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Integration of BIM with Lean Principles in Indian Construction Industry

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Abstract - *Building Information Modeling (BIM) and Lean construction principles have been used independently as significant methods to construction process improvement. Their combination presents challenges and opportunities in implementation, especially when applied in the field. This study explores two perspectives, firstly identifying factors and issues in design coordination of construction projects; secondly, applying lean and BIM functions simultaneously to overcome some of the problems in design coordination. Relative Importance Index (RII) method was adopted to identify major critical factors of design coordination and their effect on the three categories viz; design management, time management and cost management. Subsequently, BIM and lean functions such as 4D simulation integrated with Look ahead planning, Quantity take off, Clash detection during look-ahead and weekly work planning, to reduce change orders and RFIs for additional value to customer were applied in an integrated fashion. This improvised BIM-Lean process facilitates the design co-ordination during construction phase for all project stakeholders. Finally a matrix is drafted based on previous research that shows integration of Lean Principles and BIM functionalities adopted for the case study.*

Key Words: **Lean construction, Building Information Modelling (BIM), Request for Information (RFI), Clash Detection, 4D Scheduling**

1. INTRODUCTION

The design phase for any project is characterized by high level of uncertainties in resulting outputs in contrast with design requirements. The problems occurs when the requirements and the resulting outputs both are indistinct (Maier and Storrle, 2011) [1]. BIM (Building Information Modelling) and Lean are the two different intellects that are having an influence on the construction industry. Lean is a concept related to production process while BIM is rooted in technology that instead of acting as standalone systems, when mutually applied to the construction projects helps to achieve great results that solves many of the issues prevailing in the construction projects (Sacks et.al, 2010) [2].

Each project involves different stakeholders having their own and joint responsibilities. The process involves detailed inputs from each stakeholder for different building systems complying with norms (Tatum and Korman, 2000) [3]. Inadequate coordination gets reflected in form of waste for the projects in terms of design, cost and time. Instead of focusing on value addition, time is spent on resolving coordination issues (Tribelsky and Sacks, 2011) [4]. Moreover, communication through 2D information limits the ability of different stakeholders to coordinate, which in turn effects communication during meetings (Fischer et al., 2002) [5].

BIM tools have had a noteworthy impact on effectiveness of the coordination process. Studies reflect the prised and numerous use of BIM for design coordination and conflict detection (Bernstein and Jones, 2012, Eastman et al, 2008) [6]. However, research has shown that implementing BIM alone as a technological solution has a limited benefit. To this end, the synergy between BIM and Lean show that many of the design coordination issues identified by previous research can be tackled through simultaneous implementation of these two concepts (Sacks et.al, 2010) [2]. This paper attempts to first identify coordination issues in Indian construction projects and subsequently tries to implement integrated lean and BIM tools to overcome these issues.

In this case study BIM was applied in order to improve design coordination between different design disciplines. Model checking was used to control clashes at the time of execution. Moreover the methodology was also implemented to create a 4D BIM that showed the simulation of the construction process over time. 4D BIM allowed the analysis of the proposed design and its constructability that is going to be executed.

The paper is structured as follows: first section outlines main problems with design coordination in construction and their probable solutions found in literature. Second part outlines the problems in design coordination in Indian construction projects through interviews. The next section covers a case study where integrated lean and BIM functions are deployed in terms of:

Quantification, Clash detection, Cost Variation, Look ahead and 4D Simulation. Finally, discussion and conclusion are provided along with suggestions for future research. This strategy of design coordination focuses on interaction subtleties and information dispersal to support design teams in improving design course, knowledge change, and value creation while reducing wastes.

