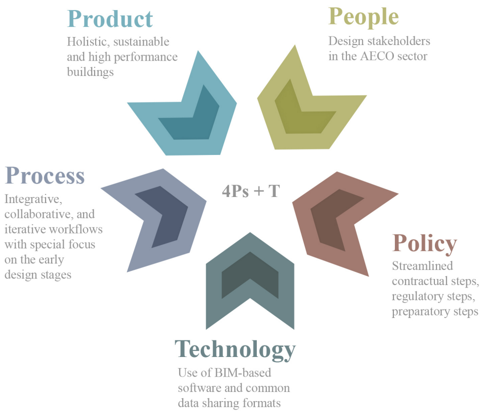

Figure 1
Complexity sources (4P+T) in a sustainable building design practice (adapted from Kamari et al. 2019b)

In the light of this, and due to face the complexity as explained earlier, the paper reviews and unfolds the related concepts and methodological characteristics of HBD to the challenge of reaching sustainability in its full sense, which leads to configure the HBD's framework. Then, the methodology is introduced and empirically practiced in a master's level course. A general overview of the applied methodology and the first results of this on-going process are presented in this paper.

THEORETICAL FOUNDATION

HBD is designed to cope with the existing complexity, as explained in section 1. It is drawn on existing concepts of systems thinking - ST (Checkland 1981), integrated design processes - IDP (Reed 2009), and application of innovative technologies through building information modeling - BIM (Eastman et al. 2011), as demonstrated in Figure 2. A brief description of each element is presented in the following. In essence, all the mentioned elements are inclusive and tend to be holistic on their own, and their application contributes to a larger integration.

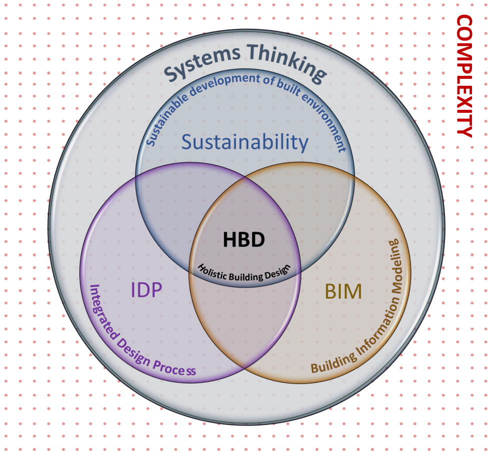

Figure 2
HBD is built on systems thinking and it happens at the intersection of sustainability, IDP, and BIM.

Due to the space problem, we cannot provide an in-depth fundamental theory and background of the mentioned concepts. However, it is worth noting that each one of these concepts has individually been studied in detail by the lead author (i.e. Kamari et al. 2018, Kamari et al. 2019a,b). As for HBD, it can be considered as an effort to simply extending and binding the potential application of these concepts together; and as for this paper, it is an effort towards bringing and bridging them in the current higher education system, and let students practice them, while they are still in the academic environment.

- ST: is an approach to integration that is based on the belief that the components of a system will act differently when isolated from the system's environment or other parts of the system. ST places a greater emphasis upon understanding systems in their entirety and within the environment that gives them context. Standing in contrast to reductionist thinking which is based on components *analysis*, ST is founded on the *synthesis* of elements and can be referred to as *Holism* (or Whole), which is a term known from modern philosophy (Bertalanffy, 1968; Checkland, 1999; Weinberg, 2001). ST is particularly useful in addressing *complex* or wicked problem situations. These problems cannot be solved by anyone actor, any more than a complex system can be fully understood from only one perspective.

- Sustainability: is defined by Brundtland Commission (1987) as meeting the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainability is composed of three pillars: Economic, Environmental, and Social-also known informally as profits, planet, and people. In building design, it can be referred as the outcome of a particular set of values focusing on increasing the efficiency of resource use (i.e. energy, water, materials) while reducing building impact on human health and the environment during the building's lifecycle through better siting, design, construction, operation, maintenance and removal (US-EPA 2013). Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) approaches are very common for measuring sustainability in building design, however, concerning a partial measurement of some environmental and economic aspects of design. Therefore, it is necessary to mention that sustainability is based on modern information and communication systems. There are always special interests to verify the need for a deep understanding of sustainability as the pattern with the agglomerated set of indicators that are defined by the relevant criteria. As a response to this, today, there is a significant range of methods accessible for assessment of sustainability, such as LEED, BREEAM, DGNB-DK.

