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# Virtual Design and Construction in CPM Project Management Using BIM

Abhishek Jitendra Pawar<sup>1</sup>, Dr. S.S. Deshmukh<sup>2</sup>

P.G Student, Department of Civil Engineering, KJ's Educational Institute's Trinity Academy of Engineering,  
Pune, India<sup>1</sup>

Assistant Professor, Department of Civil Engineering, KJ's Educational Institute's Trinity Academy of Engineering,  
Pune, India<sup>2</sup>

**ABSTRACT:** This study investigates how to use Building Information Modelling (BIM) to integrate Virtual Design and Construction (VDC) into Critical Path Method (CPM) project management techniques. With the introduction of cutting-edge technology, the construction industry has seen a paradigm change. The goal of this research is to clarify the ways in which VDC, CPM, and BIM work together to improve project results and efficiency. The article starts out by giving a thorough introduction to each of the three concepts—VDC, CPM, and BIM—and outlining their main uses and guiding principles. It then explores the difficulties encountered by conventional project management techniques and how combining VDC and BIM might resolve these difficulties. In particular, the ways that virtual environments with 3D modelling, collaboration, and data-driven decision-making may optimised resource allocation and project scheduling are discussed.

**KEYWORDS:** Virtual Design and Construction (VDC), Critical Path Method (CP, Building Information Modeling (BIM), Construction Project Management, Integration, 3D Modeling, Collaboration.

## I. INTRODUCTION

### 1.1 General

In the dynamic landscape of construction project management, the integration of innovative technologies has become instrumental in reshaping traditional methodologies. One such transformative approach is the amalgamation of Virtual Design and Construction (VDC) with Critical Path Method (CPM) project management, facilitated by Building Information Modeling (BIM). This convergence marks a paradigm shift in how construction projects are conceptualized, planned, and executed.

Virtual Design and Construction, as a concept, transcends the limitations of conventional project management by leveraging advanced digital tools to create a dynamic, three-dimensional representation of the project. BIM, a key enabler of VDC, serves as the digital backbone, housing comprehensive and interconnected data about the project's physical and functional characteristics. This integration offers a holistic and collaborative platform for stakeholders to engage in real-time, fostering improved decision-making and efficiency throughout the project lifecycle.

Critical Path Method, a stalwart in project management, provides a systematic framework for scheduling and managing tasks to ensure project completion within defined timelines. The fusion of CPM with VDC and BIM introduces a new dimension to project planning, allowing for enhanced visualization, clash detection, and risk mitigation. This synergistic approach not only streamlines the project delivery process but also enhances the accuracy and reliability of project schedules.

### 1.2 Virtual Design

If used in relation to construction, it means that when the structure or infrastructure project is built physically, digital representations of it are created. During this procedure, a 3 dimensional (3D) Advanced computer-aided design (CAD) and building information modelling (BIM) technologies are used to produce a virtual representation the the project.

#### Digital Prototyping:

Virtual Design allows for the creation of detailed digital prototypes of the entire project, including related to structure, building-based, including mechanical, electricity, and plumbing (MEP) systems. Through the use of this digital depiction, stakeholders may examine several design possibilities and better visualise the project as a whole.

**Visualization and Simulation:**

Stakeholders, including architects, engineers, contractors, and clients, can visually explore and navigate the virtual model. This facilitates a deeper comprehension of the design, the detection of any problems, and the making of wise judgements. In order to evaluate elements like lighting, ventilation, and structural integrity, simulation techniques may also be used.

**Collaboration and Communication:**

In offering a common communication platform, virtual design encourages cooperation between project participants. The virtual setting facilitates easy communication and tracking of design updates, modifications, and notes. Using a collaborative approach throughout the building process improves communication and reduces miscommunication.

**1.3 Critical Path Method (CPM)**

CPM project management within the construction industry, the application of CPM is highly valuable for planning, scheduling, and managing construction projects efficiently. Here's how CPM is applied in construction project management.

**❖ Activity Identification:**

The construction project is broken down into a series of specific activities or tasks that need to be completed. These activities can include tasks such as excavation, construction of a basis, framing, plumbing, electricity, & finishing.

