

Exploiting BIM's Potential for Project Approval

SYNOPSIS

DOCTOR OF PHILOSOPHY

(Faculty of Engineering)

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Table of Contents

S. No.	Description	Page No.
1	Introduction	1
2	Literature Survey	3
3	Problem Formulation	8
4	Objectives	9
5	Research Methodology	9
6	Work Plan	11
7	Facilities Required for Proposed Work	12
8	Proposed Place of Work	12
9	References	13

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Synopsis for proposed research work for the Ph.D. Degree

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Research work for the Ph. D. Degree

Area of research

Building Information Modeling

Title of Thesis

Exploiting BIM's Potential for Project Approval

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1. Introduction

The built environment sector in India will continue to play a significant role in the nation's infrastructure and industrial development that is being driven by economic growth, industrialisation and urbanisation. Creation of built environment assets and employment generation by the sector can significantly impact India's growth story. However, the Indian built environment sector is currently facing many challenges. It is ruined by delays, cost overruns, quality issues and other inefficiencies in the delivery process. Much of this can be attributed to current work practices, inefficient processes and lack of information sharing among industry stakeholders. Traditional construction is carried out on the basis of two dimensional drawings (manual or computer generated) and set of documents that are prone to errors and contradictions. Due to the increasing complexity of the design, construction, operation and maintenance of modern built environment assets, this has become an outdated paradigm. Globally, the built environment sector is experiencing a remarkable development in the form of Virtual Design and Construction (VDC). It is a process that uses smart and computable multi-dimensional model of the project to enhance its design, construction, operation and maintenance (Chen et al., 2014). Construction sector is second largest industry contributing to the Indian economy. With the growth of technology other industries have changed and improved their process but the construction industry is still labour intensive and following same traditional process of generating drawings by architects or designers and building is erected by contractors (Chougule et al., 2014). A majority of the architectural and engineering firms in India still depend on two dimensional Computer-Aided Design (CAD) drawings which are created separately and have no intelligent connection between separately created documents. A multi-dimensional tool, Building Information Modelling (BIM) is a process that supports virtual design and construction methodologies putting all team members together throughout the entire design and construction process and beyond to the operations in maintenance of the building, during its working life. Typically, BIM is one holistic process using real-time, intellectual modelling software effectively working in 3D, 4D (3D + time), and 5D (4D + cost) to improve productivity, to save money and time in the design and construction phases, and to reduce operating costs after construction (Construction, 2012). BIM can be used in various domains such as structural, mechanical and Business Intelligence. It can be used in cost estimation throughout life cycle of project. It can be used to save time and money. BIM can be used in finding the efficient site

location for project. Most effective solutions for energy efficiency can be found using this model. This tool can significantly improve the design of the facility and improves the energy consumption throughout the project. The significant goal of BIM is to optimise the energy standards and sustainability. It helps in making sustainable processes to be in decision making process. This usage of traditional methods neither implies that the Indian designers are not ignorant of BIM and its ability, nor does it exhibit a deficiency of skilled BIM users in the Indian AEC industry (Azhar, S. et al., 2011). In fact, there is lot of outsourcing for a full range of BIM services by development centres in India, delivering built environments for projects designed in the USA, the UK, and European countries. These international firms utilise the advantage of the cost effective production, and the proficiency that India has developed in past few years of experience (Construction, 2012).

India is a developing country; there is a need for every kind of infrastructure. Unlike in developed countries such as the USA and the UK, the Indian government does not create initiatives to promote the usage of BIM in the AEC industry. The decision is left to the private companies to incorporate BIM and to promote its use. The Indian government can easily fund the promotion of new technology advancements, but instead, no initiative is being taken, leaving the responsibility to the private AEC firms to initiate usage of new tools (Chen et al., 2014). Government has this responsibility to provide safe infrastructure, built environment on priority basis in the country. To meet this requirement Governments has to develop their standard codes. Building code compliance is considered an integral part of Engineering, Design and Construction process. Merriam Webster Dictionary defines a building code as “a collection of regulations adopted by a city to govern the construction of buildings”. The purpose of having building codes “is to establish the minimum requirements to safeguard the public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation, and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations”. The manual checking of building designs for compliance against National Codes is complex and prone to human error with significant cost implications. The complexity and changing nature of codes leads to delays in both the design and construction processes (IBC, 2006). According to a survey (Wix et al., 2008), 85% of architects are interested in automated code checking as they spend, on average, more than 50 hours