- IDP: is a method that has been evolved mostly during the last two decades, due to the new sustainability tendencies in the AECO industry. As such, the growing focus on sustainability is one of the areas that make the integrated design process highly relevant (Reed 2009). IDP can be understood as a collaborative method for designing buildings that emphasizes the development of a holistic design. According to Löhnert et al. (2005), IDP characteristics follow:

- Inter-disciplinary work from the beginning of the design process between all consultants
- Test of various design alternatives by use of simulation tools
- Development of well-formulated performance targets and design strategies
- A more active role of the client
- The architect as teamwork leader instead of the sole form designer

- BIM: is a method that focuses on generating and administrating building data (Eastman et al. 2011). BIM is an emerging methodology in the AECO industry since the intelligent digital three-dimensional model-based process of BIM can be used to plan, design, structure, manage, and analyze buildings. The BIM-model represents the foundation for the BIM-process. It functions as a database for a project and may contain information about building geometry, spatial relations, building location, properties, quantities of building components, etc. These can be extracted and used in applications for, i.e. energy simulations, acoustic conditions, facility management. These interactions between the BIM-model and other applications can be used throughout the whole lifecycle of the building, from the cradle to the grave, and all parties in the project can participate (Garber 2014). Succar (2009) addresses BIM is a set of technologies, processes, and policies enabling multiple stakeholders to design, construct, and operate a facility collaboratively.

Synergies between ST, IDP, BIM, and their application for sustainability in the framework of HBD

HBD initially is founded on critical systems thinking, which aims to combine systems thinking and participatory methods to look at the whole and address the challenges of problems characterized by large scale, complexity, uncertainty, impermanence, and imperfection, i.e. the challenge of becoming more sustainable in the built environment. Using it contributes to becoming less and less wrong while tackling very complex challenges in the built environment. Walking in this worldview, buildings are not considered as a one-off, independent entities made up of separate building systems that isolated from their surroundings-but instead as part of a holistic system (on macro or micro-level), an interdependent living part of the environment into which it is placed and belongs. The ultimate goal is for all the systems to work harmoniously, effectively, and synergistically-where each is made stronger and not in any way compromised by the presence of the others (Deutsch 2011). Decisions are made about flows-having consequences that impact both upstream and downstream.

Adding IDP potentials increase the likelihood of a sustainable outcome for the project. Because the stakeholders are together from the earliest project stages, decisions can be made-from siting and orientation of the building to the specification of green components-in a proactive and coordinated manner. The integrated design process provides strategies to achieve sustainable building design through early intervention and the bottom-up consideration by stakeholders in how the orientation and siting, building program, and design, materials and systems, and components and products of a building impact each other (Deutsch 2011). In place of engaging sustainability specialists working independently, IDP implies a holistic, collaborative approach engaging the insights and experiences of all teammates. Likewise, BIM technology allows the IDP to flourish, encourages - and provides a vessel and conduit for - the sharing of information between the design and construction team (Deutsch 2011). As such, BIM enables integrated design and makes it possible.

As for HBD in this framework, here it can be described as a collaborative approach for designing buildings that focus on the development of the holistic and sustainable design. It strives to be holistic in that it involves multiple stakeholders (architects, engineers, contractors, and clients) from the earliest design phases, each having input into what goes into making the decisions that will lead to the project ending (potential use of IDP). It, therefore, considers every stakeholders' demands and priorities and makes sure these decisions are made with all the information shared at one time, and not in the more conventional linear way, in which each stakeholder maintain and control its data and information (potential use of BIM). HBD endeavors to simplify and streamline working relations and decision making by removing the traditional constraints and restrictions to a successful outcome for all involved parties (potential use of ST). To create an extra coordinated and complete project in a shorter time and limited cost, HBD becomes the least avenue connecting the two ends of comprehension and completion.

HBD - Process and phases

Design processes fulfill solutions that satisfy a given set of design constraints and meet a given set of design intentions, often evolving from abstract to measurable indicators. Even a design solution that is far from being perfect can be accepted when the intentions are met. Building design solutions can emerge from a process of replacing poor solutions with more efficient ones following the patterns/mechanisms in the design process. As such, the design solution can improve if a) more attention and time is spent, b) more choices/solutions are considered and evaluated thoroughly, and c) positive and negative synergies of the decisions are explored cautiously.