**❖ Activity Sequencing:**

Once the activities are identified, the next step is to determine the sequence in which they need to be performed. Dependencies between activities are established to create a logical flow for the construction project. For example, the foundation must be laid before the framing can begin.

**❖ Duration Estimation:**

Project managers estimate the time required to complete each construction activity. This estimation considers factors such as the scope of work, available resources, and any potential challenges or delays that may arise during construction.

**❖ Critical Path Analysis:**

The critical path is identified by determining the longest path of dependent activities through the project network. Activities on the critical path are crucial for determining the overall duration of the construction project. Delays in critical path activities directly impact the project completion date.

**1.4 Building Information Modeling (BIM)**

Building information modelling (BIM) software is a powerful and innovative tool used in the architectural, engineering, and construction (AEC) industries. Building information modelling (BIM) software facilitates the creation and management of complex technological models that underpin construction efforts and facilities.

There are 5 Levels of Development:

- LOD 100 - Concept
- LOD 200 – Design Model
- LOD 300 – Construction Model
- LOD 400 – Fabrication Model
- LOD 500 – As-Built Model

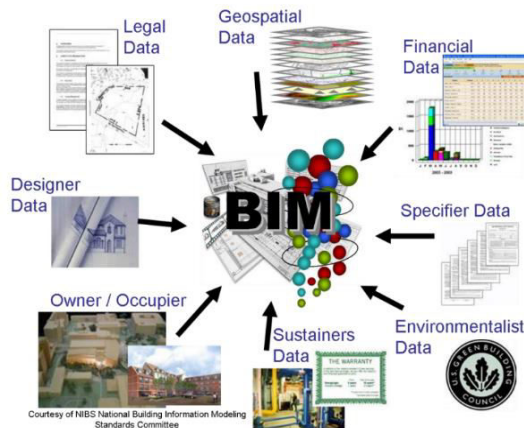


Fig 1.1: Communication, collaboration and Visualization with BIM model (NIBS, 2008)



### 1.5 5d Model – Based Building Quality Control:

Evaluation and testing are covered by quality oversight rather than the affirmation declaration or the healing move done throughout the enhancement sort out. The goal of the quality control strategy is to establish high-quality affiliations by carefully considering the diagram drawings and focus points. These establish the procedures for handling materials and equipment, the standards for work setup confirmation, and the necessary testing and assessment. By then, all of the precise and high-quality data needed to secure interest in material and instruments had been sent for acquisition thanks to cooperation between material inventors and equipment producers. The field engineer and general chief monitor the outsourced work for adherence while the project is in process. Additionally, all master as well as character defects are screened beyond the standard cut-off criteria.

- **Steps for plan of Building model:**

**Stage 1:** Collection of AutoCAD 2D drawings of the undertaking from site and venture director.

**Stage 2:** Creation of 3D model by bringing in 2D drawings in REVIT programming.

**Stage 3:** Conversion of the REVIT 3D model into Naviswork decipherable (.nwf) position by utilizing an augmentation device in REVIT.

**Stage 4:** Preparation of work breakdown structure for the venture and production of assignment plan utilizing the amount information from REVIT in Microsoft venture.

**Stage 5:** Creation of 5D model by bringing in and appending 3D model and the MSP plans (time and cost) in Navisworks programming.

**Stage 6:** Simulation and representation of 5D model in Navisworks programming.

- **Development of model in 3D utilizing Revit:**

Regarding designers and construction experts, Autodesk Revit Architecture is a reliable auxiliary arranging and documenting programming tool. It is specifically anticipated that the mechanical components and capabilities of Revit Architecture would support building information modelling (BIM) work forms. Revit Architecture may use dynamic information in clever models by using BIM rather than PC-aided drawing (CAD). This enables complicated structural components to be accurately structured and documented in a relatively brief period of period.

- **Benefits of using Revit Architecture**

People that work in compositional as well as structurally competent professions, or are seeking employment in such sectors, will find that utilising Revit Architecture offers many advantages. Revit Architecture's BIM work method increases productivity and simplifies documentation and organization, allowing you to quickly go from planning to completion while also modernizing and energizing your design with a single structural alteration.