checking laws per project, and around 11% spend more than 100 hours. Thus regulatory code compliance is one of the challenging tasks for the AEC (Architecture, Engineering, and Construction) industry due to the variations in building and safety codes across the country. Computer assisted code checking has the potential to lighten both the delays and inconsistencies associated with manual checking by giving the designer and the permit-issuing/approving body a consistent framework in which to apply and check codes. A necessary precondition for processing constraints is a computer interpretable representation of the product being designed. In the case of AEC design processes, building product models, also known as Building Information Models (BIM), form a suitable representation. These models capture not only the three-dimensional geometry of the building, but also the semantics of the individual elements by applying object-oriented modelling concepts. Technical developments in BIM offer the potential for a new generation of software tools that can automate the checking of compliance with building codes, thus improving the efficiency of building design and execution. Few efforts have been made to address the above issues for the representation and execution of building codes of practice and standards. But most of the research works can only handle some simple checking, such as checking the fire rating of a wall, they can not handle complex checking such as calculate the travel distance from a space to a nearest exit staircase (Eastman et al., 2009).

2. Literature survey

Building Information Modelling (BIM), as a new way of technical communication in construction, refers to representation of a structure as an object by using computers to simulate buildings. BIM based clash detection tools allow automatic geometry based clash detection to be combined with semantic and rule based clash analysis for identifying qualified and structured clashes. BIM-based clash detection tools allows contractors to selectively check clashes between specified systems, such as checking for clashes between mechanical and structural system, because each component in the model is associated with specific type of system. Consequently, the clash detection process can be performed at any level of detail and across any number of building systems and trades.

Fenves et al. 1995 suggested that future research must address the inadequacies of the current representations and create models that are able to represent all, or almost all, of the different

types of provisions in any given standard; investigate and deliver a much richer set of processing functionalities, such as more support for use of design standards in earlier phases of design; support the treatment of multiple, heterogeneous standards available from distributed sources; and determine what type of support is needed to go from the textual versions of design standards to the formal models that can support sophisticated computation.

Charle et al. 1998 reported that with the introduction of computers, the major changes started from manual drafting to the computer aided drafting, which helped in producing drawings quick and fast. As buildings became more complex, specialisation in the design and construction process emerged, which in turn lead to more elaborate forms of information. Use of computers, especially for 2D drawings and reports are revolutionary changes into Architectural Documentation.

Satti et al. 2004 highlighted some of the issues of integrating building code checking in CAD and outlined the conceptual frame work of a Computer-Aided Analysis of Design (CAAnD) program for building codes that could assist design professionals during project design development. The conceptual framework that will advance the automated building plan approval initiatives and inspire the continued interest in architectural design analysis.

Ding et al. 2006 presented an automated code checking system (Design Check) enables quick and easy compliance assessment against building codes. The Design Check system develops an object-based rule system using EDM (Express Data Manager) for encoding building codes. It defines a Design Check internal model based on IFCs (Industry Foundation Classes) for modelling extended design information.

Ernstrom, J. W. 2006 reported the management issues cluster around the implementation and use of BIM. The absence of clear consensus as how to implement or use BIM could be realised. The unavailability of single document or treatise on BIM that instructs on its application or usage and inability of several software firms to treat the process as a whole. There is a requirement to standardise the BIM process and the guidelines for its implementation.

Nguyen et al. 2006 presented a computerised framework which is able to interpret building designs as well as to deduce spatial relationships among individual building components to be needed for the code compliance checking. The proposed framework includes extraction of the knowledge from building code document and its representation in a computer interpretable format that will be able to identify code requirements relevant to a particular building design and notify designers whether the design violates the building code or not.

Thompson et al. 2007 divided BIM related risks into two broad categories. First is Technology related risks which is lack of BIM standards for model integration and management by multidisciplinary teams. There might be interoperability, licensing issues when team members are other than owner and architect/engineer and second is Process-related risks which include legal, contractual and organizational risks.

Kumar et al. 2009 performed a survey with the status check of BIM application in India. The study showed the acceptance of BIM in our country till date, while this application is widely accepted throughout the industry in many countries for managing project information with capabilities for cost control and facilities management.