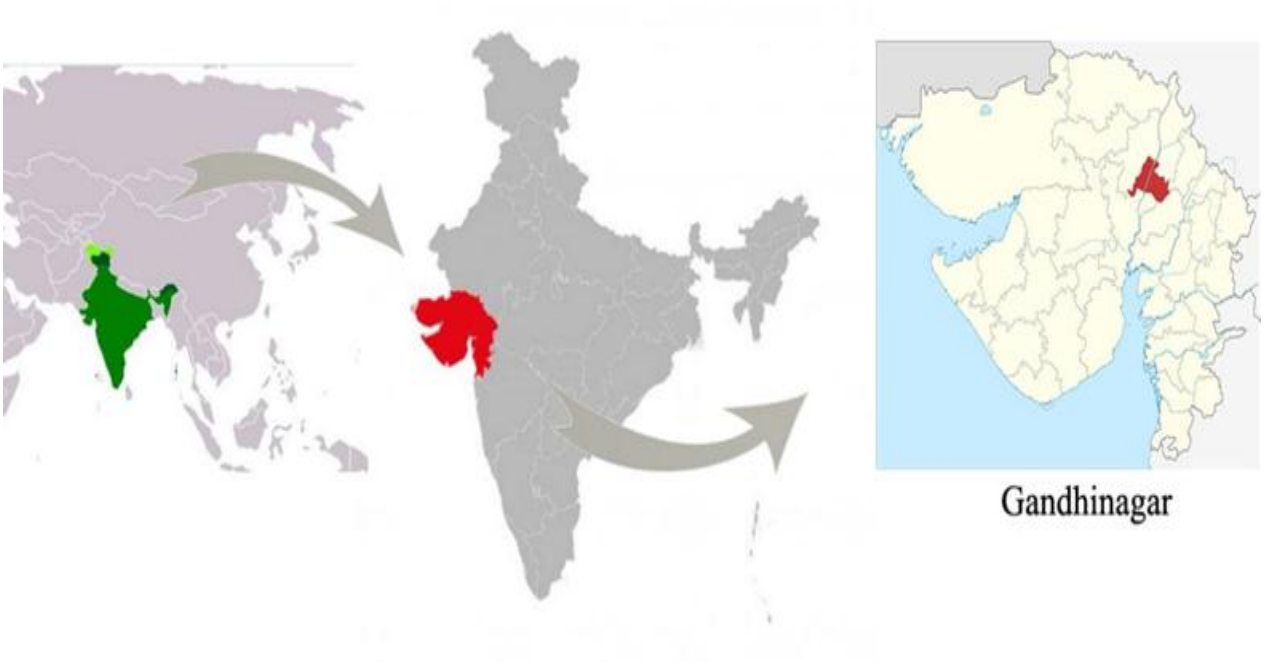

Fig - 1: Physical Location of Gandhinagar in India map (Scope of work)

2. LITERATURE REVIEW

The following are the previous research articles reviewed in which use of BIM and Lean Principles are studied elaborately:

Xiaoming Mao et. al. (2008) [7] studied on the idea of lean production, the grouping of activities, and the empirical lean principles. An outline for re-engineering is suggested, which assimilates lean principles and computer simulation techniques to maximize productivity and minimize waste. Computer simulation methods are fused into the structure to virtually simulate and assess the usefulness of re-engineered construction process that is attained as per lean principles. An original construction method modelling methodology is planned, that begins the ideas of the main, supportive, normal, and interactive activities. They explain a re-engineering outline and corresponding methodologies that amalgamate lean principles and computer simulation techniques.

Rafael Sacks et. al. (2010) [2] proposed the possible interaction when planning between Lean and BIM. The author uses CAVT (Computer advanced visualization tools) and Solibri model checker. The team also uses lean tools such as value stream mapping to monitor and develop the project processes, which aims to minimize the cycles of iterations as the design converges. They have used Deming's 14 points based on quality approach. The 56 issues identified are presented as hypothesis and are intended to guide and stimulate further research. A survey of experimental and practical literature so far shows documented evidence for 48 of the issues. The complete number of the constructive collaboration mechanisms recognized strongly supports the argument of a noteworthy interaction between BIM and Lean. .

Ankit Bhatla et. al. (2012) [8]stated that integrating LPS with BIM eliminates the wastes in the construction process, we can get better collaboration amongst the project teams during the design and construction stages of a project and improved collaboration between project participants, less number of RFIs and change orders. The research team uses 3D visualization, 4D simulation and MEP clash detection. Last planner system is used at the Master Schedule level, look ahead Schedule level and at the Weekly Work Plan Level and MEP clash detection during look ahead and weekly work planning. This research is case study based. Established a method for incorporating BIM functionalities, like 4D scheduling, MEP clash detection, into the LPS to improve work flow consistency through the construction phase.

Olfa Hamdi et. al. (2012) [9] explored BIM and Lean correlation aspects with an emphasis on the construction phase and from the viewpoint of the general contractor (GC). Exploring areas of enhancement and Lean contributions to BIM, the researchers identified that coordination and construct-ability issues are big problems for this project. They have used interaction matrix perspective identifying some current interactions. Capability Maturity Model (CMM) of the National Building Information Modelling Standard (NBIMS), determining the level of the project's BIM development and highlight areas of perfection for Lean. They concluded that one of the major BIM usages includes clash detection and some benefits of BIM and Lean combination are based on some interaction points.

Patricia Tillman et. al. (2015) [10] stated that their primary objectives were to attain faster schedule and to solve logistical challenges. They state that first, put difficulties confronted when using BIM on a project as a support to managerial practices and second, show the use of lean principles in the design- production as a means of supporting BIM. The methodology used by the authors was as follows 1. Prefabrication 2. Integrated method for production planning and control 3. BIM can help change ETO components from design to production as it lets for rapidly verifying construct-ability and coordinating all building systems before producing each piece 4. Application of LPS, interviews with team members, and LOB helped to visualize speed. ETO components helps to avoid wastes. BIM and lean blend provided basis for collaboration.

