INVESTIGATION OF BIM ADOPTION STRATEGIES IN INDIAN AEC INDUSTRY

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ABSTRACT

Building Information Modelling (BIM) is the process of creating digital parametric models for life cycle data management. Use of parametric modelling tools enables in integrating the building data from various stakeholders, on a virtual platform. On large-scale building projects with numerous stakeholders, a well-drafted strategy for BIM adoption becomes essential. This can be attributed to the complexity in the information exchange process between the various stakeholders. This paper focuses on investigating the strategies for BIM adoption in the Indian Architecture, Engineering and Construction (AEC) industry. What are the typical BIM goals on a project? What strategies can lead to effective BIM adoption? These are questions that this paper seeks to address. Case based investigation was carried out in three commercial building projects of comparable scale. A detailed investigation of the cases was carried out through interviews with the various stakeholders and documentation of the BIM adoption process. Case data were analysed to identify the strategies commonly adopted on projects. Further analysis enabled in developing a framework for BIM adoption strategies in the Indian AEC industry.

Keywords: *Building Information Modelling (BIM), BIM Adoption, BIM Goals, Strategy.*

1. INTRODUCTION

The exchange of information between participants on building projects is a complex process, particularly on large-scale commercial projects. Building Information Modeling (BIM), the process of creating digital parametric models of the building, integrates information on a virtual platform and hence eases such information exchange necessities between the various participants.(Eastman *et al.*, 2008; Smith, 2007) However, the use of BIM models and the process of creating the same varies across projects (Dossick and Neff, 2010). Why do BIM adoption processes vary from one project to another? What are the parameters to be considered while developing a BIM adoption strategy? These are some of the questions that this paper intends to address.

The objective of this paper is to investigate why the BIM adoption process varies across projects. This includes identification of the parameters that are to be considered while developing a BIM adoption strategy on Architecture, Engineering and Construction (AEC) projects. The scope of the work is limited to commercial building projects in the Indian industry.

2. BUILDING INFORMATION MODELLING

Building Information Modelling entails the development of integrated, parametric models of buildings. The process of developing BIM enables better design integration, constructability review, co-ordination for construction, building performance analysis and also facility management (Eastman *et al.*, 2008). Building Information Models (BIMs) are 3D parametric, virtual representations of the built environment. These models are capable of representing specific details to facilitate extended analysis as needed ahead of construction (Mulva and Tisdel, 2007).

One of the greatest advantages of BIM is the fact that all the information related to a project can be contained in, or linked to the virtual model of the building (Kymmell, 2008). In other words, Building Information Models function as repositories of project information, from design through construction to

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operations. It follows that BIM models can be built in a variety of ways and can be used for different purposes throughout the project lifecycle (Ning and London, 2010). One of the fundamental requisites of an organisation intending to adopt BIM is the definition of project-specific BIM-goals. BIM goals are a subset of the entire range of BIM uses that an organisation intends to pursue, depending on the project's needs.

Through an extensive literature review, we have identified the following as some of the most common BIM uses on a typical construction project, across the different phases of the project, shown in Table 1 below.

Table 1: Common BIM Uses on AEC Projects across Project Life-Cycle

DESIGN	**CONSTRUCTION**	**OPERATIONS**
Compare and analyse different design alternatives (Kymmell, 2008)	Replacement of fabrication shop drawings by 3D model (Gilligan and Kunz, 2007)	Generate "as-built" models (Manning and Messner, 2008)
Generate 2D drawings (Gilligan and Kunz, 2007)	Automated Quantity Take-offs (Brandon and Kocaturk, 2008)	Repair strategy development (Brandon and Kocaturk, 2008)
Visualisation/ walkthrough (Kymmell, 2008)	Cost tracking (cash flow analysis) (Kymmell, 2008)	
Clash detection/ design coordination (Gilligan and Kunz, 2007)	3D analysis of safety issues (Sulankivi *et al.*, 2009)	
Constructability analysis (Kymmell, 2008)	Installation procedures at congested areas (Brandon and Kocaturk, 2008)	
Cost analysis and estimation (5D) (Kymmell, 2008)	Analysis of construction sequences (Khanzode *et al.*, 2008)	
Construction schedule modelling (4D) (Brandon and Kocaturk, 2008;)	Purpose built models for specific problem solving (Kymmell, 2008)	
Energy/performance analysis (Eastman *et al.*, 2008)	Optimisation of crew(s) productivity (Gilligan and Kunz, 2007)	
Linking of methods statement to model (Brandon and Kocaturk, 2008)	Construction mobilisation procurement (Khanzode *et al.*, 2008)	
Planning of construction sequences (Eastman *et al.*, 2008)		
Resolution of coordination issues during regular coordination meetings (enhanced visualisation) (Khanzode, 2010)		

