Virtual Design & Construction – Implementation Guide and Case Study [1]

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1. What is VDC?

Virtual Design and Construction is a project management methodology for construction projects of various sizes. VDC was created in Stanford University's Center for Integrated Facility Engineering (CIFE) in 2001. It is worth noting that with the advent of AI and advances in computing power, this methodology is significantly more enabled than when introduced. It is important to define the meaning behind the acronym, and to differentiate VDC from another BIM level (as BIM is a part of VDC and not its synonym). *Virtual* refers to the design and use of a digital twin of the project, and leveraging the information it provides for planning and construction as well. *Design and Construction* refers to 2 phases of a construction project that are commonly separated, hinting that VDC is a wholistic approach to project management for construction.

The framework for VDC is divided into 3 categories answering each of the following questions:

- Why is the client doing this project?
- What needs to be achieved by the project team
- How is the project team accomplishing the project objectives)

First, to answer "Why", a correct VDC implementation should establish 2-3 specific client objectives. Second, to answer "What", project objectives need to be established. Last but certainly not least, to answer "How", the 3 main pillars of VDC need to be implemented and designed. These 3 pillars are BIM (Building Information Modeling), PPM (Project Production Management), and ICE (Integrated Concurrent Engineering) which should be used to interconnect BIM and PPM. For each of these 3 pillars, we need to establish 2-3 production metrics to measure the project's performance on that specific pillar as well as 2-3 controllable factors, these factors are decisions we can control and manipulate to steer the project towards the production metrics. The main elements to a correct VDC implementation have been outlined in the following diagram.

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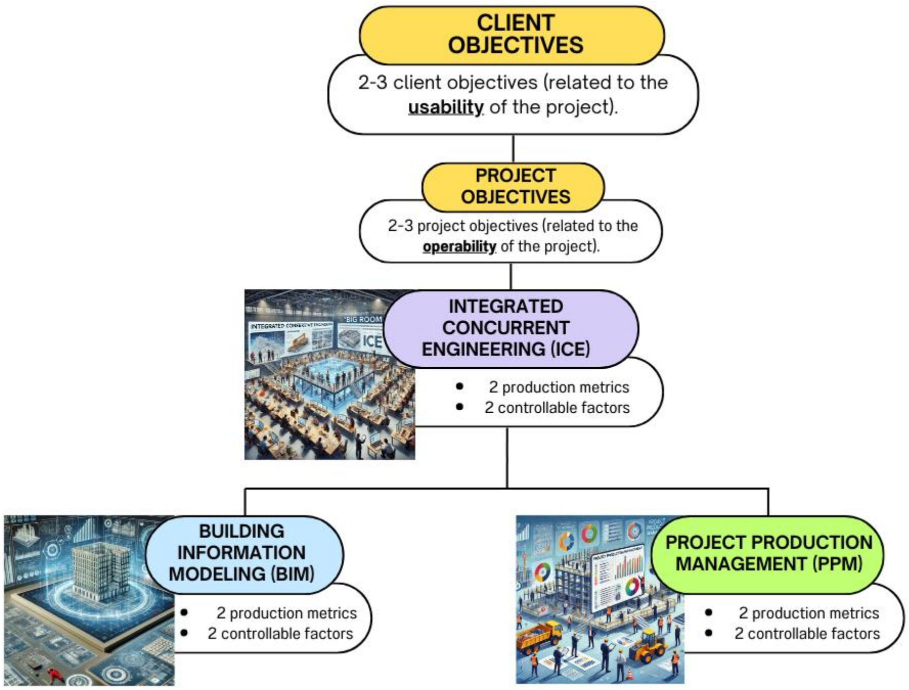

Figure 1: Diagram of the VDC pillars

2. VDC Case Study: Project Overview

As a part of the VDC certification program for Stanford University, the project in which VDC methodology was implemented was a large-scale residential construction project for a leading real estate and construction company in Lima, Peru.

Some information regarding the project:

- Height: 5 parking levels + 20 stories + Rooftop
- Built area of the project: 230,000 ft^2
- Project Value: $11,153,350.51
- Execution Time: 20.5 months
- Start Date: June 24, 2021
- End Date: February 2023

3. VDC Case Study: Implementing VDC Methodology

3.1 Client and Project Objectives

To achieve a successful VDC implementation, the planning team must have clarity on the outcomes the project team is aiming for in this project. For a project like the one in this case, the client and project objectives were limited to a timeline of 6 months.