Mauricio Toledo et. al. (2016) [11] developed BIM-Lean applied methods to handle projects and provide confirmation of the opportunities for performance improvement. Case study based data collected included: weekly and look ahead planning meetings analysis; design requests for information (RFI); and LPS metrics. Then used flowcharts to present both planning procedures and the improved planning suggestion, also, integrating the different planning levels. The synchronized use of LPS and BIM creates an increase in PPC, a reduction in reasons for non- compliance, a shortening of the meeting duration, and a lessening in the total number of design RFIs. Project meeting become more productive and the communication of project planning progresses as a result. Planning reliability and RFI management improved a when BIM-Lean integration was implemented.

3. RESEARCH METHODOLOGY

3.1 Preliminary Study

The initial part of the preliminary study was based on a questionnaire survey that was divided into several parts: Questions were about the frequency of coordination issues, impact of issues on cost and time, knowledge on concepts of Lean and BIM and these questions were mostly ranking based that helped to get the major critical issues. Further factors were categorized into its impact on design management, cost management and time management.

The data received was analysed by Relative Importance Index (RII) method to determine the relative importance of the issues/factors in design coordination identified by the survey. Some questions were framed to capture background information of the respondents.

The frequency for the questions was measured on the scale of 1 to 5 in which 1=Never and 5=Very frequent. The respondents helped in addressing the majority of design coordination issues happening on site during execution and also contributing their knowledge regarding BIM and Lean. The major critical factors of project coordination issues is mentioned in the below Table 1 The formula for Relative Importance Index (RII) used is:

$$RII = \frac{\sum W}{A \times N}$$

Table – 1: Factors of Project Coordination

Sr. No	Factors by Level of Impact	Rank
1	Time in supervising and inspecting the construction work	1
2	Waiting for the clarification on site due to changes in drawings	2
3	Changes in drawing	3
4	Client requirements changed and caused redesign	4
5	Time for instructions and communication among different tiers and trades of workers.	5
6	Delayed decisions	6
7	Waiting for others to complete their works before the proceeding works can be carried out	7
8	Changes in input data caused redesign in building services design	8
9	Issue of RFI and change orders	9
10	Time for rework/repair works/defective works	10

3.2 Case Study

A case study on a multi-storeyed commercial structure in Gandhinagar, Gujarat was carried out to study issues regarding design co-ordination and applying BIM and Lean concepts to mitigate the issues. With the construction area of around 2400 sq.m. the structure is one of its kind located in the up and coming locality of Gandhinagar outer development zone. The scope of study was limited to only 2 levels of the structure. The topics addressed in the research have been mentioned in the Table 2

Table 2: Topics addressed by the study

Design Management	Time Management	Cost
Clash detection	One month Look ahead Schedule	Quantity Takeoff
Request for Information	4D simulation	Quantity Variation
Quantity variation	Look ahead planning	

3.3 Methodology

3.3.1 Quantity Take-off

Automated quantity take off is more precise as there are less chances of error, hence reducing variability and taking less time with respect to manual calculations. The quantities automatically change if at any time in future design changes. For the purpose of this case study, quantity take-off was taken up for Slab, Brickwork and Column.

There was a significant time saving with the help of computerized Quantification as compared to conventional manual method i.e. 10-20 minutes as compared to 1-2 hours respectively. The benefits were not only limited to time saving but there was also significant variation seen from the BOQ and BIM based data. The time saving for the entire project was estimated to be about 79% and also the gap between actual vs. planned consumption can be reduced during actual execution.

3.3.2 Clash Detection

Clash detection helps to track design coordination problems at an early stage. In this case clashes were detected by appending different models in Autodesk Navisworks and the results were obtained in the form of reports that were resolved before execution started.

The clashes detected were mainly with the MEP. Plumbing pipes were clashing with the columns. With respect to the electrical design and architecture clashes were due to fixtures which could simply rectified by shifting the lights. The MEP/Structural clashes were solved by the study of detailed designs and provision of sleeves in advance. This resolved the issues and saved the consultant a major cost by avoiding later core cutting. This predetermination of the clash saved a significant amount of time and cost from 1 week to 1 day.