- **Develop Revit Architecture model:**

Modellers and other structural experts utilise Autodesk Revit Architecture to aid reduce possibility, get insight into how constructions will function before expansion starts, create better-quality designs, and enhance adventure transportation. Revit Architecture, for instance, may be the preferred tool used by a school of configuration to assist its 600 full-time undergraduate students in gaining certified experience via the utilisation of a BIM work process to collect highly influential 3D models. Revit Architecture may be utilised to quickly monitor the amazing arrangement and development of a building that folds over to accommodate taking care of machinery and taking into account a higher degree of future maintenance and updates thanks to a planning and fundamental organisations company.

## II. LITERATURE REVIEW

**João Bosco P. Dantas Filho (2015)** In his article titled "Virtual Design and Construction of Plumbing Systems," examines the challenges connected with conventional design coordination in the context of plumbing systems. The literature analysis highlights common problems resulting from traditional design coordination approaches, including overlooked errors, rework, and delays in construction projects. In order to mitigate these challenges, the research supports the effectiveness of Virtual Design and Construction (VDC) technologies. The study highlights the beneficial effects of VDC technologies on architectural, structural, and Chemical, Electrical, & Plumbing (MEP) designs by concentrating on minimizing errors and Requests for Information (RFIs). The research primarily looks at RFIs pertaining to water/sanitary facilities inside Building Information Modelling (BIM) models using a qualitative technique.

The results demonstrate how VDC has a positive impact on plumbing system designs and how it may increase project efficiency as a whole. The presentation ends with practical suggestions for identifying and avoiding various RFIs in the

fields of virtual construction and plumbing system design. The larger conversation about using VDC technologies for better coordination and efficiency in construction projects is enriched by the valuable insights provided by this study.

**Mehmet Yalcinkaya (2017)** investigates how building modelling and modelling, or BIM, is used in building management in the study "Building Information Modelling (Bim) And The Construction Management Body of Knowledge." The importance of BIM as an electronic method for creating, evaluating, and analysing facility features is highlighted in the article. It explores how BIM fits into the corpus of knowledge for building oversight, emphasising how useful it is at key project stages. The study underscores the necessity of updating construction manager (CM) duties and responsibilities to enhance efficiency in BIM-based projects. It addresses the existing ambiguity in aligning traditional CM roles with BIM functionalities, providing insights into bridging the gap between established construction management practices and the transformative capabilities of BIM.

**Hisham M. Said (2018)** carried out research on the "The aim of this study is to gain a better understanding of the impact that design and scope changes have on the execution of electrical suppliers in virtual design and construction (VDC) projects. Specifically, the study focuses on how VDC projects are executed for electrical along with field freelancers. Through the use of a hybrid research technique that blends interviews and questionnaires, the study explores the variables that lead to VDC cost overruns. The report provides best practices for minimising and recovering these charges in addition to outlining the breadth and reasons of Electrical contractors discovered inefficiencies as well as price excesses when overseeing VDC construction plans. The first significant contribution of the research is its thorough analysis of cost overruns and inefficiencies unique to electrical contractors working on VDC projects. Providing a set of best practices specifically designed for electrical contractors and other speciality subcontractors in the build engineering and management sector is the second significant contribution. These best practices provide insightful information to improve project performance overall and are intended to improve the successful oversight, timetables, and control of VDC work.

**Musa Adamu Musa (2015)** " Evaluation of BIM for Construction Project Leadership Scheduling Risk Prevention" was the title of a research carried out in 2015. The study tackles the significant issue of insufficient risk management in the construction sector, specifically with regard to the timely completion of projects. It is difficult to effectively schedule risk management in construction projects because of their dynamic nature and the many risk elements that are involved. Building Information Modelling (BIM) is being used more often to close the gap between construction risk and conventional 2D computer-based technologies, according to the report. The investigation's main goal is to better understand how BIM may be used to improve scheduling mitigation of risks in building projects. Presented as an early part of a larger research project, the study emphasizes how important it is to digitize construction sequencing processes. It highlights how BIM can effectively include important project management components, providing notable advancements in the area of scheduling risk management in the construction sector.