This paper intends to investigate how these BIM goals are achieved in various building projects.

3. RESEARCH DESIGN

We set out to investigate three commercial building projects of comparable scales, in order to ensure similar levels of complexity in the planning and design phases. Another important criterion for case study selection was that the projects must adopt BIM. A qualitative research methodology was adopted to explore the BIM adoption process on each of these projects (Scott, 1965). Case data was collected through unstructured interviews and through participatory observation. Unstructured interviews along a predetermined line of enquiry were conducted with each project participant. Participatory observation of the BIM adoption process was a major source of data that aided in the identification of parameters that affect the BIM adoption strategies on AEC projects. Standard axial and open coding techniques were used to analyse our data (Strauss and Corbin, 1988).

4. DATA COLLECTION – CASE STUDIES

4.1. CASE STUDY 1

The first case - an eight storied office building - was a traditional Design-Bid-Build project. Mechanical, Electrical and Plumbing (MEP) coordination in this particular case was very complex due to the number of service systems involved and the corresponding number of participants. This complexity motivated the use of BIM (Simonian *et al.*, 2008). The sole BIM goal on this project was MEP coordination.

We participated and observed the MEP coordination of above false ceiling works as a "fly on the wall" (Mahalingam and Levitt, 2007) for a period two months. The BIM adoption process was documented and participants were interviewed. Individual design consultants would develop drawings of their corresponding service systems and submit these 2D CAD drawings to the principal architect, who in this case was the MEP coordinator. Figure 1 below shows the BIM model developed for MEP coordination.

Figure 1: Integrated BIM of Above False Ceiling MEP Works

Following an integration of all the individual models developed, the architect identified problems that could be broadly classified under three categories namely, lack of adequate details, clashes between components and changes (in scope, specifications or system type). The identified problems were resolved during a coordination meeting.

Typically, the BIM model was projected, and the consultants were able to "see" the exact location of the problem. Although, the initial BIM goal was clash detection of MEP, it extended to enhanced visualisation for problem resolution as well.

4.2. CASE STUDY 2

Our second case - a multi-use retail facility - was a Design-Build project. In the case of a Design-Build project, design and construction are parallel activities. The EPC contractor decided to use BIM tools primarily for constructability review, apart from other uses. The BIM goals of the project included,

i. Visualisation / Client walkthroughs
ii. Clash detection / Design coordination
iii. Visualisation for regular coordination meetings
iv. Generating 2D drawings
v. Quantity take-offs for cost estimation

In this case, the BIM adoption was driven top-down. A co-located meeting space was part of the management's BIM agenda. As has been suggested in the literature, the primary purpose of this space was, to explore the potential of such a space to empower individual team members to communicate their design ideas to the rest of the team (Fernando, 2008).

Hence, the BIM team worked in a co-located workspace - referred to as a "workshop", meant for representatives from various disciplines to work collaboratively. Of the various BIM goals, clash detection required collaborative decision making and hence the objective of the workshop was, initially clash detection and design coordination alone. The workshop was headed by the design coordinator, assisted by one modeller from each design team. The layout of the workshop is shown in the Figure 2 below.

