Correa, S.L.M. 2020. “Virtual Design and Construction Application During the Bidding Stage of Infrastructure Projects.” In: Tommelein, I.D. and Daniel, E. (eds.). *Proc. 28th Annual Conference of the International Group for Lean Construction (IGLC28),* Berkeley, California, USA, doi.org/10.24928/2020/0103, online at iglc.net.

VIRTUAL DESIGN AND CONSTRUCTION APPLICATION DURING THE BIDDING STAGE OF INFRASTRUCTURE PROJECTS

Stefania Limp Muniz Correa[1]

ABSTRACT

The bidding stage of infrastructure projects involves dealing with high levels of uncertainty and risks, as information at the early stage of the projects are often incomplete. Hence, the process of delivering a tender implies in making hypothesis, often based on the experience of the engineers. This leads to a series of error-prone tasks, in which Virtual Design and Construction (VDC) can add value by the implementation of its structured framework and concepts. This article aims to present the case study of VDC implementation at the bidding stage of infrastructure projects. The results show that VDC can help define a structure to the demands made to the design teams and to do better following up of the project, evidencing opportunities of improvements by the collection of lessons learned. The collocation also promotes collaboration between design and bidding teams, once the workflow and metrics were known and followed up, giving more transparency during all the process.

KEYWORDS

Standardization, Collaboration, Workflow, Virtual Design and Construction

INTRODUCTION

Virtual Design and Construction (VDC) theory dates back to 2001. The term was defined by the Centre for Integrated Facility Engineering (CIFE) at Stanford University and relates lean concepts with Building Information Modeling (BIM) in order to fulfil client’s objectives (Kunz and Fischer 2012). In recent years, there has been an increasing interest in applying its concepts in the Architectural, Engineering and Construction (AEC) industry and projects lifecycle, but there is still a gap when it concerns to the bidding stage of the projects. Most of the research available revolves around its application during the construction stage (Eastman et al. 2011; Fosse et al. 2017; Reed et al. 2017) and strategies for successful implementation are still missing (Alarcón et al. 2013).

This article aims to present the implementation of VDC concepts during the bidding stages of a general contractor in Brazil, which have been formally using Lean Construction initiatives since 2010 and BIM since 2018. Three case studies will be presented in order to answer the following three questions:

- How can VDC be implemented during the bidding stages of infrastructure projects?
- What are the benefits of implementing VDC during the bidding stages?
- What are the barriers against it?

[1] Bidding Engineer, Andrade Gutierrez Engenharia, São Paulo, Brazil, stefania.correa@agnet.com.br, orcid.org/0000-0002-2324-533X

LITERATURE REVIEW

CHARACTERISTICS OF THE BIDDING PROCESS

The bidding stage of a project often requires estimators to do the interpretation of 2D documents, manually extracting information to cost estimations (Ma et al. 2013). However, the accuracy of the interpretation and information extraction needed often rely on the estimators' experience, resulting in an manual, time-consuming and error-prone process (Aram et al. 2014). It is commom that information during the bidding stages of a project is not accurate nor complete, which, added to human limited capability to process information, can generate significant amount of uncertainty (Aslesen et al. 2018). Therefore, finding ways of reducing uncertainty by decreasing manual activities and subjectivity would result in a faster and more accurate bidding process.

VIRTUAL DESIGN AND CONSTRUCTION

Virtual Design and Construction (VDC) framework was conceived by the Center for Integrated Facility Engineering (CIFE) two decades ago and it is defined as "the use of multi-disciplinary performance models of design-construction projects, including the Product (i.e., facilities), Work Processes and Organization of the design - construction - operation team in order to support business objectives" (Kunz and Fischer 2012). The methodology aligns with Lean Construction practices as it focus on fulfilling client's objectives.