**Taija Puolitaival's article (2015)** The influence that Virtual Design and Construction (VDC) has on construction project management education in the architectural, engineering, and construction (AEC) industry is examined in "Assessment In Virtual Design And Construction Education". The goal of the research is to comprehend how academic institutions adjust to the changing dynamics of these sectors. The essay examines the many approaches used by educational establishments to include VDC into their courses. It highlights the difficulties in developing evaluations that are in line with the desired learning goals. Using a developmental action research approach, the article offers a case study based on an undergraduate Construction Project Management (CPM) course to exemplify these principles.

The search for the ideal balance between knowledge in Construction Project Management (CPM) and skill with Building Information Modelling (BIM) software is one of the main themes of the paper. The essay highlights the difficulties that teaching staff and students have while adjusting to the unfamiliarity of the VDC setting. Essentially, the study clarifies the complex dynamics of integrating VDC into construction project management education, highlighting the need of customized evaluations and tackling the subtle issues that arise from the convergence of CPM and BIM in the educational setting.

**Anoop Sattineni and Kyle Mead (2013)** examined how The Architecture, Engineering, and Construction (AEC) sector makes extensive use of Building Information Modelling (BIM), and BIM implementation standards are growing concurrently. Though well-known frameworks like the "National BIM Standard" and the "BIM Project Execution Planning Guide and Templates" provide direction on the use of BIM, the study found a major deficiency in addressing

critical problems with collision detection and coordination, especially when looking at things from the contractor's point of view.

In order to close this gap, the study is concentrating on creating "Coordination Guidelines on Virtual Design and Manufacturing." Contractors and subcontractors from Atlanta and Birmingham, USA, participated on the cooperative project. Unlike previous suggestions, these rules address topics like model naming standards and communication protocols for colour schemes in order to improve the BIM-based construction coordination process. The report highlights that these recommendations provide particular enhancements for expediting construction coordination, in contrast to widely accepted industry norms. The study adds to a more thorough knowledge of efficient BIM use in building projects by emphasizing the significance of tackling communication and coordination problems.

**Mikkel Toppel Andersen's (2018)** Building information modelling, or BIM, is not widely used in the Danish construction industry, particularly during the design and construction phases. The study "Exploring the positive effects of organized information with the application of simulated construction and design principles through a BIM life-cycle approach" attempts to close this gap in understanding. The main goals of the project are to choose a design methodology and evaluate the benefits of a systematic and methodical approach to BIM adoption at various stages. Important research topics were found via a literature review, which resulted in a case study that integrated a real project with a theoretical project that academics and students created. The study's output was a useful design methodology that uses structured data and multidisciplinary collaboration to guide a digital building process from design to construction to operations. The creation of a BIM roadmap paradigm, which aids in the growth of a common language and comprehension of the digital building process, is a crucial study result. The research offers both theoretical and practical implications for the topic and explores the possibility of academic institutions and business experts working together to change work practices.

**Jack Steven Goulding (2013)** investigates the use of a "Cloud BIM Platform and Integrated Ace Projects Based on Virtual Reality." The purpose of the research is to use Building Information Modelling (BIM) to enhance design team collaboration throughout the course of the project. The research emphasizes how important it is to integrate project data at every stage of the the field of engineering, design, manufacturing, and building procedure, and maintenance phases. It also presents BIM Level 3 (Cloud) as a component of Integrated Project Delivery (IPD) due to its possible advantages in handling projects, design enhancement, and overall project delivery. The study presents a web-based virtual reality cloud platform in a gaming context with the goal of enabling end users who are spread out geographically to share pertinent information continuously. This cutting-edge cloud computing platform was developed using an iterative development approach that included the Unified Software Development Approach's Elaboration, Construction, and Transition stages.

In addition to shedding light on the platform's technological details, the research investigates how remote design teams make decisions. Novel insights into the elements that contribute to efficient decision-making pave the way for future developments in relationship models, especially in group contexts and with a particular emphasis on user interfaces for video games. In the context of integrated AEC projects, the article offers a proactive method for using technology to improve decision-making and cooperation.