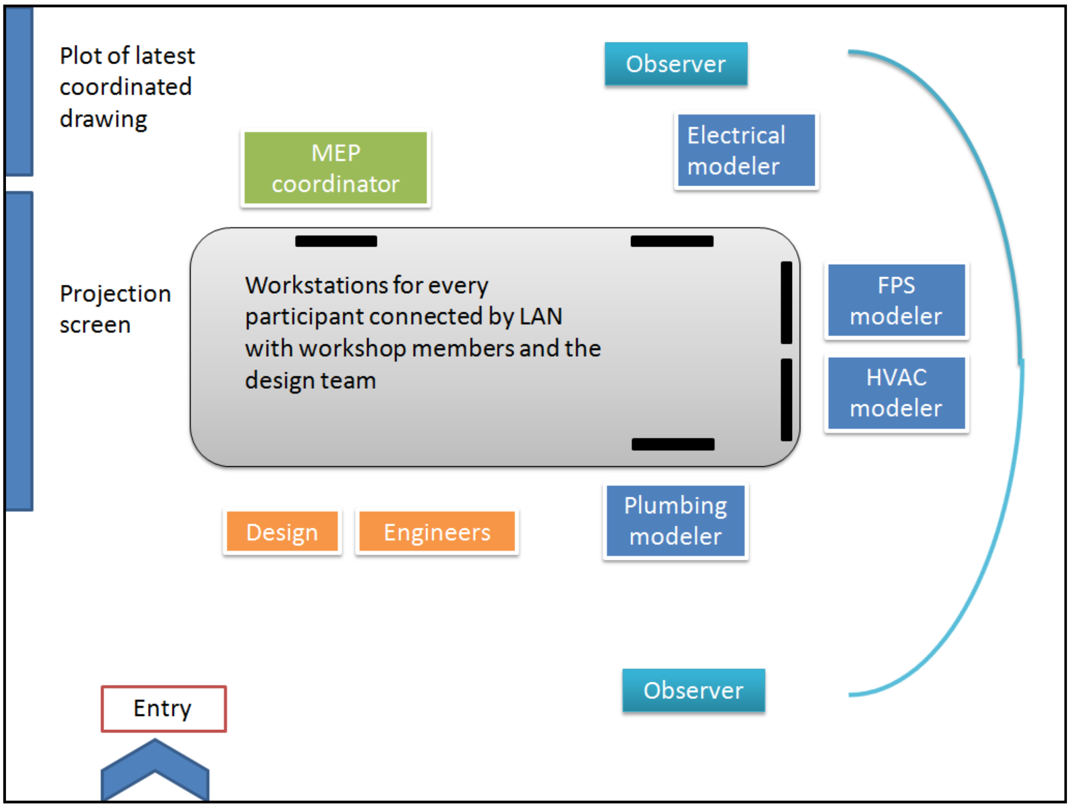

Figure 2: Co-located Workspace Layout

During the workshop, the coordinator integrated individual BIM models of each discipline, and performed an interference check. The results were reviewed, and critical clashes were projected onto a screen. Clash resolution was done either in the co-located workspace or in a coordination meeting depending on the magnitude of changes that would be required to resolve the clash. Coordination meetings were typically attended by all the chief engineers/architect. The workshop was the venue for every coordination meeting, during which, the coordinated BIM model was projected on the screen. This not only facilitated better visualisation, for the engineers/designers, but also provided scope for value engineering.

Over our three month observation period, interferences used to be resolved in such coordination meetings during the first few weeks. Progressively with time, the engineers visited the workshop frequently, suggesting changes to the modeller, wherever necessary to improve the performance of the system. After a couple of months at the workshop, the engineers realised that minor changes that would not affect the performance of the system could be done by the modellers. This resulted in saving the time lost in frequent visits to the workshop for the engineers.

The output from the workshop was the coordinated BIM model, which in turn was delivered to the construction team. 2D drawings generated from these models were issued to site, stamped as Good for Construction (GFC). The construction team utilised this model for quantity take-offs.

4.3. Case Study 3

Our third case is a commercial facility in which the owner played the role of the contractor as well. Design was outsourced to various individual organisations while the construction team was in-house. The project brief was based on a specific construction methodology that involved the use of a particular type of formwork, novel to the Indian construction industry. The designs were conceived such that spaces were modular; to suit the specific needs of the formwork.

Initially the owner decided to use BIM for client presentations and modelling of architectural and structural components to check for dimensional compatibility with the formwork. This BIM goal can be broadly classified under the constructability analysis category. An in-house BIM team worked on model development of the architectural, structural and MEP components.