One crucial element of VDC is integration and collaboration. Many of VDC components can be applied independently of the other, but it is the combination of them that presents the highest potential. Alarcon et al. (2013) claim that the combination of VDC and Lean enables higher potential benefits. Rischmoller et al. (2018) share this vision and state that the application of BIM and PPM during Integrated Concurrent Engineering (ICE) sessions can support collaboration, as presented in Figure 1. "BIM+" refers to the combination of BIM models with external data, as schedules, costs or energy data, for example.

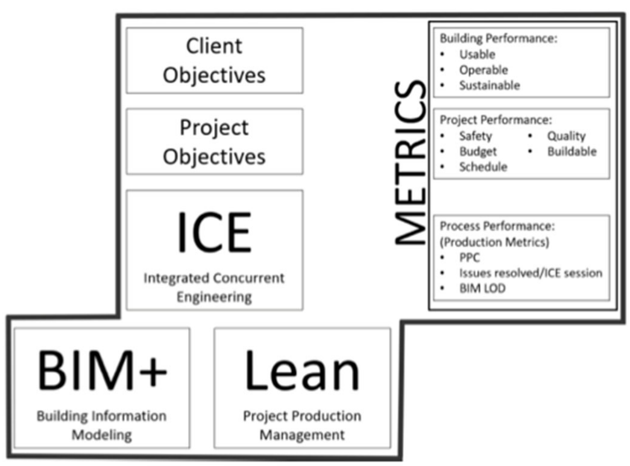

Figure 1: VDC as a set of integrated elements (Rischmoller et al. 2018)

Sacks et al. (2010) studied the interaction of BIM and Lean and proposed a framework that can be used by companies during the implementation of both methodologies. Collaboration, in their context, can be divided in “internal” (when multiple users within a single organization or discipline edit the same model simultaneously) and “external” (when multiple modelers simultaneously view merged or separate multidiscipline models). The authors research shows that BIM functionalities in design and preconstruction stages revolve around, for example, collaboration and rapid generation and evaluation of construction plan scenarios (through the use of four-dimensional visualization of construction schedules).

Taboada and Garrido-Lecca (2014) suggest the use of standards as templates and naming convention promotes more promptiness, flexibility and reliability to the process when making an offer.

In order to foster integration between project participants, knowledge sharing and lowering feedback latency, it is also recommended that the team is at least partially co-located (Fischer et al. 2014). Collocation is advised once different stakeholders might have different business objectives, standards, workflows, vocabulary, etc. This might be seen as a challenge to the process on one hand, but on the other, it could generate complementary perspectives for a project (Kunz and Fischer 2012). Integrated Concurrent Engineering (ICE) is therefore recommended, through the control of critical success factors as: design staff focus, communication media richness and fidelity and goal congruence.

General contractors’ participation in upstream phases of buildings’ lifecycle and the use of envelope mock-ups, as well as the completion rate of construction documents seem to influence the projects’ outcomes (Korkmaz et al. 2010). Hence, the better a project team understands the purpose of the project, the better the final performance of the project should be.

CASE STUDY

The main purpose of this section is to describe how Andrade Gutierrez Engenharia is using VDC to reduce uncertainty and promote a better understanding of the projects that are bid by the company.

COMPANY’S BIDDING PROCESS

Andrade Gutierrez Engenharia (AGE) has been using Lean Construction (LC) practices since 2010 in its jobsites, and since 2016 in its backoffices. These practices enabled significant improvements on the daily activities of the overall company, including the bidding department.

When bidding to a project, general contractors estimation teams usually start by analysing the documents sent by the client, normally comprised by 2D drawings and Microsoft Excel spreadsheets. This is a time-consuming and error-prone task, as it requires from the bidding team a previous amount of knowledge to identify omissions and inconsistencies in the documents presented. Questions and Answers (Q&A) forums are common, and give estimators the oportunity to assure their project understanding is right. On the other hand, questioning the client is an open door to changes in project scope or on the design itself, requiring estimators to restart their analysis from scratch.