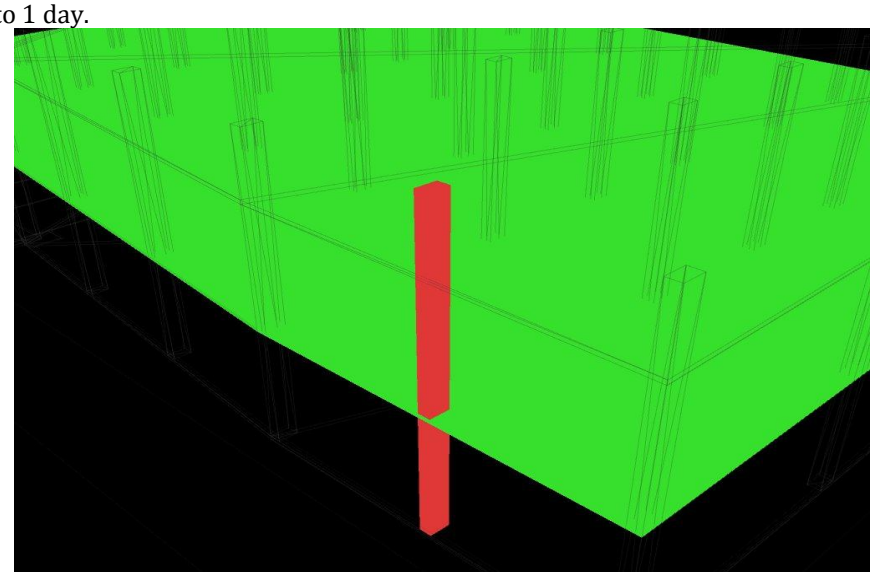

Fig – 2: Clash Detection in Navisworks

3.3.3 One month look ahead schedule

A one month look ahead schedule was helpful in monitoring the challenges that would be faced in the coming month at the execution phase and were able to be solved saving time and cost overruns. The schedule integrated with BIM faced challenges such as plan visualization, resource allocation and management in general.

The activities to be performed in the coming month were pulled from the schedule and were worked upon zone wise such as: Column, slab, beam and so. All these zones were at the initial stage and major challenges were identified giving major quantum of weekly planning.

3.3.4 4D Simulation

Based on the one month look ahead schedule and the clash free 3D model created in Revit we prepared a 4D simulation of the project for the constructability of the same. The schedule was integrated with BIM in Navisworks and a simulation was generated for the major activities carried out for the Ground floor and the First floor.

The whole process aided in visualizing the activities, the issues related to them and prepare the resource allocation schedule in advance along with the material and labor to avoid any disruptions to the construction flow when executed.

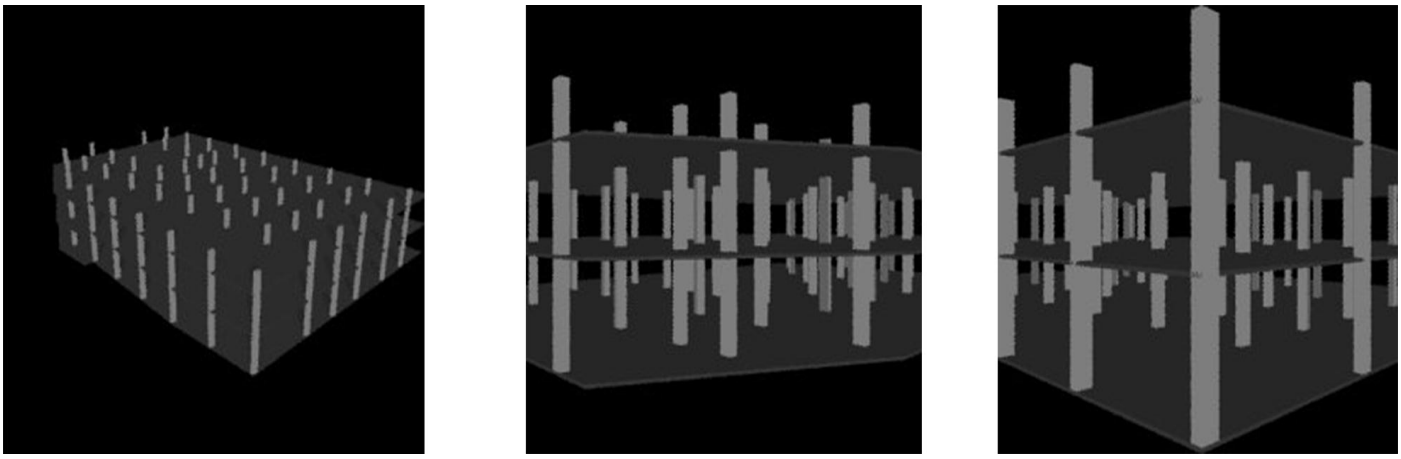

Fig – 3: 4D simulation with BIM

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BIOGRAPHIES

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