This adaptive character identifies solutions/concepts and then transform them progressively towards meeting the project goals. That emphasizes the heuristic and circular nature of the design process, which needs to regularly re-characterize the initial design intentions to meet the project requirements. This process involves many actors and decision-makers who influence the final design. When the project is built, the final design is evaluated by many individuals, including the architect, client, consultants, local communities (including owners of the neighboring properties), and finally, by anyone who occupies it or even passes by it.

The discussion above is based on the understanding that given a project there are both many actors involved and many factors influence the final design. As such, there is not only one best/optimal solution to building design problems but a broad set of possible solutions, that depends on conditions and circumstances (i.e., cultural or geographical), should carefully be considered and assessed by the design team from multiple perspectives. It hints to the fact that finding a solution for a carefully defined and structured design problem is not a linear, straightforward process. Instead, the designers should walk through development and selection between a set of possible design solutions relevant to its environment, being only partly able to evaluate the consequences of their preferences to the final design. It requires to continually identify, develop, and evolve optimal solutions while considering the aims, design criteria, and target values of the project. This is obtained only in an adaptive-evolutionary-integrated-dynamic and non-linear design process (to tackle complexity), begin with the end in mind, and through systematically defined phases consisting of iterative cycles, which contribute to the emergence of most appropriate and optimal final design solutions. That is also the foundation for the development of HBD's process and phases in this paper. As illustrated in Figure 3, HBD consists of six iterative design phases. Depends on the situation, iteration can happen between phases and lead to evolving solutions to the later phases. Here, we describe each phase.

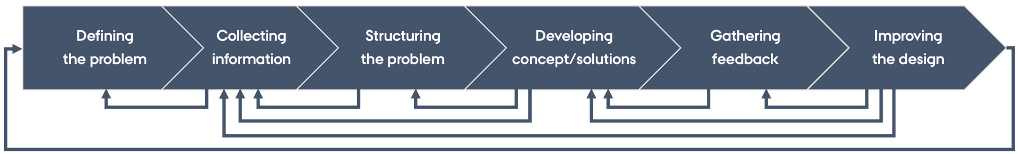

Figure 3
Six phases of HBD

- Defining the problem: Inspired by the systems thinking approaches to facing and solving complex problems, HBD strives to picture design problems as holistically as possible from the beginning. As such, in order to have a clear idea of what the problem is in this framework, HBD proposes uses of the product, people, process, policy, and technology (4P+T) lenses. Nevertheless, the process here will be based on using IDP, and the technology is related to the application of BIM-based tools and software. Questions that can be used include: What are you doing? How are you doing it? What are you trying to achieve? Who should you involve? What technology do you need to use, and why? What data do you need to collect? Likewise, questions that can help the design stakeholders to expand their view of the problem defining are: What are the trends? Where are they going? What will be the future price we pay? How do we want the future to play out?

- Collecting information: HBD proposes to collect information from various resources, including a) studying of the existing cases of Sustainable Buildings, Integrated Design, and High-Rises; b) contextual, site, comfort, and climate analysis c) industry practitioners and academic instructors.

- Structuring the problem: HBD proposes the model in Figure 4 to structuring the collected information and so design constraints and intentions, including performance, context, and design variables. Performance variables express desired characteristics of the building under design, and in terms of which the building will be evaluated (e.g., construction cost, aesthetic appeal, overall quality, etc.). Context variables are those factors affecting the object to be designed but not controlled by the design team (e.g., land price, the likelihood of earthquakes, type eating habits, etc.). Design variables describe the possibilities of the designer, her/his ranges of choice, her/his design variables (e.g., form of building, type of façade, type of HVAC, type of materials, etc.). Here a problem can be said to exist when there is some misfit among three variables in an environment.

- Developing concepts/solutions: In this phase, the design stakeholders evaluate different concepts/solutions to solve a specific problem (refers to optioneering) concerning the aims, design criteria, and target values of the project (refers to synthesizing).