A technical proposal made by a general contractor normally presents a preliminary version of the master schedule, where bidding teams input their previous experiences to plan the construction activities. This means that previous knowledge is used to formulate hypothesis to the risks and uncertainties presented at this stage, in order to establish productivity rates and to define construction methodologies.

The case studies presented in this article will focus on enhancing the understanding of the project by the bidding team, and also on improving the quality of the master schedule developed, not including the cost estimation tasks of the bidding process.

BIDDING CASE STUDIES

This section will discuss the VDC concepts application in two different biddings during the year of 2019.

The main objective of VDC application in AGE bids is to do value engineering as to have the best bid, clearly demonstrating the company has deeply analyzed the client's documents.

As Kunz and Fischer (2012) suggest that each project should set, track and manage a small set of explicit objectives (divided in 3 types: controllable factors, process performance parameters and project outcome objectives), besides the project outcome objectives, the controllable factors of AGE VDC application were: the attendance to the ICE (Integrated Concurrent Engineering) sessions, the compliance with the modelling guidelines, the number of 4D scenarios produced, and the design of the workflows. The production metrics and targets involved PPC (Percent Plan Complete), reduction of the use of equipments, as well as the quantity of piles. According to the BIM model and PPM (Project Production Management), the completion according to the milestones and the rework between phases were examples of the metrics to be assessed.

Case Study #1

This study comprised the construction of a brand-new port in the northern region of Brazil. As there was no 3D or BIM model available on the inputs from the client, a design company was subcontracted to do the modelling based on the 2D documentation provided. Physical collocation was not possible as the design team was based approximately 500km from AGE's headquarters, so videoconferences were schedule as an alternative way to do the ICE sessions.

As it was the first attempt to implement VDC concepts, training the team on VDC principles was essential. The first version of AGE modelling guidelines were developed to orient the design team in order to assure the BIM model was compliant to AGE needs in terms of bidding. These guidelines included requests related to the necessary information the model should have, for example, a unique ID or tag to each model component.

A series of workshops were done to conceive a possible detailed workflow with the tasks that should be accomplished in order to achieve and control the VDC objectives, shown in Figure 2. The red boxes were not considered at the first version of the workflow, but they were included at the second one, as it was noticed that it was necessary to define the Work Breakdown Structure (WBS) of the project before establishing the model scope definition. The BIM Execution Plan was suggested in the second version of the workflow, as a way of detailing the guidelines written previously to the subcontracting of the designers. This intent was to better specify the modelling and the participation of the designers during the VDC application.

