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APPLICATION OF BUILDING INFORMATION MODELLING IN CONSTRUCTION PROJECT MANAGEMENT

[1]Dattatraya Rajendra Khade, [2]Aishwarya Kadoo
[1]Student, [2]Professor
[1]Project and Construction Department,
[1]MIT-ADT College of Management, Pune, India.

ABSTRACT

Construction projects are inherently multi-disciplinary, documentation intensive, dynamic in design requirements, and constrained by budgets and schedules. Building Information Modelling (BIM) is an information management approach for developing, coordinating and maintaining digital representations of construction assets. This study investigates the use of BIM in construction project management, focusing on design coordination, planning, scheduling, quantity and cost review, progress measurement, information for quality and safety management, and project handover. The methodology is primarily descriptive and literature based, with a supporting illustrative use of a multi-story residential building process. The process considers architectural and structural, and mechanical, electrical and plumbing (MEP), model development, model federation, clash detection, 4D schedule development, and 5D quantity/cost take-off and costing. The review found that BIM can provide support for visualization, coordination, information traceability, communication, but only when model quality is assured, responsibilities and approvals for models are designated, and model sharing and modification protocols are established. Barriers to implementation include set-up costs, educational investment, interoperability, non-value-add model development and acquisition costs, lack of clarity as to who owns models and managing change, and potential interference with established working routines. The case study is demonstrative only and does not claim measured project savings. The paper recommends determining BIM requirements, using a project BIM Execution Plan, establishing a Common Data Environment, and assessing project benefits.

Index Terms- Building Information Modelling, construction project management, 3D BIM, 4D BIM, 5D BIM, clash detection, Common Data Environment.

I. INTRODUCTION

Project management is the discipline of planning, organizing, motivating, and controlling resources, procedures and protocols to achieve specific objectives. Project management is the project delivery process. Construction project management includes the planning, coordinating, and controlling of a project from inception to completion, including the utilization of resources and the achievement of predetermined objectives (time, cost, scope, quality, and stakeholder satisfaction) with the aim of bringing about beneficial change and added value.

Building Information Modelling (BIM) is an information-management process that makes use of digital models. The BIM model simulates building components as objects with geometry and organized property sets (size, classification, material, identifiers, data etc). BIM is not just a 3D visualization – the quality of a BIM is based on information trustworthiness, clear responsibility and coordinated creation by project participants.

The paper investigates the application of BIM to support construction project management during the lifecycle of the project. It highlights current practice of 3D modelling and multidisciplinary coordination, 4D construction sequencing, 5D quantity and cost review, progress communication, and quality and safety information, asset handover

II. OBJECTIVES AND SCOPE

The aims of the research are: (i) to introduce the concept and dimensions of BIM; (ii) to review BIM usage in construction planning and management; (iii) to explore 3D modelling, 4D scheduling and 5D cost integration; (iv) to understand design coordination and clash detection; (v) to highlight the benefits, constrains and BIM implementation challenges; and (vi) to demonstrate a BIM implementation work sequence in a building project. Limitations are that only building construction projects and the administration of the planning, design coordination, time, cost, quality, progress and handover activities have been considered. The paper is based on secondary information and a suggested workflow. It does not identify any survey results or measured savings for a named contractor.

III. LITERATURE REVIEW

A. BIM and Project Advantages

Bryde, Broquetas and Volm investigated the factors giving project benefit with respect to a BIM project and their relationship to project success criteria [1]. This research is applicable to the construction management domain because benefits associated with a BIM project can be compared to the project objectives: cost, time, quality, communication and stakeholder satisfaction. Having a model by itself does not ensure that the project performance has improved.

B. Information Management and ISO 19650

ISO 19650-1:2018; Concepts and principles of information management using BIM for the entire lifecycle of assets [2]. It explains the importance of structuring, sharing, storing, versioning and managing project information; which enables the use of specified information requirements, approval processes, and a Common Data Environment (CDE).

C. 4D & 5D BIM

The 4D BIM research highlights how model elements can be connected with construction activities for sequencing, visualization and progress communication [3], [4]. 5D BIM builds upon the application of model elements by linking predefined quantities with a cost structure. Outputs are only as accurate as the model, measurement conventions, cost coding and validation process.