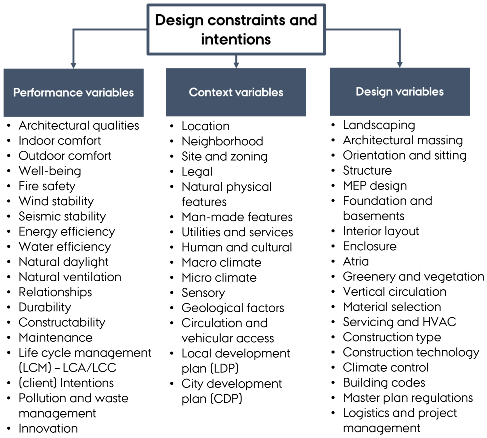

Figure 4
Problem structuring categories in HBD

We define the concept as a strategy for moving from the project needs to building solutions. As demonstrated in Figure 5, in this phase, the design is developed to meet the design constraints and intentions concerning the building's form, context, and needs.

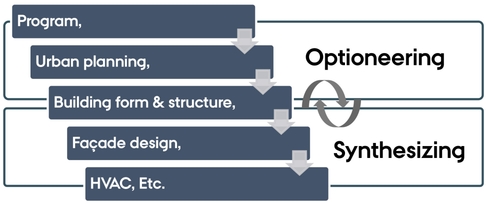

Figure 5
Developing concepts/solutions in HBD

It is here that the design stakeholders reach a point in the design process where design variables are being synthesized with context variables, to meet performance variables with respect to improving sustainability objectives and criteria. Likewise, the various elements used in the project should be optimized, and detailed calculation models document the building performance. Questions that can be used are:

How conditions arise and change? What are the key conditions? What is the rate of change? What may bring a better change? In addition, HBD suggests the use of Rich Design Space, Incubation Techniques, or War rooms, from systems-oriented design approaches, for this purpose too.

- Gathering feedback: In this phase, design stakeholders are trying to get everyone to see the same thing, to paint a common picture. Therefore it initially includes the presentation of the project. Digital models, VR technology, small physical models, visual diagrams, images, ppts, posters, or any other methods can be used. Questions that can be used in order to see if feedback loops are operating in the process include: Do we have the same picture of the issue or strategy? If not, how do we get it? Is it clear and unambiguous? Is it rigorous?

- Improving the design: In this phase, the design should reflect on all of the feedback and decide if or to what extent it should be incorporated. It is often helpful to take solutions back through the design process to refine and clarify them. In using systems thinking-based manners, the designers need to continually present, test and improve the picture until there is nothing left to improve. And they know they have done it well if their mental model of the issue is as simple as possible. The questions that can be asked include: How do we build confidence in the theory? How do we keep it as simple as possible, but not simpler? Is the model too complex? Could we remove some of that complexity?

METHODOLOGY

The research in this paper adopts a Qualitative Comparative Analysis (Ragin 1987), looking at the team and project performance of students projects (design of a high-rise building) in groups (four groups and so four cases in total). QCA is used when there is not sufficient data to statistically consider but when the richness of the information about each case allows powerful and compelling stories about the likely causes for desired outcomes to be told (Cheng 2015). In employing a QCA method, it is required to defining a model with a set of variables. In the current research study, these variables are designed and surveyed in connection with the team and project performance of students in groups and from different perspectives. The survey consisted of twenty-four questions, as presented in Table 1.

IMPLEMENTATION

The HBD has been being developed and taught by the authors of the present paper in the Integrated Engineering Project - IEP course at the Department of Engineering, Aarhus University, since 2016. A general overview of HBD methodology was presented, and here we present the results from the teaching and application of it in the IEP course in spring 2019. The course ran with 29 third semester master's students from different specializations, including 12 students from construction management, four from structural engineering, three from tectonic design, three from ventilation, four from energy and indoor climate, and one from geotechnical engineering specializations. It is important to mention that students with tectonic design background played a role as architects in this exercise; nevertheless, there is a massive potential to running the similar course in collaboration with architecture schools (e.g., Aarhus School of Architecture), and so having and involving the architecture students in the same practice, in future.

Project description

In groups (four groups with different specializations), students were called on the development of a high-rise building. Throughout the framework of HBD, the instructors delivered several lectures related to ST, IDP, BIM, and their application for the development of sustainable high-rises. In particular, there were multiple lectures about BIM, its framework, benefits, challenges, the potential for mass modeling, model development, detailing, performance analysis, collaboration (C4R), construction management, as well as its integration with VR technology, LCA/LCC analysis tools, and several analytical tools. Revit was partially taught (since the students were already famil-