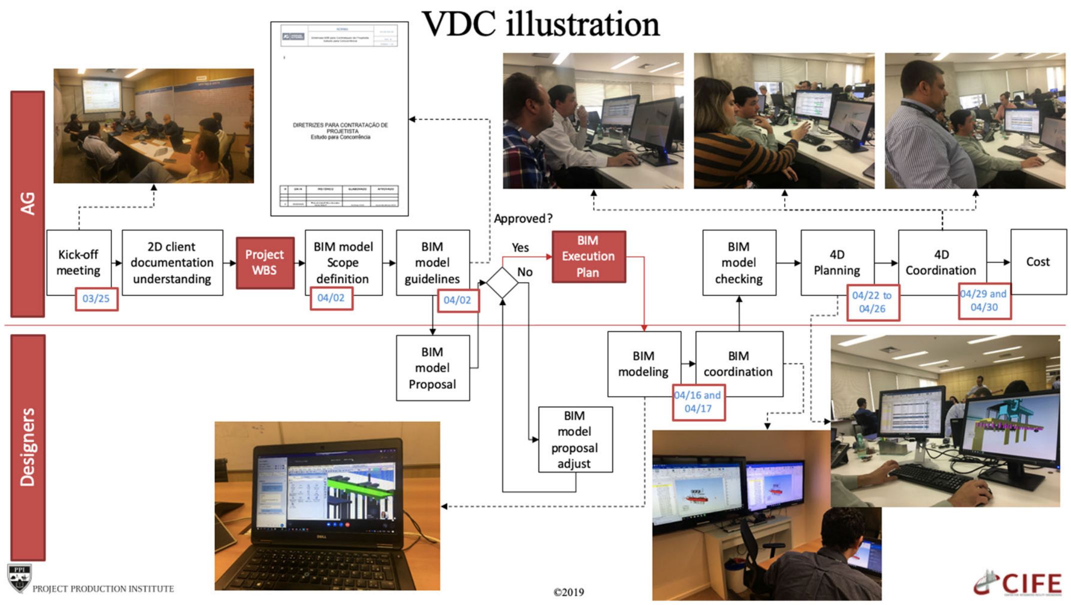

Figure 2: VDC workflow used in case study #1

During the model checking, it was noticed that the model did not comply with some of the guidelines. The main examples concerned the model breakdown structure (with had differences from the WBS of the project), and the issues detected when converting the IFC model.

Two different 4D planning scenarios were studied, but the other metrics could not be assessed properly as an alternative project was conceived a couple of weeks before the deadline of handling the bid to the client, representing a significant amount of rework and preventing the modelling of the new version of the project itself. The bid of the new project was then made on traditional way, not using VDC concepts.

Case Study #2

The second case study was also a brand new terminal at the Brazilian northern region, but instead of a bulk terminal, it was a liquefied natural gas terminal. The BIM model was part of the inputs sent by the client, so the main primary task was to check if the model was a valid input to the bidding needs.

It was noticed that there was room for improvement on the model provided by the client, so two design companies (one for the civil works and the second to the mechanical assemblies) were subcontracted to do the modelling, in order to provide alternatives to the design made by the client.

VDC concepts were implemented in partnership with the civil works design team considering the workflow designed for case study #1, including WBS (Work Breakdown Structures) analysis and BEP (BIM Execution Plan). 4D planning scenarios were part of the metrics, which included specific topics on ABC / Pareto cost curve that are critical in ports projects.

Compared to case #1, the guidelines template helped in the faster definition of modelling requirements, which were used to select the best design team. Moreover, the previous workflow were an adequate tool to explain to the designers what would be done after their handling out the model to AGE. A series of 6 ICE session were performed, in which the metrics and an action plan were followed up. The revision of the metrics provided a series of graphics and insights that were of highly importance to all the team, as shown in Figure 3.

