

MANAGING DESIGN-CONSTRUCTION INTERFACE IN BIM PROJECTS

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by

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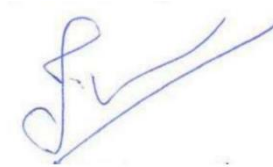


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CERTIFICATE

This is to certify that the thesis titled, '**MANAGING DESIGN-CONSTRUCTION INTERFACE IN BIM PROJECTS**' submitted by Lt Col Arun Sekhar to Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is a record of bona fide research work carried out by him. He worked under my supervision for the submission of this thesis, which to the best of my knowledge has reached the requisite standard. The research reports and the results presented in this thesis have not been submitted in parts or in full to any other University or Institute for the award of any degree or diploma.



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ABSTRACT

Researchers have attributed poor design-construction interface and inadequate stakeholder synergy as the root cause for time and cost overrun in construction projects. In the modern world, financial viability and value for money are weighed against all other criterion for the project's success. Constructability of design and accountability to the cost are the bench marks of value engineering in a collaborative multi-disciplinary industry like construction. Majority of the research study carried out in the design-construction interface is monitoring and control specific as it is traditionally believed that managing manpower and material on the site is the most challenging activity having a direct bearing on schedule and cost. The main cause of schedule deviation is change orders in majority of the projects, apart from force majeure situations. Gap exists in addressing constructability during design process and accountability in procurement management which triggers change order at a later stage of execution. The design sequence and ingredients which defines the cost and envisaged value of the project are still a grey area due to presence of uncertain parameters of constructability. Constructability and accountability need to be targeted during design phase to deliver the intended target values set by the initiation and planning team.

Two pilot studies on completed projects suggested a relook into the rationale of defining constructability and accountability through the lens of a designer. Lack of coordination among civil, mechanical and electrical disciplines were evident in clashes detected. The accountability of coordination and collaboration with visualisation were not well defined which caused hiccups during execution. The design-construction interface issues have proved to be affecting time and cost overrun in the case-lets examined. The need to understand design challenges over a wider spectrum of scenarios was felt to suggest better incorporation of constructability as a design philosophy in Building Information Modelling (BIM). BIM is still in an evolutionary phase and in the last two decades, construction industry has invested good sum of money for automating the design process viz. architectural models, structural analysis, detailing software, cost estimation and clash detection. But the commensurate saving in schedule and budget are not evident. The literature available on the subject recommends robust automation for monitoring and control techniques to pass on real time information from site to design office to address time and cost overrun. The lack of collaborative visualisation and design-construction interface issues which caused the change orders are not adequately addressed to suggest a way forward.

Hence the main objective of the research is to examine the role of BIM in decision making during design through visualisation. Constructability, accountability and stakeholder synergy are analysed through fourteen case studies to understand the design-construction interface issues in BIM projects. To address the objectives, a mix of qualitative and quantitative approach has been adopted to benefit from the advantages of both. Case-lets involving design and construction failures are analysed to study the role, composition and hierarchy of the design team to assess the degree of constructability in the decision-making process. Requests for Information (RFIs) and its role in improving the constructability has been examined in detail through two case-lets. A constructability impact index (CII) has been formulated by iterative design process where a numerical approach provides quantification parameters to constructability. Visualisation of schedule, cost, sustainability and facility management in BIM are explored to draw a more realistic picture on constructability and ascertain accountability at an early stage of the project. Iterative design process and forensic schedule analysis have been adopted to extract the essence from the case-lets. The results of the study suggest the need of better quantification and statistical significance in defining constructability and accountability. Target value design and design for excellence (DfX) challenges are analysed in case-lets involving off-site construction to address specific design-construction interface problems. Varying degrees of design-construction interface issues have been critically examined to highlight the necessity of collaborative visualisation and clash detection during design phase.

The research brings out the importance of objective collaboration between various stakeholders to achieve better synergy during design and construction in an interdisciplinary field of construction project management. Policy changes for achieving better stakeholder synergy and accountability have been proposed after analysing the results. The constructability-cost trade off puzzle has been addressed with a fair degree of accuracy by the iterative design process where accountability can be fixed to a greater extent as envisaged in the research design. Role of BIM in off-site and manufactured construction to formulate a water tight design framework are also included in the research itinerary, being closely associated with constructability and accountability.

Key Words: Design-Construction Interface, Constructability, Accountability, Stakeholder Synergy, Procurement, Iterative Design, Visualisation, DfX, BIM, RFIs.