No.	Questions	No.	Questions
1	Using HBD enhanced our ability to reach a more sustainable design	**13**	BIM improved the coordination and quality of our design
2	Using HBD enhanced our ability to address context variables from the problem structuring phase	**14**	3D visualization and clash detection allowed for a better understanding and coordination of our design
3	Using HBD enhanced our ability to incorporates design variables from the problem structuring phase	**15**	Successfully implementing BIM should result in better coordination and fewer change orders
4	Using HBD enhanced our ability to meet performance variables from the problem structuring phase	**16**	HBD improved our team vision to achieving the project objectives
5	It was easier to design using HBD	**17**	HBD increased support for innovation
6	Early understanding and agreement on workflows is critical to successful HBD	**18**	HBD acquired participative safety in decision-making and support in proposing new and improved ways of doing things
7	Understanding of 'lead/lag' and interdependency is critical to successful HBD	**19**	HBD facilitated task orientation in groups that led to the success of project
8	Using HBD I gained a new understanding of other disciplines	**20**	HBD enhanced task cohesion (united to reach goals)
9	Successfully implementing HBD should result in better coordination and fewer change orders	**21**	The Integrated Engineering Project course was a more effective learning experience than my previous design courses
10	Creating and sharing BIM models was relatively easy	**22**	After the Integrated Engineering Project course I am more comfortable working on multidisciplinary teams
11	Sharing information from software to software was relatively easy	**23**	The Integrated Engineering Project course helped me prepare for the "real world" of design and construction
12	Our actual workflows turned out to be similar to our plan	**24**	After the Integrated Engineering Project course I know more about other discipline roles, how they interface with each other and how each can collectively contribute to the design process

Table 1
Qualitative comparative analysis of HBD implementation

iar with software) and used as the main software together with Dynamo (for parametric design, and performance analysis), Naviswork (for 4D and 5D analysis), Sigma database (Danish cost databased), Autodesk Green Building Studio (for energy and sustainability analysis), Robot (for structural analysis), One-Click LCA, and Autodesk CFD. Two groups used IFC for data exchange for running structural analysis. Moreover, students used their Revit models for solar, shadow, energy, heating and cooling load, and location-based scheduling analysis in Revit. The outcomes were presented and documented in the form of A3 portfolios, followed by a group presentation and individual oral exams.

Project outcome

For evaluation of the HBD implemented in the course, we used the methodology explained in section 2. We conducted a survey at the end of the semester, using the questions in Table 1. Since the survey was implemented after the exam was done, therefore, there is no data available for this course related to the trending of individual and group performance over the life of the project. Likert scale was exploited in the survey follows as: 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, and 5= Strongly Agree. The outcome of the survey is presented in Figure 6.

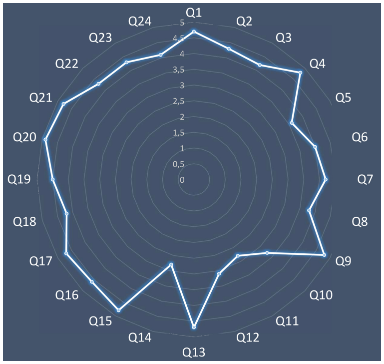

Figure 6
Evaluation outcome of HBD methodology in Integrated Engineering Project course (see Table 1 for the surveyed questions)

The survey outcome was in total very desirable and produced several results. Concerning outcomes, it is evident that there is a correlation between the ability of the groups to work together effectively and the quality of the student work product. Almost most of the students felt they learned more about other specializations' roles, and after the course was done, they felt much more comfortable joining in multidisciplinary groups. Most students appreciated the learning about HBD in the IEP course was a very effective learning experience. Some students commented on how exciting it is learning and practicing on BIM, IDP, and Sustainability in one package, as they are repeatedly hearing about them in both academia and industry. All groups found that the development and sharing of a BIM model were somewhat challenging, however beneficial. Actual workflows turned out to be similar to the planned workflows. Almost all confirmed that they learned more about other disciplines within the design process.

Students found it relatively difficult to using IFC for data exchange between the applied software. Likewise, they felt that the connection between BIM and sustainable design was not as strong as anticipated (or should be), possibly due to workflow challenges encountered by the student groups. This requires adding and covering more contents and practical exercises on BIM's ability to achieving sustainability in the future. All groups, specifically in the early phases of the project, found HBD somewhat difficult and more time consuming (comparing designing the project on their own or in a smaller group). On the other hand, all agreed that the successful implementation of HBD will result in better and more sustainable design outcomes.