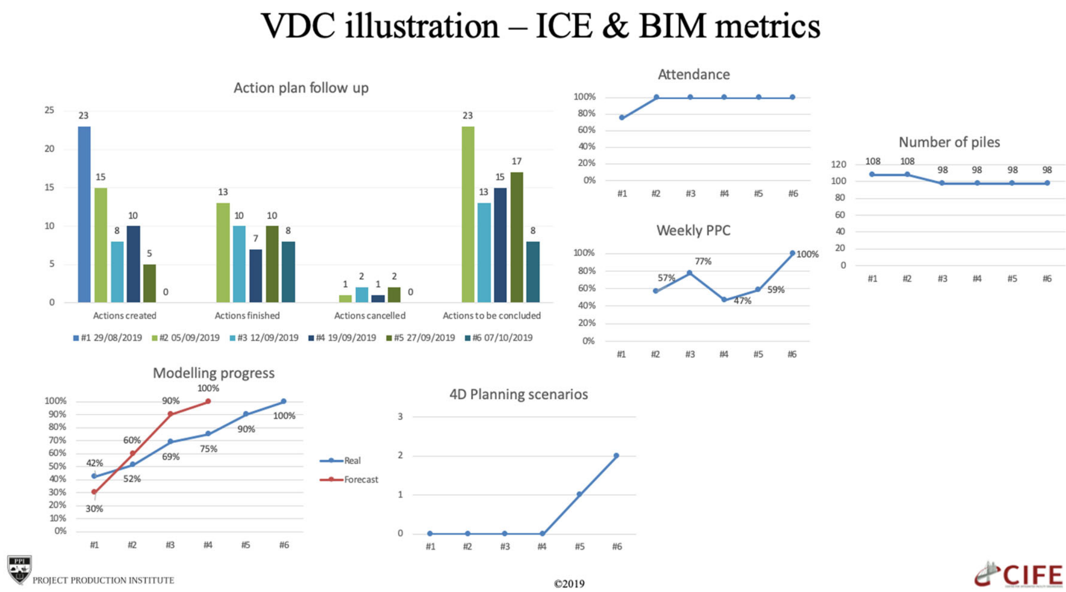

Figure 3: Metrics used in case study #2

The modelling progress graph, for example, altogether with the follow up of the action plan indicated that there was a delay in the modelling progress, due to the no-completion of tasks in the action plan, easily detected by the increase in the number of actions to be concluded and by a lower PPC rate. This metrics were used in a specific problem-solving meeting with the design team, and it was crucial to determine what measures should be taken.

After the bid was handled, a lessons learn session was made with the designers, so that it could determined, in detail, the reason why there was a delay in the modelling progress. Hence, a detailed workflow on the steps used to do the design showed a series of opportunities of improvement (Figure 4).

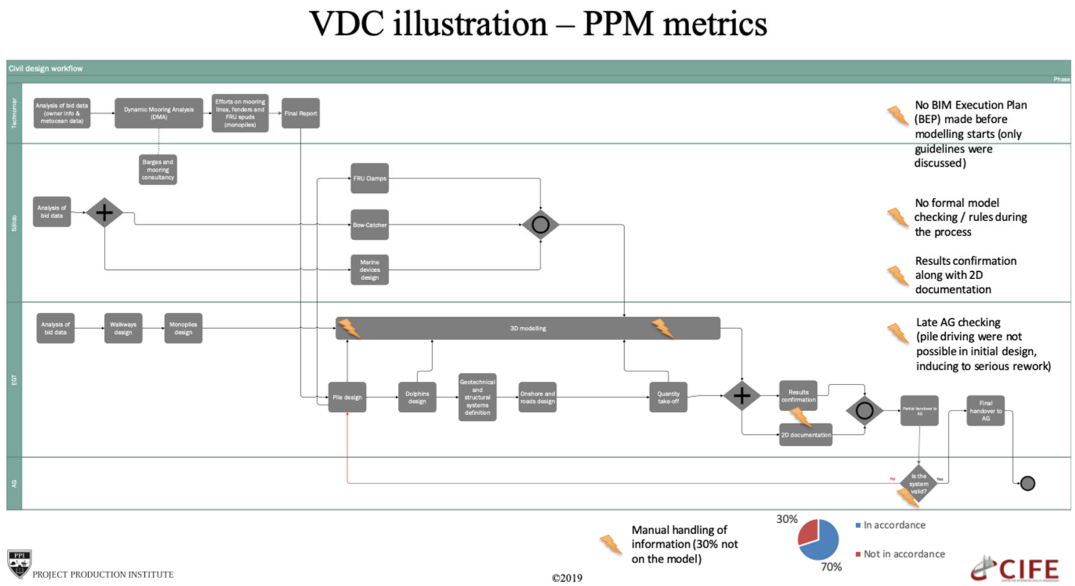

Figure 4: Design workflow detailed in case study #2

All the process showed a clear maturity gain from case #1, and the feedback from the teams (designers and bidding teams) was that VDC has helped them to organize and coordinate better between activities, focusing on the increasing of quality of the following deliverable. The review of metrics also contributed to a better alignment between teams, as all the parts involved agreed on them previously and tried to improve the data in each ICE session performed.

RESULTS

The case studies presented in the paper illustrate the application of VDC concepts in the bidding stages of infrastructure projects. It was thought that the tight schedules of the bids would prevent the application of the methodology, but it was proven wrong.