D. Coordination and execution

BIM-based co-ordination integrates architectural, structural and MEP information within a shared review environment. Clash detection may locate potential geometrical conflicts but each item must be manually checked by a professional to ascertain whether the collision is an actual construction issue. The literature also cites a number of difficulties: software and hardware costs, training, interoperability, ambiguous obligations and resistance to new working procedures.

E. Studies/ Research Gap

The literature describes a spectrum of possible BIM benefits but their realization depends on a manageable work routine. For example; who keeps the model up to date, who closes issues, who verifies quantities, who logs schedule status and how is information transferred once approved? This paper answers this through an integrated work flow.

IV. RESEARCH METHODOLOGY

The research adopts a descriptive, secondary data and process analysis study design. The methodology comprises four steps: (1) preparation of a preliminary literature review on selected academic literature, standards and professional literature, (2) determination of construction-management functions that can benefit from the use of BIM, (3) compilation of a residential-building workflow, (4) a qualitative discussion on benefits, limitations and implementation precursors.

The workflow is not an empirical study. There are no primary interviews, questionnaire answers, actual project quantities or measured time and cost savings. An empirical study on the workflow in future should be based on authorized project records, a clear baseline, a clear measurement period and open performance measures.

A. BIM Adoption Procedure

A logical process of implementation is as follows: project objectives and project adopted BIM uses are identified; information requirements defined, and a Project BIM Execution Plan (BEP) implemented to set out roles, responsibilities and plans, including software, model decomposition, exchange formats, model reviews, approval processes; discipline models are created, and checked and federated, for coordination; approved model information is associated with the project program to deliver 4D plan.

B. Needs for Data and Shared Data Environment

Information that may be needed:- Project brief, site survey, architectural plans, structural design, MEP, specifications, WBS (work breakdown structure), schedule activities, cost codes and asset data. A CDE is a centralized source of stored and exchanged information. Before modelling data is exchanged, naming conventions, levels of access and permissions, revision control and approval processes have to be agreed.

V. APPLICATION OF BIM IN CONSTRUCTION PROJECT MANAGEMENT

A. 3D BIM: Visualization & Design Co-ordination

3D Bim Building elements and their spatial relationships are modeled in three dimensions. Architectural, structural and MEP models can be viewed together to communicate design intent and clarify interface issues, or to communicate solutions. A federated model can be used for design coordination meetings, and to allow project team members to review shafts, openings, overhead clearances, routes for services and equipment space. Views should be based on existing correctly aligned discipline models.

B. Clash Detection and Issue Management

Clash review may discover a pipe crossing through a beam zone, a duct at odds with a ceiling plan, an unpermitted service opening or limited equipment access. Each problem should be documented with a location, description, responsible person, priority, due date and status. The responsible designer or contractor considers the problem, recommends an approved resolution and modifies the model. The problem remains open until confirmation is received that it has been resolved.

C. 4D BIM: Planning and Scheduling

4D BIM connects model objects to construction schedule activities. A program for a residential project might include excavation, foundations, substructure, reinforced concrete frame, masonry, MEP first fix, plastering, flooring, painting, testing and commissioning. Activity codes are uniform so that objects in the model can be 'linked' to program tasks. 4D simulation can show the order that work is to be carried out, floor by floor, by zone or trade, and enable planning of access, delivery of materials, congestion and setting out milestones. Planned and actual progress should be separate, and refreshed from validated site records.

D. 5D BIM: Quantity and Cost Estimation

5D BIM links specific model quantities to cost codes/bill-of-quantities items. The quantity figures are model dependent, ie depending on level of detail, they could relate to the total concrete volume, slab area, wall area, floor finish area, number of doors and windows, length of MEPs, number of plant etc. The QS should verify that the model scope, specifications and measurement rules are aligned with the right cost report. Cost data should include material, labour, plant, wastage, preliminaries, tax and contractual exclusions where relevant. Model quantities are not automatically certified payment quantities and will need to be checked and approved.