CONCLUSION

HBD is under development, and there are many plausible perspectives yet to be explored. The basis for a major R&D project into HBD was configured and practiced in this paper. The methodology as a research project will be moving through other stages where experiences will be considered more systematically, and the concepts developed further, and emerging patterns of use and application will be elaborated and reported on.

HBD is intended to integrate knowledge from engineering and architecture and let them interact with each other in order to solve the often very complicated problems connected to the design of sustainable solutions. Based on the result of the present study and our experience since 2016, it is observed that the HBD framework could significantly facilitate the understanding of the design process and enhancing it by promoting iterative decision-making and turning the focus to the earlier stages of the design process. That encompasses the level of awareness, communication, and cohesion concerning the used technology between the entire involved students in their group and their relevant demands (from different specialization, i.e. structure or construction management) for the sustainable development of a complex building, or the high-rise building that is the focus in this project. Likewise, it appears that HBD can also influence on more productive teamwork and process from the used technology perspective, and as a result of this, it contributes to improvement in time-saving, accuracy and quality of the final decisions, as well as encouraging the users (in this project students) to deal with a broad set of sustainability-focused design variables.

Hands-on integrated BIM practices are crucial to prepare students for a professional career in the fast-changing fields of the AECO industry. It is essential not just to teach the new software or digital technology, but also to expose students to approaches that foster successful collaboration and break down specializations' silos, as well as the compartmentalization of the design process. It is simply a question of becoming familiar with the process and how this awareness is learned and acquired. For students to be successful in these rigorous collaborative learning exercises, they need to join into the integrated building design courses with adequately well-developed BIM competences, be equipped with efficient computers and labs to handle digital and team collaboration. This entails receiving on-going support from academia and individuals who have a broad range of disciplinary knowledge and experience with the BIM and IDP, applied in real-world cases.

REFERENCES

Bergman, D 2012, *Sustainable design: a critical guide*, Princton Architectural Press, New York

Bertalanffy, L. von 1968, *General system theory: foundations, development, applications*, George Braziller, New York

Brundtland, GH 1987, *Report of the world commission on environment and development: Our common future*, Oxford University Press, Oxford

Checkland, P 1981, *Systems thinking, systems practice*, John Wiley and Sons, Chichster

Cheng, R 2015 'Integration at its Finest: Success in High-Performance Building Design and Project Delivery in the Federal Sector', *University of Minnesota Digital Conservancy*

Deutsch, R 2011, *BIM and Integrated Design*, Wiley & Sons, Hoboken

Eastman, C, Teicholz, P, Sacks, R and Liston, K 2011, *BIM Handbook: A Guide to Building Information Modeling for Owners Managers Designers Engineers and Contractors*, Wiley & Sons, Hoboken

Fischer, M, Ashcraft, H, Reed, D and Khanzode, A 2017, *Integrating Project Delivery*, Wiley & Sons, Hoboken

Flood, RL and Romm, N 1996, *Critical systems thinking: current research and practice*, Plenum Press, New York

Kamari, A, Corrao, R and Kirkegaard, PH 2017, 'Sustainability focused Decision-making in Building Renovation', *International Journal of Sustainable Built Environment*, 6, pp. 330-350

Kamari, A, Jensen, SR, Corrao, R and Kirkegaard, PH 2019a, 'A Holistic Multi-methodology for Sustainable Renovation', *International Journal of Strategic Property Management*, 23(1), p. 50–64

Kamari, A and Kirkegaard, PH 2019b, 'Potential shift of Integrated Design (ID) through BIM in Sustainable Building Renovation', *IOP: Earth Environment Science*, 329, pp. 12-25

Kamari, A, Laustsen, C, Petersen, S and Kirkegaard, PH 2018, 'A BIM-based decision support system for the evaluation of holistic renovation scenarios', *Journal of Information Technology in Construction*, 23, pp. 354-380

Keeler, M and Vaidya, P 2016, *Fundamentals of integrated design for sustainable building*, Wiley & Sons, Hoboken

Löhnert, G, Dalkowski, A and Sutter, W 2005 'Integrated Design Process: a guideline for sustainable and solar-optimised building design', *Proceedings of World Sustainable Building Conference 2005*, Tokyo, pp. 894-901

Ragin, CC 1987, *The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies*, University of California Press, Berkeley

Reed, B 2009, *The Integrative Design Guide to Green Building*, Wiley & Sons, Hoboken

Weinberg, GM 2001, *An introduction to general systems thinking*, Dorset House, New York