Homayouni et al. 2010 represents a general methodology and steps and theory for implementing BIM. It has been found that there is a successful collaboration between spans organizational boundaries which enhances the productivity of the design and construction process. Using data from observations over fifteen months of the integrated design process of a laboratory building project, a typology of the strategies of successful collaboration within the AEC industry was built and tested the proposed typology.

Greenwood et al. 2010 reviewed previous research into automated code compliance, identified the key issues for future development and examines the causes of information paucity for compliance checking in the current generation of BIM tools. Technical developments in Building Information Modelling (BIM) offer the potential for a new generation of software tools that can automate the checking of compliance with building codes, thus improving the efficiency of building design and procurement.

Tan et al. 2010 represents automating the checking of building envelope design according to design regulations is a complex process because these regulations consist of complicated logic sentences covering multiple functions. Existing mechanisms of building code computer-aided checking have some limitations dealing with design regulations.

Azhar et al. 2011 identified the risks for BIM implementations, current trends, benefits ownership of BIM data, Control over entry of data and responsibilities for inaccurate data. Building Information Modelling (BIM) is one of the most promising recent developments in the architecture, engineering, and construction (AEC) industry. With BIM technology, an accurate virtual model of a building could be constructed in digital form. The results provide useful information for AEC industry practitioners considering implementing BIM technology in their projects.

Khemlani L. 2011 provided interactive communication with end users, the system enabled the services for automatic classification of building designs and compliance checking of building codes. This artificial intelligence based system checks architectural plans, 2D representation of building designs, for compliance to building codes of the relevant authorities in Singapore.

Ku et al. 2011 identified the barriers to BIM implementation related to learning curve and lack of skilled personnel, high cost to implementation, reluctance of other stakeholders, lack of collaborative work processes and modelling standards interoperability. This research study benchmarks the current status of BIM implementations, organizational structures, training requirements, and strategies of construction companies and examines their expectations in regard to BIM knowledge and skills.

Pauwels et al. 2011 discusses the improvements generated by deploying semantic web languages which can overcome limitations imposed by IFC, thus enabling a range of significant improvements and possibilities for automation in building design and construction. By deploying the Industry Foundation Classes (IFC) as a description language, these systems offer building information in a widely interoperable format. An implemented test case for acoustic performance

checking illustrates the improvements of such an environment compared to traditionally deployed approaches in rule checking.

Nawari O. 2011 proposed a new framework based upon XML and LINQ (Language Integrated Query) language to enable basic and complex level of rules which provides a consistent query experience across different data models.

Lachmi et al. 2011 provided interactive communication with end users, the system enables the services for automatic classification of building designs and compliance checking of building codes. This artificial intelligence based system checks architectural plans, 2D representation of building designs, for compliance to building codes of the relevant authorities in Singapore.

Khemlani L. 2012 described a few major reasons for barriers with BIM implementation for Indian AEC firms. The costs of BIM software packages are more expensive compared to CAD software packages which are available on the market at a fraction of the cost of BIM software. Besides the initial cost of the software package, the price to keep the subscription updated is astronomically high by Indian standards.

Wang et al. 2013 reported two major categories of factors affecting the acceptance and implementation of BIM and listed the specific impact factors corresponding to each category. BIM user acceptance model was proposed by applying Technology Acceptance Model (TAM) and relevant theories on the premise of the feasibility of the research ideas demonstrated. Through this model, the impact factors and degrees of influence can be tested and modified.

Chougule et al. 2014 provided overviews on the status of implementation of BIM in India. The applicability of BIM for project delivery method and in various phases of construction industry, and hurdles in BIM implementation in architecture, engineering, and construction (AEC) industry has also been discussed.

Liu et al. 2015 proposed a BIM-based integrated scheduling approach which facilitates the automatic generation of optimized activity level construction schedules for building projects

under resource constraints, by achieving an in depth integration of BIM product models with work package information, process simulations, and optimization algorithms.

Zhang et al. 2015 realised need for automate regulatory compliance checking of construction projects, regulatory requirements to be automatically extracted from various construction regulatory documents and then transformed into a formalized format that enables automated reasoning. An approach has been proposed for automatically extracting information from construction regulatory textual documents and transforming them into logic clauses that could be directly used for automated reasoning.