**Leonardo Rischmoller's (2018)** "Integration Enabled by Virtual Design & Building as a Lean Execution The strategy," a theoretical study, explores the relationships between lean construction, mass production, traditional construction, These include the Simple Framework for Integrating Project Delivery paradigm and virtual design and construction (VDC). The study indicates that integration is now required for global production and architectural optimization, similar to Toyota's previous use with lean construction methods. The article presents the Simple Framework for Integrating Project Delivery as a system model that may be used to get the required degree of integration for producing valuable, high-performing structures. The following investigation explores the ways in which Virtual Design and Construction (VDC) enriches and supplements the Simple Framework concept. The research carefully describes every component of VDC and clarifies how project teams may use it to continuously provide high-performance results in construction projects.

**Mughees Aslam (2021)** examines how the construction industry may merge the use of the Lean Project Delivery System (LPDS) with Virtual Design and Construction (VDC). Examining possible overlaps between VDC and LPDS, the research takes into account the difficulties in implementing Lean Construction (LC) concepts including enhanced visualization and effective exchange of data. The research focuses on the utilization of VDC to successfully deploy

LPDS, shedding light on this relatively unexplored topic. The paper identifies 351 positive hypothetical interactions, showcasing a robust synergy between VDC and LPDS. Parallels between the two are clarified by an extensive literature review. The research also identifies 65 opportunities for VDC to support LPDS rollout. There are six areas where VDC's difficulties may be addressed via lean intervention. The study comes to a close with implementation suggestions meant to improve the construction industry's general performance. The strategy recommends using LPDS and VDC simultaneously to maximize their combined advantages. It offers practitioners a road map for maximizing efficiency in building projects.

**David Bryde (2012)** explores "The project benefits of Building Information Modelling (BIM)" in this investigation. The study explores the useful benefits of using BIM into building projects. Using secondary data from 35 BIM-enabled construction projects, the research evaluates the advantages that are said to exist for various project situations. The research uses content analysis and specifies criteria to assess project performance. The most often reported advantage among those identified was cost management and reduction throughout the project. Remarkable time savings were also recorded. The research identifies the main drawbacks as being related to the difficulties in using BIM software. Strategic measures are critical in overcoming barriers and optimising the benefits of BIM adoption in construction projects, according to the report. Performing cost-benefit analyses, spreading awareness, and putting programmes for education and training into action are some of these measures. This thorough analysis offers insightful information to practitioners looking to use BIM in the building sector.

**John Kunz (2012)** explores the concept of "Virtual Design and Construction: Themes, "Case Studies and Implementation Suggestions" to promote open and transparent corporate goals in design-build initiatives. In this study, integrated interdisciplinary performance models are used to Virtual Design and Construction (VDC). Projects are represented digitally in VDC, with an emphasis on the intended and managed elements of the process, organization, and final output. The paper explores VDC theory and methods, presenting specific model examples and provides thorough suggestions for practical implementation. Due to their interdisciplinary nature, these VDC models serve as performance models for different project stakeholders, gauging and projecting project results in accordance to predefined objectives. The logical integration of various models is emphasized as a crucial element, since it allows for common data access and highlights dependent characteristics during revisions. Companies that use these models to implement VDC principles often see increases in their overall company performance. The paper advances knowledge of and application for VDC in the context of design-build projects.

**Peggy Yee's study**, "Prospective Validation of Virtual Design and Construction Methods," explores the vital need to fully understand the potential of new virtual design and construction (VDC) methods before investing funds in their creation or use in actual construction projects. The fundamental difficulty is that every project is different, which means that getting precise updates on its status takes time. Prospective validation is presented in the study as a developing method that gives researchers the chance to evaluate new VDC strategies on real projects in a timely manner. The article describes the general purpose of prospective validation, explains how to use it, and offers suggestions for researchers on how to do so. The study's results are used in the article to highlight the value of prospective validation in conducting comparison studies between novel VDC techniques and those that practitioners have previously implemented in actual project contexts. The study highlights the technique's applicability in evaluating its possible influence on future project choices as well as whether a new approach can be implemented within a realistic timeline. All things considered, Peggy Yee's research offers insightful information on how to effectively assess and use VDC techniques into the dynamic setting of building projects.

