# BIM AND ITS IMPLICATIONS ON DESIGN THINKING AND TEACHING OF THE DESIGN PROCESS

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***Abstract***

The construction industry is currently undergoing major changes that are affecting business methodologies for those involved in design and construction of the built environment. The adoption of new technologies which are aligned with sustainable practices such as BIM can be directly attributed with the significant shift in methodologies. As professional architects and engineers move rapidly from (CAD) Computer-Aided Drafting to (BIM) Building Information Modelling, architecture programs face several challenges and opportunities. The BIM process provides significant and latest advantages to the students of university programs who have only recently started to investigate, however it could also lead to substitution of traditional skills which might be neglected. Some of the faculty members are concerned that latest BIM exercises could jeopardize design thinking. The implications of changing processes on design education, specifically architectural design teaching, are examined in this review of literature.

***Keywords***

BIM and integrated design; Architectural education; integrated design studio; Building Information Modelling; BIM; Design Education: Design Process.

## 1 Introduction

The embracing of technology in the construction industry has been steadily growing over the years. The need to adopt sustainable practices driven by technology is being mandated by many governments across the world. In this context, the evolving concepts for an "Integrated Practice" in the construction industry, through BIM (Building Information Modelling), have the potential to significantly change the way architectural education deals with issues of design knowledge, technology, representations, and collaboration (Ambrose, Lostritto and Wilson, 2008). Today's design graduates are entering a professional landscape that is widely varying from what it was a decade ago. Frequently, challenges faced by the

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construction industry is the need to adopt and manage rapidly unfolding technology in order to implement complex design projects across the globe.

The skills and understanding required for graduate level positions are expanding for young architects seeking job opportunities with design firms that carry out large-scale projects. The major professionals involved in creating any built space includes architects, engineers, interior designers, contractors, and a host of project and building category specific consultants. Design curriculum must include industry relevant technology as part of academia for architects and interior designers to be viewed as professional, knowledgeable, and capable members of the project team. (Crumpton & Miller, 2008).

As design educators, it is important to consider emerging skills that are important for the design process. This is due to changes that are emerging in the practice. The main purpose of this literature review is the understanding of integration of technology called (BIM) Building Information Modelling and its potential inferences on the field of Architectural Design education.

## 2 Comparison of BIM and traditional 2D Drafting Tools

2D drafting software has been around for many years and is still widely used today. BIM, or Building Information Modelling, is a newer technology that is quickly gaining popularity.

While 2D drafting software is a tried-and-true method for creating construction drawings, BIM is quickly becoming the preferred method for many reasons. BIM allows for a more three-dimensional view of a project, making it easier to visualize the final product. Additionally, BIM files are more easily shared and updated, making collaboration between team members simpler.

Designers create drawings with the aim of delivering construction drawings throughout the design process, that the contractor can use to build from. These documents can include floor plans, sections, elevations, construction detailing, reflected ceiling plans, plumbing layouts, electrical and lighting layouts, and others. Up until the introduction of BIM to the industry, CAD technologies were at best mimicking the hand drafting practices. Wherein the intent of design and construction were represented in 2D form only. The modern-day designers were no different from the two to three decades old designers who would sit in front of a paper on drawing board and draft the drawings, just that the paper, pencil and drafting board were replaced by computer, mouse, and workstations. Instead of drawing real lines, designers would end up drawing virtual lines on the computer. Thinking of multitude of factors and automation were minimal, the document set was still treated as a group of individual sheets or drawings and each drawing had to be individually coordinated.

BIM and CAD are two very different things. The traditional pen and paper system is replaced by CAD, while BIM is a 3-D virtual "proto-building" process. “BIM programs produce documents that flow from and are a derivative of the virtual building process” (Tobin, 2008). BIM technology embeds the important project data such as construction details, materials, finishes, price and other vital information, and specifications, into the models. Having this project data within the 3D model means that construction and other

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related documents of all the disciplines can be pulled out from a single source of truth (Aubin, 2011). This drastically cuts down on the time needed for drafting and coordination between disciplines. Being able to work with a comprehensive holistic model from the get-go is changing how designers and engineers approach the design problem.

## 3 Adoption and Implementation of BIM in the Industry

The use of BIM in the real estate and construction industry is growing rapidly, with more and more companies adopting and implementing the technology. There is no denying that BIM process has become a staple in the construction industry, with more and more firms adopting the technology each year. In 2010, the adoption of BIM by leading firms reached a critical tipping point, and now many firms are in the process of transition, utilizing various aspects of the software to streamline their workflow. This suggests that while many of the projects are either started using BIM tools or are gradually being moved from conventional 2D to BIM platforms, BIM's full potential is yet to be realized. "Firms may own the software but don't yet own the process" (Deutsch, 2011). There is a difference between adopting and implementing BIM. Adopting BIM means purchasing the technology while implementing it requires systemic, industry-wide changes. This will take time to grow into an integrated practice. Some of the firms, especially smaller ones, cannot invest into the exercise of converting to a new software, while other firm, like the residential firms, do not need the extent of information that the BIM process provides. In the field of education currently, Design students are expected to learn both types of software for them to be marketable after graduating (Crumpton & Miller, 2008).