The client objectives steer the project team (including every stakeholder that is part of the project) in the right direction. This increases client satisfaction and ensures the project is delivered with the expectations that were set by the construction company. The project objectives are set to ensure the client objectives are met, which is the main goal in any construction project. Therefore, there needs to be a synergistic relationship between these two. In this case, the objectives were as follows:

- **Client Objectives:**
  1. Complete the pouring of the 6th floor by February 23, 2022
  2. Budget overrun = S/. 0 until February 2022

- **Project Objectives:**
  1. Complete the excavation phase by December 28, 2021, and reach the structural frame up to the 7th floor by February 23, 2022.
  2. Generate 0 additional costs for rework or incompatibilities until February 2022.

3.2 Production Metrics, and Controllable Factors, by Pillar

As mentioned previously, production metrics and controllable factors were selected for each pillar of the VDC framework. It is important to establish goals for each production metric and measure these at least once a month to analyze the progress of your VDC implementation. For the controllable factors, these need to be phrased strategically, and quantified, so as to be an exact value you can measure (and at the same time something you can control and manipulate to obtain the goals set for your production metrics).

3.2.1 ICE

The first pillar is *Integrated Concurrent Engineering (ICE)*, which is a format for conducting meetings in a collaborative manner especially effective in multidisciplinary project teams such as those seen in construction projects. To successfully design an ICE meeting, an established agenda with time allocation for each item needs to be proposed, every stakeholder that takes part of the project should be present in the meeting, modern technology should be implemented for enhanced visualization and information integration of the project during the meeting. The production metrics and controllable factors for this pillar are the following:

Production metrics:

- ICE PM 1: Reduce the latency of RFI (Requests for Information) resolution by implementing ICE meetings. The goal is to resolve at least 90% of queries in less than 2 days.
- ICE PM 2: Collaboratively improve project process flows (during each ICE session, each participant should at least propose 2 workflow optimizations).

Controllable factors:

- ICE CF 1: Number of queries presented during each ICE sessions by the participants
- ICE CF 2: Percentage of queries that received a proposal for a possible solution presented by a participant during the ICE session

3.2.2 BIM

The second pillar is *Building Information Modeling (BIM),* this pillar is related to the digital twin that was constructed during the design phase of the project. The project analyzed during this case study had a VDC implementation during the construction stage but also had a BIM model available designed by the design team of the construction company. As a part of the VDC implementation strategy, it was crucial to ensure the use of this BIM model with the best of the project team's capabilities. Not only to enhance visualization during meetings or to answer questions by stakeholders, but also to optimize production, reduce reworks, detect interdisciplinary clashes (by having a 3D model where not only a depth perception is included but also the user can view elements from 360° angles), and ultimately avoid delays or additional costs. The main objective for this pillar was to ensure the project utilized the BIM model, replacing regular 2D drawings with a 3D model that contained information like quantity take offs, design considerations, etc. The production metrics and controllable factors for this pillar are the following:

Production metrics:

- BIM PM 1: Implement the BIM model with the goal of having at least 90% of clashes/ potential rework issues identified BEFORE the execution of the work item.
- BIM PM 2: Use the BIM model for quantity take offs before planning or executing them. The aim is to ensure that at least 90% of the planned work's items have used the BIM model to obtain the quantity take offs.

Controllable factors:

- BIM CF 1: Percentage of work items for which the project team has resorted to the BIM model before executing any work item.
- BIM CF 2: Frequently updating the BIM model with any changes.

3.2.3 PPM

The third pillar is *Project Production Management (PPM),* the main objective of this pillar is to organize and optimize production in the project (especially during construction but can be tailored for the design stage as well). Some of the most used PPM tactics are to utilize Last Planner System, from Lean Construction Philosophy, Percent Plan Complete (PPC), workflow mapping to reduce waste and variability, and more. For this case study, the PPM production metrics and controllable factors are the following:

Production metrics:

- PPM PM 1: Ensure compliance with the construction schedule and reduce its variability by updating the Percent Plan Complete format to achieve a value greater than 75%.
- PPM PM 2: 100% of the construction elements (columns, beams, slabs, etc) must be executed correctly (without rework or corrections).