**Ju Gao & Martin Fischer** carried out a thorough investigation under the heading "Case Studies concerning the Implementation & Impacts of Virtual Design and Construction (VDC) for Finland." Through case studies of 3D/4D models used in 11 construction projects, the study investigates the present status of augmented reality engineering and construction (VDC) utilization in Finland. The objective is to provide experts in the domains of building, engineering, and construction (AEC) a deeper comprehension of the uses and difficulties associated with 3D/4D modelling. The researchers examine how Finnish AEC professionals use 3D/4D models to improve process integration, communication, collaboration, and product development via an investigation of particular project papers and presentations. Over thirty hours of interviews were conducted for this study, which provides insights into how project challenges and phases affect model usage, how organizational and technical factors are taken into account during implementation, and how benefits like enhanced design reliability, efficient change order management, and a stronger emphasis on value-added tasks are perceived. Important conclusions show how VDC affects project management and



product design in the Finnish construction industry. In addition to identifying implementation trends, the study suggests a framework for recording and contrasting 3D and 4D modelling.

**María Guadalupe Mandujano** Titled Rodriguez's paper, "A Method to Identify Virtual Design and Construction Implementation Techniques from the Lean Construction Viewpoint," provides a thorough analysis. This study examines two key components of virtual design and construction (VDC) in the architecture, engineering, and construction (AEC) industry: building information modelling (BIM) with agile building. Although synergies have been discovered, the body of work currently in publication does not thoroughly examine their conceptual underpinnings. This study aims to expand on our knowledge of these interactions in order to improve the use of Lean and VDC in the AEC sector. With Lean Construction acting as a moderating element, the research focuses on building a systematic strategy to find optimum VDC implementation options and evaluate their influence on performance, given the broad use of VDC, especially in combination with Lean approaches. A comprehensive study of the literature, the development of an interaction model, the formulation of null hypotheses, statistical analysis using partial least squares, and the reporting and discussion of the findings are all included in the technique. The study's output is a VDC/Lean impact model that is based on statistically significant data and provides practitioners with insightful information to help them make choices about the adoption of VDC and Lean in the AEC industry. The results highlight the need for a more evidence-based approach to be used in order to deploy VDC globally. This research fills a significant vacuum in the literature by addressing both academic and practical issues, and it offers a basis for well-informed decision-making in the ever-changing environment of construction industry practices.

#### IV. CONCLUSION

Finally, a thorough examination of Virtual Design and Construction (VDC) and its incorporation into many aspects of the architecture, engineering, and construction (AEC) industry is provided by the wide range of literature that has been evaluated. The studies together show the revolutionary potential of VDC technologies, ranging from resolving challenges in traditional design coordination to examining the effect of design modifications on VDC performance for electrical contractors. The literature emphasises the critical role that technology plays in maximizing project efficiency and results, whether it is looking at the use of Building Information Modelling (BIM) in construction management, evaluating the advantages of structured information in a BIM life-cycle approach, or suggesting coordination guidelines for improved BIM-based construction coordination. Studies that examine the potential validation of VDC techniques or the synergies between VDC and the Lean Project Delivery System (LPDS) provide valuable insights into how construction practises are changing. These studies, which highlight the need for customised assessments, cooperative strategies, and evidence-based approaches to ensure the successful implementation of VDC in construction project management and beyond, offer a rich foundation for well-informed decision-making as the AEC industry continues to embrace digital advancements.

Virtual Design and Construction (VDC) has a bright future ahead of it, as industry practises and technological breakthroughs continue to drive this field forward. Future plans call for improved VDC integration with cutting-edge technology like artificial intelligence and augmented reality, which will improve project visualization and decision-making procedures even more. It is anticipated that interoperability and collaborative platform use would increase, promoting smooth communication between project stakeholders. The integration of VDC in optimising resource utilization and reducing environmental effect may also result from a heightened attention on sustainability and environmentally friendly construction practises.

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