The term (IPD) 'Integrated Project Delivery' has been receiving a lot of attention from the industry recently. Definition of IPD as stated by AIA (AIA Guide, 2007): "Project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction." The link between IPD and BIM is evidently very strong, with BIM facilitating IPD.

## 4 Design Process & its Multiple Theories

Firstly, understanding of the existing design evolving methodologies leads us to understand that design process may undergo multiple stages. Key design process has been studied and tabulated below for further research.

During the early stage, designers try to understand user needs, conduct market research, and figure out the business requirements. Once this is done, designers then move on to the design stage where they follow the design cycle—understanding problem, idea generation, sketching, user testing, and prototype creation. Once the design cycle covers the process, it then undergoes refinement. While it may be hard to define the design process, multiple theories may explain the design cycle. The idea of architectural design process has been around for centuries, however, it wasn't until the 1960s that designers began to approach it as a formal process (Davis and Gristwood, 2016). Markus (1967) & Thomas Maver (1970)

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inferenced that design process is a decision-making sequence progressing from analysis to synthesis to appraisal to decision at detailed stages, as shown in Figure 1.

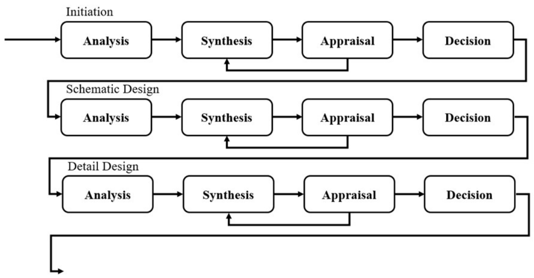


**Figure 1:** Design methods by Markus & Maver.
**Source:** (Lawson, 2006)

There is another design process perspective which was propounded by John Wade (1977). He says: "design is all about coming up with ideas to change things for better". He breaks the design process down into three parts: current situation, process of transformation and desired future state, as shown in Figure 2.

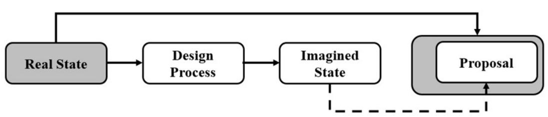


**Figure 2:** Design Process by John Wade.
**Source:** (Wade, 1976)

Tim MacGintry offered different perspective on the design process into five steps: "initiation, preparation, proposal, evaluation, and action". This process transforms the initial state to a future imaginary state (Snyder, 1979), as shown in Figure 3 & Figure 4.

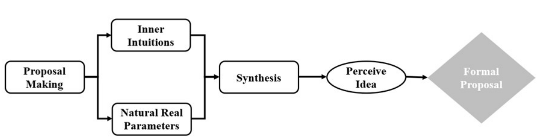


**Figure 3:** Formal Proposal creation through false procedure by Ata Chokhachian.
**Source:** (CiNdiOğlu, 2014)

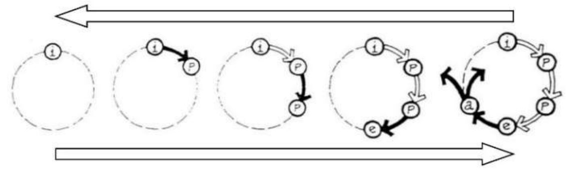

**Figure 4:** Five Step Design Process - Initiation, Preparation, Proposal Making, Evaluation, Action.
**Source:** (Snyder, 1979)

The map, as it stands, no longer provides a clear path through the entire process. He suggests a more accurate and realistic portrayal of the connection between analysis, synthesis, and evaluation as seen in Figure 5. This shows that the relationship between these three elements is more than a linear process, meaning they work together in a systematic way.

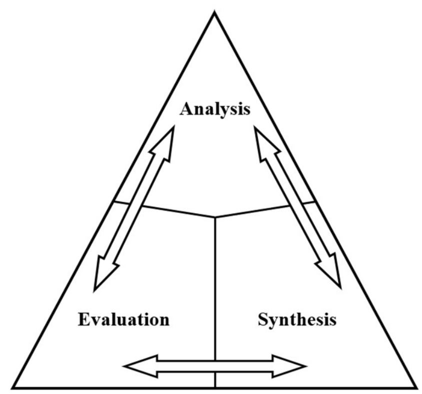


**Figure 5:** Illustration of Practical Design Process
**Source:** (Lawson, 2006)

There are many other Design Process theories propounded over the years. A tabulation of a few theories and identifying influence of BIM process over the traditional methods is tabulated in the next section or the readers to understand impact of BIM processes.