Controllable factors:

- PPM CF 1: Frequency in which the project team updated the Look-Ahead plan and Collaborative Weekly Planning (uploaded to the cloud)
- PPM CF 2: Identify and solve possible future constraints during the construction process

3.3 Integration between VDC Elements

It is important to establish that several of the controllable factors selected need action by the project team. To achieve a successful VDC implementation, it is important to understand the difference between *measuring* and truly *controlling* results in your project. For example, ICE CF 1 seems like a very straight forward controllable factor in which you only count the number of queries asked by each participant in an ICE session, but it is the duty of the person in charge of the VDC implementation to foster a culture of collaboration and communication to improve this controllable factor and eventually achieve the results the project team is seeking.

After identifying which production metrics and controllable factor are going to be used for the VDC implementation, it is useful to analyze the integration and interconnection between each of the controllable factors and its corresponding production metric. Any controllable factor could be interconnected with a production metric from a different VDC pillar. The main objective of doing this analysis is to ensure you are choosing the right controllable factors, as they might be effective at helping the project team achieve several production metrics. The team created the following diagram to help understand the interactions between the pillars:

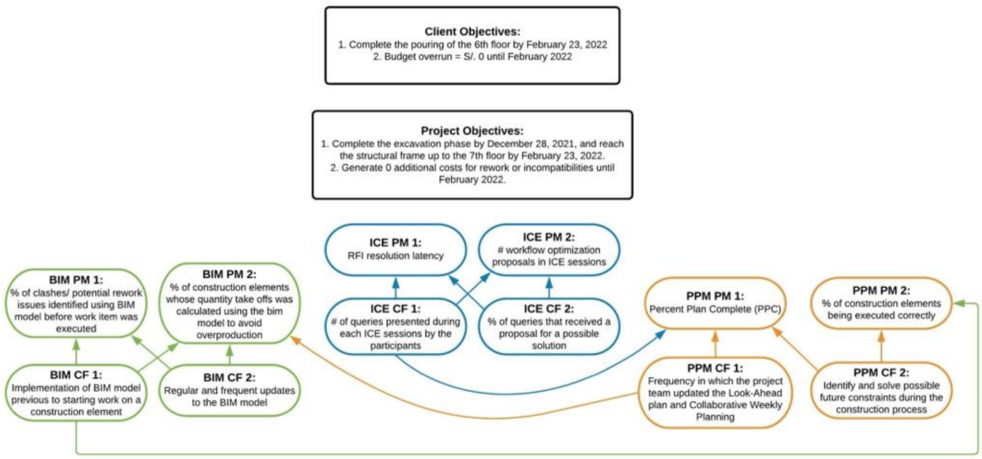

Figure 2: Integration between VDC elements

4. VDC Case Study: Results Obtained

4.1 Workflow Mapping Results

As a part of the PPM and ICE pillars (ICE PM 2) of our VDC implementation, workflow maps were developed to determine bottlenecks or improvement possibilities. This practice enabled the project team to detect and eliminate bottlenecks in the workflow for the overall process of the project.

In addition to this, a specific workflow map for the internal process of building concrete columns (from planning to concrete casting) was developed during several ICE meetings. This workflow mapping optimization process resulted in a 37.5% optimization (reducing the overall time to build a concrete column in the project from 16 days to 10 days). This also translated to a reduction in material, labor, and overall resources by the participants in this work.