सार

शोधकर्ताओं ने निर्माण परियोजनाओं में समय और लागत बढ़ने का मूल कारण खराब डिज़ाइन-निर्माण इंटरफ़ेस और अपर्याप्त हितधारक तालमेल को जिम्मेदार ठहराया है। आधुनिक दुनिया में, वित्तीय व्यवहार्यता और पैसे के मूल्य को परियोजना की सफलता के लिए अन्य सभी मानदंडों के मुकाबले तौला जाता है। डिज़ाइन की निर्माण क्षमता और लागत के प्रति जवाबदेही निर्माण जैसे सहयोगी बहु-विषयक उद्योग में मूल्य इंजीनियरिंग के बेंचमार्क हैं। डिज़ाइन-निर्माण इंटरफ़ेस में किए गए अधिकांश शोध अध्ययन निगरानी और नियंत्रण विशिष्ट हैं क्योंकि परंपरागत रूप से यह माना जाता है कि साइट पर जनशक्ति और सामग्री का प्रबंधन करना सबसे चुनौतीपूर्ण गतिविधि है जिसका शेड्यूल और लागत पर सीधा असर पड़ता है। शेड्यूल विचलन का मुख्य कारण अप्रत्याशित परिस्थितियों के अलावा, अधिकांश परियोजनाओं में परिवर्तन आदेश हैं। डिज़ाइन प्रक्रिया के दौरान निर्माणशीलता और खरीद प्रबंधन में जवाबदेही को संबोधित करने में अंतर मौजूद है जो निष्पादन के बाद के चरण में परिवर्तन क्रम को ट्रिगर करता है। डिज़ाइन अनुक्रम और सामग्री जो परियोजना की लागत और परिकल्पित मूल्य को परिभाषित करती है, निर्माण क्षमता के अनिश्चित मापदंडों की उपस्थिति के कारण अभी भी एक अस्पष्ट क्षेत्र है। आरंभ और योजना टीम द्वारा निर्धारित इच्छित लक्ष्य मूल्यों को वितरित करने के लिए डिज़ाइन चरण के दौरान निर्माणशीलता और जवाबदेही को लक्षित करने की आवश्यकता है।

पूर्ण परियोजनाओं पर दो पायलट अध्ययनों ने एक डिज़ाइनर के लेंस के माध्यम से निर्माणशीलता और जवाबदेही को परिभाषित करने के औचित्य पर फिर से विचार करने का सुझाव दिया। पाई गई झड़पों में सिविल, मैकेनिकल और इलेक्ट्रिकल विषयों के बीच समन्वय की कमी स्पष्ट थी। विज़ुअलाइज़ेशन के साथ समन्वय और सहयोग की जवाबदेही अच्छी तरह से परिभाषित नहीं थी जिसके कारण निष्पादन के दौरान दिक्कतें आईं। डिज़ाइन-निर्माण इंटरफ़ेस मुद्दे जांचे गए केस-लेट्स में समय और लागत में वृद्धि को प्रभावित करने वाले साबित हुए हैं। बिल्डिंग इंफॉर्मेशन मॉडलिंग (बीआईएम) में डिज़ाइन दर्शन के रूप में निर्माण क्षमता को बेहतर ढंग से शामिल करने का सुझाव देने के लिए परिदृश्यों के व्यापक स्पेक्ट्रम पर डिज़ाइन चुनौतियों को समझने की आवश्यकता महसूस की गई। बीआईएम अभी भी एक विकासवादी चरण में है और पिछले दो दशकों में, निर्माण उद्योग ने डिज़ाइन प्रक्रिया को स्वचालित करने के लिए अच्छी रकम का निवेश किया है। वास्तुशिल्प मॉडल, संरचनात्मक विश्लेषण, विवरण सॉफ्टवेयर, लागत अनुमान और टकराव का पता लगाना। लेकिन शेड्यूल और बजट में आनुपातिक बचत स्पष्ट नहीं है। विषय पर उपलब्ध साहित्य समय और लागत वृद्धि को संबोधित करने के लिए साइट से डिज़ाइन कार्यालय तक वास्तविक समय की जानकारी देने के लिए निगरानी और नियंत्रण तकनीकों के लिए मजबूत स्वचालन की सिफारिश करता है। सहयोगात्मक विज़ुअलाइज़ेशन और डिज़ाइन-निर्माण इंटरफ़ेस मुद्दों की कमी जिसके कारण परिवर्तन आदेश हुए, उन्हें आगे का रास्ता सुझाने के लिए पर्याप्त रूप से संबोधित नहीं किया गया है।