## 5 Overlay of BIM in Design Process

Table 1 highlights a few other significant design processes. Here we can look at the

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critical process steps marked in grey which are directly influenced by the new BIM processes. The direct impact can be seen due to changing working conditions by implementation of systems such as Integrated Project Delivery, Virtual reality and Augmented reality.

| Design Process Theories | Design Process Defined Steps | | | | |
|---|---|---|---|---|---|
| Thornley Student Design Process (1963) | Program Formulation | Investigation Assessment of Design Possibilities | Create | Refinement | Presentation |
| J. C. Jone's Design Method | Idea | Information Analysis | Synthesis | Evaluation | Optimization |
| R. Whitaker`s Eight-step Design Process (1971) | Recognition Definition | Preparation Analysis | Synthesis | Evaluation | Execution |
| RIBA Architecture Service (1972) | Inception | Feasibility | Outline Proposals Schematic Design Detail Design | - | Production Tender Action Project Planning Completion Feedback |
| G. T. Moore`s Design Process (1974) | Identify Problem | Programming or Analysis of User Requirements | Synthesis | Choosing from Alternatives | Post Occupancy Evaluation Implementation |
| Five step Design Process (Snyder, 1979) | Initiation | Preparation | Proposal | Evaluation | Action |
| Gavin Ambrose & Paul Harris (2009) | Define and Research | Ideate | Prototype | Select & Implement | Learn |
| AIA Basic & Supplementary Services | Predesign Services | - | Schematic Design | Design Development | Contract Documents Bidding Administration of Contract Post Design Service |

**Table 1:** Design Process Theories
**Source:** (CiNdiOğlu, 2014) & Author

## 6 Impact of BIM on Design Process, Collaboration and Project Delivery

BIM has changed the flow of projects from being linear to being more efficient. The traditionally followed system of design-bid-build project delivery usually starts with the architectural design team targeting the exterior or "shell" of the built form and interior design components like the column grids, basic structure, stairwells, and elevators or "building core". The engineering team carry out feasibility studies and design the environmental control systems, such as heating & ventilation, air conditioning, plumbing after the first stage. Later, the interior designing team and other project consultants are involved in the project. As each discipline is on boarded, their related information is layered over the architectural core and shell. This information is then cross-checked and incorporated into all the construction documents through a back-and-forth process. This leads to segregation of disciplines into "silos" of expertise and knowledge, and also requires frequent coordination among the teams, leading to errors and confusions, schedule delays and unanticipated costs.

## 7 Working in a team environment

Since the consolidated project team will be working very closely and much earlier in the process, participating members of the design team will be examined for their skills of collaboration and leadership abilities. Successful execution of interdisciplinary and team-based project schemes, demonstrating the tools, techniques, and importance of a collaborative environment, can be challenging in the current and limited academic setting. The challenges students face in appreciating and understanding the nature of a design firm without experiencing a professional work atmosphere are further aggravated when professionals have not yet identified best practices from the perspective of the designing themselves. During this time of change, it is reasonable that context and team working is best extrapolated by a mix of academic learning and real-world experience, like an internship combined with classroom discussion and reflecting on what the student learns in the process (Black, 2000).

In the past, collaboration typically involved a project-based team in accommodated in one location physically, who could communicate with each other face-to-face. However, technology today permits sharing of all the required information, which evolves into a new type of collaboration. Geographical distances and cultural differences can pose

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challenges for designers who are increasingly working in multicultural and multidisciplinary teams. The ability of emotional intelligence and cooperation with other members has been vital for productive teamwork, however, importance of cultural awareness as a skill has become an important factor for global teams (Weko, 2011).

## 8 Conclusion

BIM encourages students to think and resolve architecture, structure, & mechanical systems in a coherent manner, and emphasis on factors of construction & materiality at nascent stages of the design process than compared to traditional 2D design. It's evident from the enquiries that students often had difficulty in understanding the impacts of Structural or other services related decisions over Architectural elements, and vice versa until the implementation of BIM. In the traditional approach, students develop an architectural plan and then superimpose structural framing plans, where individual members are represented by single lines. Though relationships between systems appeared three-dimensional, they are usually under-developed. In the new paradigm, students come to understand the benefits of an integrated design process by visually constructing the building, rather than through abstract representation as done in the old paradigm. This necessitates that they reflect on how distinct systems cooperate within the framework of the space (Denzer and Hedges, 2008).

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