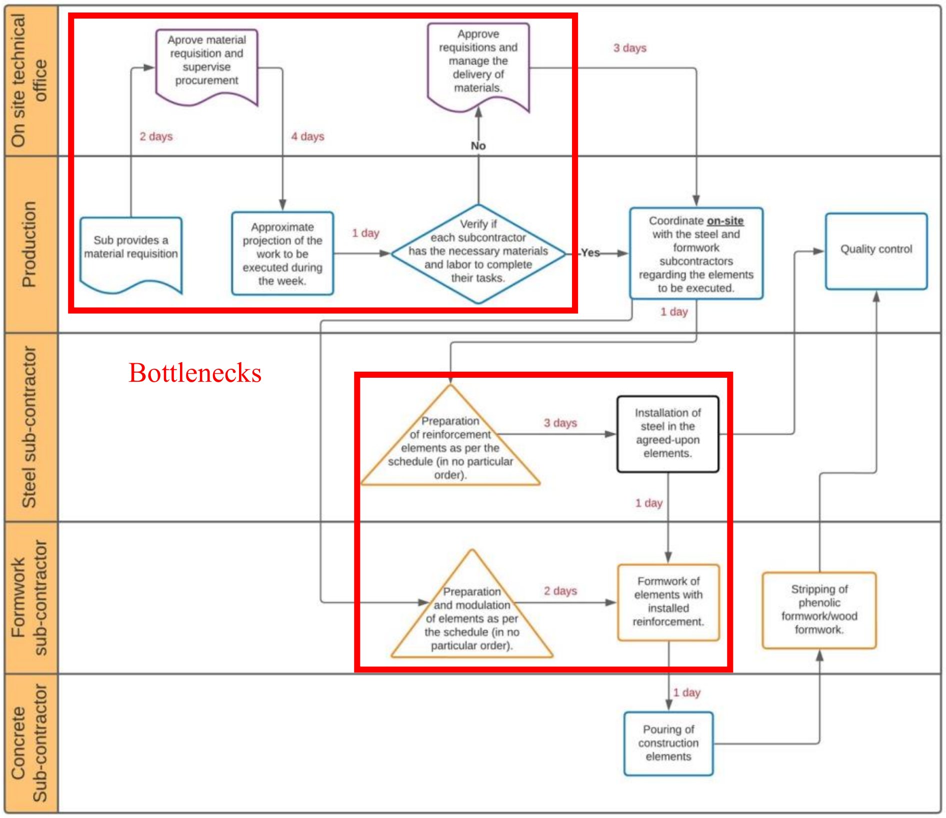

Figure 3: Traditional workflow to build concrete columns

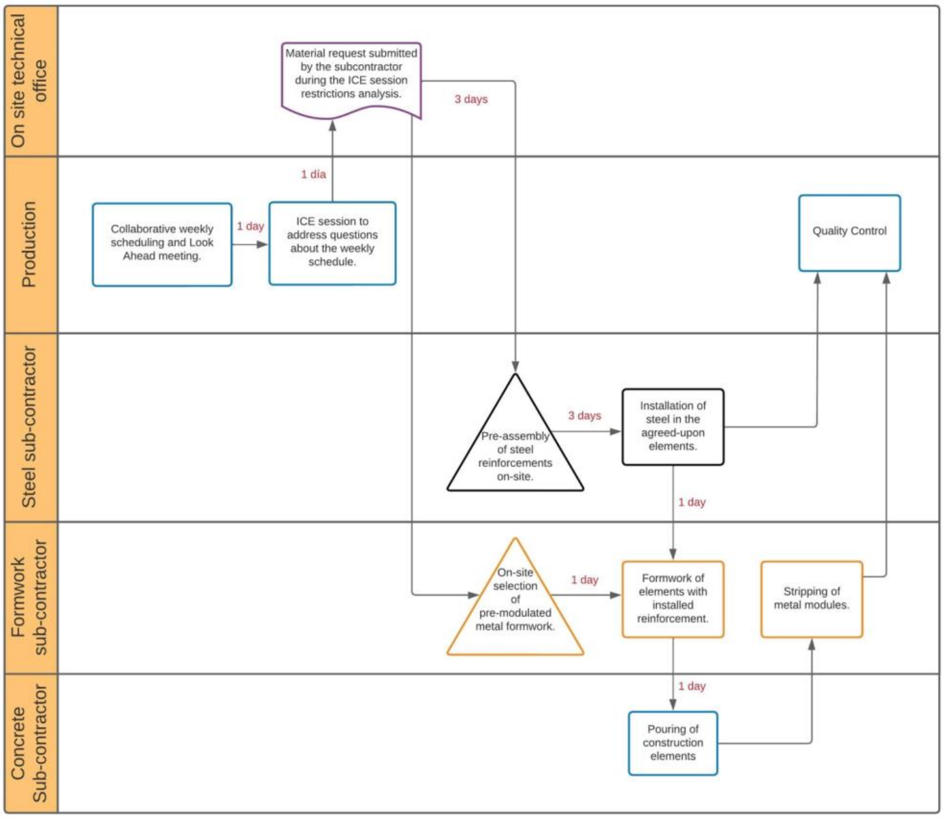

Figure 4: Optimized workflow to build concrete columns

4.2 Production Metrics Results

Some of the results observed from this VDC implementation came as an effect of the ICE sessions that were organized for process flow optimization in which the number of improvement proposals per session member was measured. AS a goal value for this metric, we had at least 2 improvement proposals from stakeholders during each ICE meeting, and for the last and most successful month of implementation, this value was 4.5 improvement proposals per meeting. These meetings resulted in an optimization of the vertical casting process, reducing the total time from the material request to the casting of the element from 16 days (without VDC) to 11 days (optimized flow with VDC).