Solihin et al. 2015 introduced a general classification of rules across application domains using criteria that apply to all known aspects of automated rule checking by taking extensive international exposure with various building codes and rule checking areas in the AEC domain. The exposure covers both academic research as well as actual production implementation done with CORENET ePlan Check project in Singapore, and also various pilot implementations in the US and other countries.

3. Problem Formulation

Among Indian architects, engineers, and contractors, there is a need for directed development, integration of information technology and business processes for simulation, coordination, communication, and knowledge sharing to support design and construction. Currently, there is no clear consistency about the process of implementing or using BIM for AEC firms in India. Even the Associated General Contractors (AGC) of America realizes that there is an absence of a single document that instructs BIM application for firms. Indian government should also realise that there is a absence of a single document that instruct BIM application for firms. In India, adoption of code compliance checking is not yet reported. Further research is still needed to develop the object-based, more efficient, sharable and standardized and open source representations for both code provisions and building designs.

Many of the Governments have now started using e-governance as a mechanism to engender change in their governance systems for achieving development goals and to ensure better service

delivery to citizens and other stakeholders. So the development of a code compliance tool for a country can be considered as an e-governance tool which has potential to provide better service delivery at reduced costs, increase public sector efficiency. The proposed research is about developing a system to automatically check building codes based on National Building Code of India with respect to Steel Industrial buildings and to provide a build environment for writing rules.

4. Objectives

The objectives of the research are:

1. To critically examine current state of art of computer assisted code checking in the field of AEC.
2. To conduct survey of Pre-Engineered structures to know current level of adoption or usages of BIM in India.
3. To develop suitable model to represent Codal constraints.
4. To develop a computer assisted code checking prototype system for checking National Codes on a building design, with respect to structural safety aspect of Steel Industrial Buildings.
5. To validate the developed model.

5. Research Methodology

The core intention of this study is to measure how many architects, engineers, and contractors in India use or tap the true potential of BIM at their firms (in comparison to technologically advanced countries such as the USA). The focus is to assess the barriers for slow BIM adoption in India. Indian AEC firms struggling with the issues of transition from traditional methods to BIM. This study is in the category of exploratory research which is undertaken to investigate an area where little is known or to consider the possibilities of undertaking a particular research

study, i.e. factors affecting as potential barriers for implementing BIM in the Indian construction industry.

The research methodology steps for proposed work:

1. Study previous work on computer based systems for checking designs against building regulations.
2. Examine a building code document, e.g. National Building Code (NBC) of India, from which the knowledge will be extracted and represent them in a computer-interpretable format for the prototype implementation.
3. Explore the IFC methodology and extend it to build relationships.
4. Represent building design data in a 3D CAD system having facility to export data in IFC format.
5. Develop a framework linking building information with relevant building code information, which enables the automated code compliance checking.
6. Generate a code compliance report displaying check results whether the design violates the building codes.

6. Work Plan

Activity	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	-----									-----		
2.	-----											
3.			-----									
4.			-----									
5.					-----		-----					
6.									-----			
7.											-----	

Note: Q1, Q2, Q3, Q4 represents quarters of a year.

The events 1 to 7 are enlisted below:

1. Literature Survey to critically examine the current state of art of computer assisted code checking.
2. To conduct survey for better understanding the current level of adoption or usages of BIM in India.
3. Develop a framework linking building information with relevant building code information, which enables the automated code compliance checking.
4. Implementation of Proposed Methodology for code checking prototype system for checking National Codes on a building design, with respect to structural safety aspect of Steel Industrial Buildings.
5. Analysis and survey of work done and getting feedback from professionals.
6. Revise proposed work to meet desired results.

7. Thesis writing and submission.

7. Facilities Required for Proposed Work

The following facilities are required for proposed research work:

1. Software Tools: BIM Software, Tekla Software, Revit software, Design Check, E-Plan Checker, Solibri model system.
2. Hardware Tool: Personal Computer, 2GB RAM.
3. National Building Code of India (NBC 2005).
4. Bureau of Indian Standard Codes.

8. Proposed Place of Work

Guru Nanak Dev Engineering College, Ludhiana.

Chandigarh University, Gharuan (Mohali).

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