इसलिए शोध का मुख्य उद्देश्य विजुअलाइज़ेशन के माध्यम से डिज़ाइन के दौरान निर्णय लेने में बीआईएम की भूमिका की जांच करना है। बीआईएम परियोजनाओं में डिज़ाइन-निर्माण इंटरफ़ेस मुद्दों को समझने के लिए चौदह केस अध्ययनों के माध्यम से निर्माणशीलता, जवाबदेही और हितधारक तालमेल का विश्लेषण किया जाता है। उद्देश्यों को संबोधित करने के लिए, दोनों के लाभों से लाभ उठाने के लिए गुणात्मक और मात्रात्मक दृष्टिकोण का मिश्रण अपनाया गया है। निर्णय लेने की प्रक्रिया में निर्माण क्षमता की डिग्री का आकलन करने के लिए डिज़ाइन टीम की भूमिका, संरचना और पदानुक्रम का अध्ययन करने के लिए डिज़ाइन और निर्माण विफलताओं से जुड़े केस-लेट्स का विश्लेषण किया जाता है। सूचना के लिए अनुरोध (आरएफआई) और निर्माण क्षमता में सुधार में इसकी भूमिका की दो केस-लेट्स के माध्यम से विस्तार से जांच की गई है। एक निर्माण क्षमता प्रभाव सूचकांक (सीआईआई) पुनरावृत्त डिज़ाइन प्रक्रिया द्वारा तैयार किया गया है जहां एक संख्यात्मक दृष्टिकोण निर्माण क्षमता के लिए परिमाणीकरण पैरामीटर प्रदान करता है। बीआईएम में शेड्यूल, लागत, स्थिरता और सुविधा प्रबंधन के विजुअलाइज़ेशन का पता लगाया जाता है ताकि निर्माण क्षमता पर अधिक यथार्थवादी तस्वीर खींची जा सके और परियोजना के प्रारंभिक चरण में जवाबदेही सुनिश्चित की जा सके। केस-लेट्स से सार निकालने के लिए पुनरावृत्त डिज़ाइन प्रक्रिया और फॉरेंसिक शेड्यूल विश्लेषण को अपनाया गया है। अध्ययन के नतीजे निर्माणशीलता और जवाबदेही को परिभाषित करने में बेहतर मात्रा निर्धारण और सांख्यिकीय महत्व की आवश्यकता का सुझाव देते हैं। विशिष्ट डिज़ाइन-निर्माण इंटरफ़ेस समस्याओं के समाधान के लिए ऑफ-साइट निर्माण से जुड़े केस-लेट्स में लक्ष्य मूल्य डिज़ाइन और उत्कृष्टता के लिए डिज़ाइन (डीएफएक्स) चुनौतियों का विश्लेषण किया जाता है। डिज़ाइन चरण के दौरान सहयोगात्मक विजुअलाइज़ेशन और टकराव का पता लगाने की आवश्यकता को उजागर करने के लिए डिज़ाइन-निर्माण इंटरफ़ेस मुद्दों की अलग-अलग डिग्री की गंभीर रूप से जांच की गई है।

यह शोध निर्माण परियोजना प्रबंधन के अंतःविषय क्षेत्र में डिज़ाइन और निर्माण के दौरान बेहतर तालमेल हासिल करने के लिए विभिन्न हितधारकों के बीच उद्देश्यपूर्ण सहयोग के महत्व को सामने लाता है। परिणामों का विश्लेषण करने के बाद बेहतर हितधारक तालमेल और जवाबदेही हासिल करने के लिए नीतिगत बदलाव प्रस्तावित किए गए हैं। निर्माण क्षमता-लागत व्यापार बंद पहली को पुनरावृत्त डिज़ाइन प्रक्रिया द्वारा काफी हद तक सटीकता के साथ संबोधित किया गया है, जहां अनुसंधान डिज़ाइन में परिकल्पना के अनुसार जवाबदेही को काफी हद तक तय किया जा सकता है। वॉटर टाइट डिज़ाइन ढांचे को तैयार करने के लिए ऑफ-साइट और निर्मित निर्माण में बीआईएम की भूमिका को भी अनुसंधान कार्यक्रम में शामिल किया गया है, जो निर्माण क्षमता और जवाबदेही के साथ निकटता से जुड़ा हुआ है।

मुख्य शब्द: डिज़ाइन-निर्माण इंटरफ़ेस, निर्माणशीलता, जवाबदेही, हितधारक तालमेल, खरीद, पुनरावृत्त डिज़ाइन, विजुअलाइज़ेशन, डीएफएक्स, बीआईएम, आरएफआई।

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LIST OF ACRONYMS

AAI	Airport authority of India
ACI	American Concrete Institute
BIM	Building Information Modelling
BIS	Bureau of Indian Standards
BOQ	Bill of Quantities
CADD	Computer Aided Design and Drafting
CII	Constructability Impact Index
CPWD	Central Public Works Department
D-B	Design Build
D-B-B	Design Bid Build
DfA	Design for Assembly
DfL	Design for Logistics
DfM	Design for Manufacturability
DfP	Design for Procurement
DfX	Design for Excellence
DSR	Delhi Schedule of Rates
ELF	Evidence, Logic and Falsification
EOT	Electric Operated Travelling (Crane)
EP&C	Engineer, Procure and Construct
FAR	Floor Area Ratio
FFL	Finished Floor Level
GDP	Gross Domestic Product
GR	Grid Reference
HVAC	Heating, Ventilation and Air Conditioning
MEP	Mechanical, Electrical and Plumbing
NDT	Non-Destructive Test
NHAI	National Highway Authority of India
PCC	Pre-Cast Concrete Construction
PEB	Pre Engineered Building
PMBoK	Project Management Body of Knowledge
PMC	Project Management Consultant
PPP	Public Private Partnership
PT	Post Tensioned
QFD	Quality Function Deployment
RCC	Reinforced Cement Concrete
RFIs	Requests for Information
SBC	Safe Bearing Capacity
SCADA	Supervisory Control and Data Acquisition
STP	Sewage Treatment Plant
TVD	Target Value Design
UG	Under Ground
WBS	Work Breakdown Structure