When MEP design was in progress, the MEP execution engineer of the construction team suggested that BIM be used for accurate modelling of the various MEP components. The dimensionally accurate coordinated BIM model, according to him, could be used by the piping and HVAC subcontractors to prefabricate and deliver in kits (Figure 3) for specific areas for a crew on site. The models were developed with a high level of detail, and hence the construction team started referring to the model for cross-checking their quantity take offs during estimation.

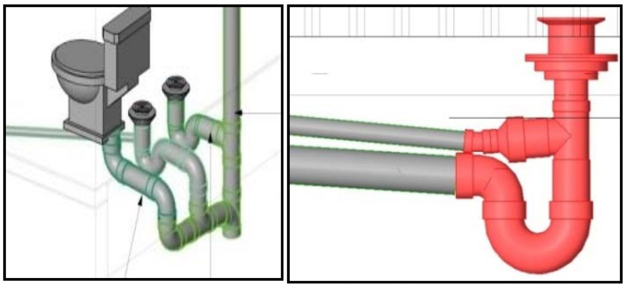

Figure 3: Example of BIM Models of Plumbing 'Kits'

While the construction team was developing the schedule they faced several hurdles, since they were unclear as to the construction methodology that was to be used for installing their new type of formwork. At this juncture, 4D simulation of the developed BIM model was resorted to, for quick review of the developed schedule. Therefore, we observed the development of a detailed BIM model that integrated structural, architectural, MEP components; took in construction related inputs, and was used for a variety of purposes throughout the design and construction lifecycle, in this case. The BIM team which was initially another department in the office slowly started becoming the nucleus of most activities in the office.

5. DISCUSSION

5.1. COMPARISON OF CASES

BREADTH OF BIM ADOPTION						
	DESIGN				CONSTRUCTION	
CASE 1	Clash detection/Design coordination	Generate drawings	Resoulution of coordination issues in meetings			
CASE 2	Clash detection/Design coordination	Generate drawings	Resoulution of coordination issues in meetings	Visualization	Automated QTO	
CASE 3	Clash detection/Design coordination	Generate drawings	Constructability anlaysis	Construction schedule development -4D	Automated QTO	Replacement of fabrication shop drawings by BIM model

Figure 4: Number of BIM Goals across the Three Cases

An interesting observation across the three cases was that the number of BIM goals progressively increased from one case to another, as shown in Figure 4 above. We then proceeded to investigate what factors influenced the same. Our analysis revealed that the "breadth of BIM adoption" represented by the number of BIM goals was dependent on the project structure. The project structures of each of the cases are illustrated below in Figure 5 below. The breadth clearly spanned some design goals in the first case, extended to design and construction goals in the second case, and increased to a larger set of visualisation, design and construction goals in the third case.

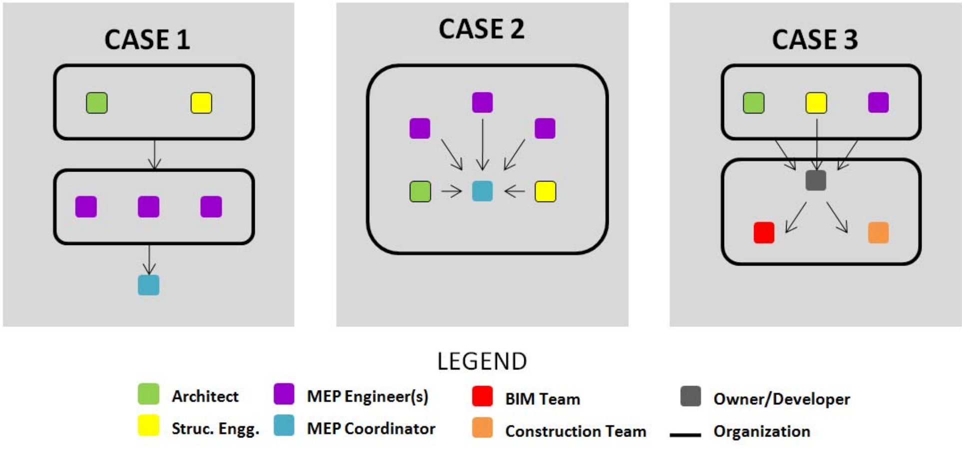

Figure 5: Project Structures of the Cases

The first case had a project structure with maximum fragmentation where participants of each engineering discipline were from a different organisation, and had the least breadth of BIM adoption. The third case had the least amount of fragmentation with the owner and the contractor being a unified entity, and had the greatest breadth of adoption. Hence, it appears that the breadth of adoption is inversely proportional to the fragmentation of the project organisation. The more integrated the contractual and project organisational structure, the greater the ability to collaborate and involve multiple trades in decision making, and consequently the greater the scope for exploring a variety of BIM applications. We thus state the following proposition:

Proposition: Integrated projects structures enable the use of BIM over a wide range of diverse BIM goals across the project lifecycle.

One of our research questions was to identify parameters that aid in achieving the BIM goals. In other words, we set out to identify factors that need to be considered while developing a BIM adoption strategy. We analysed our interview transcripts and documentation of the BIM adoption process on each of these cases to identify parameters that were considered in developing a strategy for the same. The three parameters that need to be considered while developing a BIM adoption strategy include assigning BIM roles to various participants, employing contractual innovations that specify the use of BIM and incorporating collaborative work procedures. Each of these parameters is discussed in detail in the section below.

5.2. Assigning BIM Roles to Various Participants

Kymmell (2008) identifies three primary BIM-related roles: the BIM manager, the BIM operator, and the BIM facilitator; and suggests that creation of such roles within a project organisation is necessary for successful creation and use of BIM models. Each of these three roles has specific responsibilities and skill-sets. The responsibility of the BIM manager is to plan and manage BIM processes at various levels. The BIM operator (modeller) has the skills to perform tool-related tasks. The BIM facilitator acts as an interface between the BIM team and the construction team on-site, who may not have enough skill to extract the required information from the BIM. Our investigation revealed that assigning appropriate BIM roles is significant to achieving the BIM goals on a project.

5.3. Contractual Innovations Specifying the Use of BIM

Contracts that specify the use of BIM and Integrated Project Delivery (IPD) contracts excluding litigation are examples of some possible contractual innovations that encourage BIM adoption. The IPD contract is a type of relational contract (AIA, 2007) that explicitly mandates collaboration between project participants. It is critical to ensure that contractual innovations aid in augmenting existing resources to achieve BIM goals.

5.4. INCORPORATING COLLABORATIVE WORK PROCEDURES

Collaborative procedures represent one set of organisational strategies that enhance the integration of the project team. For instance, Dossick and Neff (2010) highlight the need for communication innovations such as 'messy-talk' as a strategy to effectively adopt BIM. Regular coordination meetings that feature multiple disciplines are examples of collaborative procedures for effective BIM adoption. The BIM development team is an inevitable participant in such coordination meetings, and is either the contractor with BIM development capabilities or an external BIM consultant.

Collaborative work processes also include creative brainstorming sessions in "big rooms" and continuous co-located workspaces (Dossick and Neff, 2010; Homayouni *et al.*, 2010). Continuous co-location of a team composed of critical members sharing the same space improves access to one another, thus aiding in reducing the project latency while co-creating the BIM model, as was seen in case 2. Where continuous co-location might not be possible, one of the most efficient ways of achieving complete collaboration is to get critical participants in a "Big Room" where they brainstorm together and interact to resolve design and construction conflicts. Table 2 below compares and summarises our cases based on these parameters.

Table 2: Comparison of BIM Goals and Adoption Strategies across the Cases

	GOALS	ROLES	COLLABORATIVE PROCEDURES	CONTRACT TYPE
CASE 1	1.Clash Detection/Design Coordination 2.Generate 2D drawings 3.Resolution of coordination issues in meetings (enhanced visualisation)	MEP coordinator with additional responsibility of developing BIM models	Coordination Meetings: Periodic Coordination and Iteration	Design Bid Build
CASE 2	1.Clash Detection/Design Coordination 2.Generate 2D drawings 3.Resolution of coordination issues in meetings (enhanced visualisation) 4.Visualisation 5.Automated Quantity Take-Off	Design Coordinator: BIM manager Modeller: BIM operator	Workshop: Continuous co-location Workshop (Coordination meetings): Periodic coordination and Iteration	Design Build
CASE 3	1.Clash Detection/Design Coordination 2.Generate 2D drawings 3.Resolution of coordination issues in meetings (enhanced visualisation) 4.Visualisation 5.Automated Quantity Take-Off 6.Construction Schedule Development – 4D 7.Replacement of fabrication shop drawings by BIM	Dedicated BIM team: BIM operators, BIM managers, BIM facilitators.	BIM team: Continuous co-location	Design Build. Owner is the contractor

