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Postgraduate Diploma Thesis

A Comprehensive Review of Virtual Design and Construction (VDC) in the Construction Industry and the Value of the BIM Element

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Abstract

The persistent fragmentation and inefficiencies of the construction industry have driven the emergence of Virtual Design and Construction (VDC), an integrated management framework that brings together digital modeling, organizational collaboration, and production control. Developed at the Center of Integrated Facility Engineering (CIFE) at Stanford University, VDC is based on the Product-Organization-Process (POP) model and makes use of digital and organizational technologies in order to match project objectives with measurable performance results. In this thesis, VDC is investigated as a holistic methodology that connects the technological, organizational, and managerial aspects of construction. This is accomplished by combining these aspects through a consistent focus of objectives, measurements, and continuous improvement.

The study first establishes the theoretical foundations of VDC, drawing upon systems theory and organizational theory to interpret construction projects as socio-technical systems. It revisits the Virtual Design Team (VDT) model as an early attempt to simulate communication and coordination, highlighting its influence on the evolution of the POP framework. The POP model defines what is built (Product), who builds it (Organization), and how it is built (Process). Thus, it forms the conceptual basis for modeling and evaluating project performance through interdependent components that together capture the complexity of construction delivery.

Building upon this foundation, the thesis explores the core VDC elements which are Building Information Modeling (BIM), Integrated Concurrent Engineering (ICE), and Project Production Management (PPM) as the operational manifestations of the POP dimensions. BIM represents the product model and provides the technological backbone while ICE structures the organization for collaborative, real-time decision-making and PPM applies operations-science principles to control flow, variability, and reliability across processes. Extending the analysis of the elements, the study attempts to clarify a common misconception that equates BIM with VDC. It emphasizes that while BIM is essential to collaboration and the digital enabler of VDC, the latter extends far beyond and includes managerial, organizational and performance-driven aspects.

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Another aspect of this research lies in the examination of productivity metrics and controllable factors, which transform VDC from a digital coordination method into a comprehensive performance-management framework. Metrics serve as indicators of project progress and efficiency, while controllable factors represent the decisions and behaviors within the team's influence. Their combined use allows proactive management and improvement throughout a project's lifecycle. The research suggests a taxonomy of 17 existing Project Metrics from Literature, aligning them with the POP/VDC framework and connecting them to controllable factors to create a conceptual structure for classification and interpretation.

The study also positions VDC within related frameworks, demonstrating its alignment with Lean Construction principles and the PDCA cycle, and identifying Integrated Project Delivery (IPD) as the most effective delivery model for VDC implementation. The analysis of international implementation efforts -such as Singapore's VDC Guide- illustrates how goal hierarchies, collaboration mechanisms, and performance measurement can be legislated to embed VDC principles into industry practice.

Emphasis is placed on how emerging technologies shape and redefine the VDC framework. The POPi model, which introduces infrastructure as a fourth dimension alongside Product, Organization, and Process, highlights the importance of technological ecosystems. Advanced tools such as digital twins, Internet of Things (IoT) sensors, artificial intelligence (AI), and immersive reality (AR/VR) enable real-time visualization, predictive analytics, and enhanced collaboration within the BIM environment. While these technologies expand the capabilities of VDC, challenges remain concerning data quality, interoperability, cost, and the need for organizational readiness and training.

In conclusion, the thesis asserts that VDC should not be viewed as a successor to BIM but as a comprehensive managerial framework that embeds BIM within a broader system of collaboration, production control, and measurable performance. By integrating people, processes, and technology through shared objectives and metrics, VDC represents a fundamental step toward the digital and organizational transformation of the construction industry, turning technological innovation into sustainable and quantifiable project value.