Detecting interferences and analyzing restrictions suring ICE sessions using the BIM model prior to the execution of the work allowed us to execute an average of 98% of cast elements without the need for rework and meeting quality standards on the first attempt. The goal value for this metric was 100% but with 98% we were well above not only the industry average but the internal average for similar projects in the organization. Another result of this implementation was an increase in Percent Plan Complete by an average of 15%-20%, meaning that the production in the project was this much more reliable. The implementation called for a 75% goal value for the PPC and the result was 86.3%. The project team compared said production to an aggressive bi-weekly plan with the goal of delivering the project under budget and on schedule. Having this said, the variability of the production decreased to 20% of what was observed in the project before the implementation, accounting for a more stable production throughout the project.

Also, the percentage of clashes or interdisciplinary interferences in the project detected before doing work on site (to avoid reworks) was 91%, meaning that 91% of the construction issues were detected before any work was done. This was a BIM production metric that was very challenging to achieve as the project team had little to no experience using a 3D model.

5. Conclusion

The implementation of VDC (Virtual Design and Construction) initially faced resistance from the project team and subcontractors, who did not have experience utilizing BIM technologies and scheduled collaborative meetings. The VDC implementation in this project began with basic change propositions, creating a slow transition to these modern technologies and techniques. Shortly after, attitudes shifted positively as the positive outcomes and other benefits from VDC became apparent, leading to the adoption of the methods and techniques suggested by the implementation plan.

After a post-implementation reflection session with the project team, the team concluded that to ensure a successful VDC implementation in any project, it is crucial to set project goals in a collaborative manner, plan work processes meticulously, organize detailed ICE sessions, provide ongoing training, and optimize process workflows in a regular basis. Regarding resistance to change, we found having some ‘early wins’ was important to gain buy-in from the team and reduce that resistance. It is also very important to document lessons learned from past projects, setting objectives collaboratively, and to gradually introduce VDC to build trust and confidence from all the stakeholders in the project.

6. Acknowledgement

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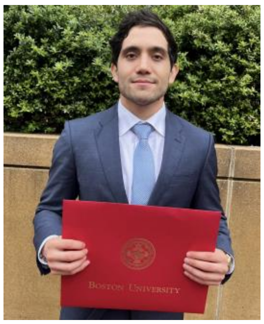
About the Author



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Luis Arguelles graduated in December 2020 with a bachelor's degree in civil engineering from the Pontifical Catholic University of Peru (PUCP), specializing in construction management. He began his career at V&V Bravo, where he modernized project management and production control for large scale residential construction projects. Using advanced techniques from a certification in "Virtual Design and Construction" (VDC) at Stanford University and a "Lean Construction" implementation, de reduced production variability by 20% and improved concrete pouring time by 31%, increasing reliability to the schedule and budget and more.

Promoted to Corporate VDC Coordinator at V&V Bravo, Luis expanded these practices to the whole project portfolio and standardized BIM/VDC implementation guides for the company. He then pursued a master's in project management at Boston University, graduating with a GPA of 3.9/4. While at BU, he worked as a research assistant contributing to a new course design and managed risk for construction projects.

Currently, Luis is a Project Manager at Bella Home Construction in Virginia, overseeing 15 to 20 luxury real estate projects annually. He focuses on planning, scheduling, subcontractor coordination, and risk management, significantly enhancing project reliability and performance. He also obtained the state certification and license of "General Contractor (Class A)".

Luis aims to earn the PMP certification and considers starting a consulting firm to optimize construction processes with advanced technologies like BIM and VDC. He was recently invited to participate in the "B'yond PM Podcast"; and to lecture at Boston University, highlighting his impact on the construction industry.