6. DEVELOPMENT OF A FRAMEWORK FOR BIM ADOPTION

The comparison of the cases eventually enabled us to develop a framework for BIM adoption, which is shown in Table 2 above. Our framework maps the potential BIM goals on a project against the BIM roles, contractual innovations and collaborative procedures. A cross mark on the framework indicates the set of BIM roles to be assigned, the contractual innovations required, and the collaborative procedures that need to be adopted in order to achieve a certain BIM goal. For instance, from the framework it can be inferred that to use BIM for clash detection/design coordination, one of the strategies that could be adopted is: A contract that specifies the use of BIM can be used thereby ensuring that all participants such as architect, structural engineer and MEP engineers provide respective models.

The framework was populated based on opinion from industry experts with experience in working with BIM. Using the framework, an appropriate BIM adoption strategy that suits the project structure can be resorted to, in order to achieve the project specific BIM goals.

Table 3: Framework for BIM Adoption

BIM GOALS	BIM ROLES							CONTRACTUAL INNOVATIONS		COLLABORTIVE PROCEDURES			
	BIM CONTRACTOR	ARCHITECT	STRUCTURAL ENGINEER	MEP ENGINEER	BIM MANAGER	BIM OPERATOR	BIM FACILITATOR	CONTRACTS SPECIFYING USE OF BIM	IPD CONTRACTS EXCLUDING LITIGATION	BIM CONTRACTOR	EXTERNAL BIM CONSULTANT	BIG ROOM	CONTINUOUS CO-LOCATION
DESIGN													
Compare and analyse different design alternatives		x	x	x	x	x							x
Generate drawings	x					x		x					x
Clash Detection/ Design Coordination	x	x	x	x	x	x		x	x	x	x		x
Visualisation/ Walkthrough		x				x				x			
Constructability Analysis	x		x	x	x	x			x		x		x
Construction schedule development (4D)	x				x	x		x	x	x	x		x
Cost analysis and estimation (5D)	x				x	x		x		x	x		x
Energy/Performance analysis		x		x		x		x					x
Linking of methods statement to model	x				x	x	x	x	x	x			x
CONSTRUCTION													
Resolution of coordination issues during regular construction meetings (enhanced visualisation)	x				x	x	x	x	x			x	x
Planning of construction sequences	x				x	x	x	x	x	x			x
Cost tracking (cash flow analysis)	x				x		x	x		x			
Replacement of fabrication shop drawings by 3D model	x				x	x	x	x			x		x
3D analysis of safety issues	x				x	x	x	x		x			x
Analysis of construction sequences	x				x	x	x	x	x	x			x
Installation procedures at congested areas	x					x	x	x	x	x			x
Purpose built models for specific problem solving	x				x	x		x	x		x	x	x
Construction mobilisation, procurement	x				x	x	x	x		x			x
Optimisation of crew(s) productivity	x				x		x			x			
OPERATIONS													
Generate "as-built" models	x				x	x		x	x	x	x		x
Repair strategy development	x				x	x	x			x	x		x
Emergency response planning	x				x	x	x			x	x		x

7. SUMMARY

This study has attempted to empirically investigate how BIM adoption varies across projects, and the factors that affect the same. By comparing and analysing our cases, we propose that the breadth of BIM adoption is directly proportional to the level of integration of the project structure. The exploratory study of the cases coupled with a detailed review of literature lead to the evolution of a framework for BIM adoption on various projects. The framework is a mapping of the various BIM goals and the means to effectively achieve these goals, by assigning BIM specific goals, through contractual innovations and choosing appropriate collaborative procedures. This framework would aid organisations in drafting a suitable strategy for BIM adoption. Hence, the framework needs to be coupled with forethought into the organisational and contractual structure prior to developing a BIM strategy.

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