E. Progress, Quality and Safety Management

Views within the model could convey the current state of work packages, e.g. not yet begun, underway, checked, complete and accepted. For each status, site records including daily reports, photographs, inspection records and signed off measurements should be available. Information on quality could be related to model components via inspection and test plans, material approvals, checklists and non-conformance reports. Views within the model could also be used to discuss safety planning for access routes, work zones, lifting points and trade segregation. Decisions on safety should rest with trained people and approved risk assessments.

F. Handover and Facility Data

For project handover the client may mandate approved record drawings, asset identifiers, equipment data, warranties, operation and maintenance manuals, schedules and commissioning information. Such demands need to be determined early so that the project team gathers and verifies data during construction rather than reconstructing it at completion. Open information sharing and structured asset data can allow for future operation and maintenance.

VI. ILLUSTRATIVE RESIDENTIAL WORKFLOW

This example case is a multi-story residential building with architectural, structural and MEP disciplines. At project start the client and project manager agree on BIM objectives, deliverables and responsibilities. The BIM coordinator is responsible for the BEP and defining the CDE, coordinate system, model and element naming conventions, and exchange schedules. The architectural model illustrates the spaces, walls, doors, windows and finishes; the structural model illustrates the foundations, columns, beams, slabs, stairs and other structural elements; and the MEP model illustrates the plumbing, drainage, fire protection, HVAC, electrical containment and equipment.

The discipline models are validated and federated for integration. Clash reports are generated and assigned to responsible parties. Once validated, elements from the model are linked to construction tasks to produce 4D schedule views. Selected quantities are linked to cost codes for 5D validation and checked against approval drawings and measurement instructions. Progress reports are validated using site reports. The as-built asset information is collated at handover in accordance with client standards.
The workflow here shows how BIM uses can be linked together on a building project. This is a hypothetical academic example and has not been tested for measured performance on an actual site. No cost savings, time reductions or productivity benefits are claimed.

VII. Result and analysis

The literature review and example workflow show how BIM can support construction project management through enhanced visualization, multi-disciplinary coordination, schedule communication, traceable quantities and project handover. 3D BIM supports design review; 4D modelling incorporates construction sequence, and 5D adds cost and quantities. A common data environment (CDE) and a BIM execution plan (BEP) stipulate the information-management protocols needed for coordinated exchange and authorization.
These are subject to: proper up to date models with defined areas of responsibility, compatible software and systems, personnel trained on the software and systems, accurate site information. Poor model detail can result in false quantities, inadequate revision control can mean teams are referencing out of date models. A large

number of clashes can be due to effective clash detection not poor design, so performance indicators must be used in context.

A. Recommended Performance Measures

The project team could measure the use of BIM using the number of issues raised and resolved, the average time to close an issue, the percentage of submitted information delivered on time, the difference between model and independently checked quantities, schedule milestone.

B. Implementation Challenges and Recommendations

Typical difficulties experienced by users are software and hardware investment, modelling effort, training, lack of file-format compatibility, partial object attributes, lack of clearly defined model ownership and fear of change. A contractor should initiate a pilot project and establish BIM uses based on the development of a project problem. A champion should be designated for coordinating activities, a workable BEP should be prepared, file exchanges should be tested, revision control should be maintained, relevant personnel should be trained and an issue register should be formally used. Model quantities and progress information should be independently validated before they are used for commercial and contractual purposes.

VIII. CONCLUSION

A process of integrated building information modelling can improve construction project management when supported by adequate technologies, standards, people and workflow. 3D BIM enables visualisation and interdisciplinary coordination; 4D BIM allows matching of model elements with construction processes; and 5D enables quantities and costs can be continuously monitored. And model-based data can facilitate progress communication, quality documentation, safety planning discussions and asset handover.

The residential-building workflow provides a working example for linking model creation, coordination, scheduling, cost management, and handover. It stops short of providing any quantifiable cost benefits or performance enhancement. The project owner needs to set out BIM targets, along with required information, initially. The project manager should develop a BEP and CDE, check model reviews against a design team matrix, and update revision control list. Contractors should train their teams and flag up issues. Quantity surveyors and planners should check the models.

In future the framework should be used in a building project and verified coordination, quantity, schedule and handover data should be tested. All findings should include project context, data sources, length of observations and limitations.

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