The main benefits shared by the teams (not only AGE bidding teams but also designers) were: a clearer understanding of the overall process and deliverables of each team. The opportunity to apply a new methodology and the increasing integration of the teams are reported as being a key learning of the VDC implementation. The construction bid manager who participated in both case studies mentioned that he would like that all bids had that level of control and follow-up, and one of the bid managers mentioned that he would like to do the roll-out in bids of other areas (roads and buildings, mainly). VDC has also enabled the knowledge transference, as (mainly planning team members) are now capable of training other members of the bidding area on the new concepts used.

One of the main challenges of the implementation resides in the fact that VDC involves a cultural change of all the players involved in the bid. Another considerable obstacle is interoperability in infrastructure projects. As IFC schema is not well developed to consider infrastructure projects objects, dealing with different software platforms can pose a difficult to general contractors when implementing VDC. Specifically to AGE, as BIM adoption is in its beginning (it has completed 2 years of formal adoption in 2020), defining the guidelines and model requirements are pre-requisites to VDC implementation.

CONCLUSION

The two case studies show that VDC principles can be applied in the bidding stages of infrastructure projects, providing general contractors with a better integration and control of its deliverables, assuring their alignment with client's objectives. The maturity gains are notorious and the teams have perceived these benefits. The synergies between Lean, BIM and VDC were clearly beneficial to the higher quality of AGE's bidding activities and its teams, which are gaining maturity from the application of the concepts. Relevant were the workflow design and the revision of metrics, as shown in both cases, as they gave teams transparency and prevented misunderstandings during the process. The main threats involve interoperability issues and lack of time in training the different stakeholders. Teams gave positive feedback from VDC implementation as it gave them a feeling of satisfaction when used during the bids.

ACKNOWLEDGMENTS

The bidding and designing teams presented a high level of interest in learning VDC concepts and applying them to their daily activities. The BIM department and the IT department were crucial to the success of the cases presented in this article, due to their constant manner of questioning the status quo. The AGE bidding directory of AGE must also be acknowledged for its support during all the journey.

REFERENCES

Alarcón, L.F., Mandujano, M.G., and Mourgues, C. 2013. "Analysis of the Implementation of VDC from a Lean Perspective: Literature Review." *Proc. 21st Annual Conference of the International Group for Lean Construction*, C. T. Formoso and P. T. Fazenda, eds., Fortaleza, Brazil, 781-790.

Aram, S., Eastman, C., and Sacks, R. 2014. "A knowledge-based framework for quantity takeoff and cost estimation in the AEC industry using BIM." *Proc. 31st International Symposium on Automation and Robotics in Construction and Mining*, S. X. Ha Q. Akbarnezhad A., ed., University of Technology Sydney, Sydney, Australia, 434-442.

Aslesen, S., Kristensen, E., Schanche, H., and Heen, P.I. 2018. "Winning the Bid - A Step-Wise Approach Using BIM to Reduce Uncertainty in Construction Bidding." *Proc. 26th Annual Conference of the International Group for Lean Construction*, V. A. González, ed., Chennai, India, 68-78.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. 2011. *BIM Handbook - A guide to Building Information Modeling*. John Wiley & Sons, New Jersey.

Fischer, M., Reed, D., Khanzode, A., and Ashcraft, H. 2014. "A Simple Framework for Integrated Project Delivery." *Proc. 22nd Annual Conference of the International Group for Lean Construction*, B. T. Kalsaas, L. Koskela, and T. A. Saurin, eds., Oslo, Norway, 1319-1330.

Fosse, R., Ballard, G., and Fischer, M. 2017. "Virtual Design and Construction: Aligning BIM and Lean in Practice." *Proc. 25th Annual Conference of the International Group for Lean Construction*, K. Walsh, R. Sacks, and I. Brilakis, eds., Heraklion, Greece, 499-506.

Korkmaz, S., Riley, D., and Horman, M. 2010. "Piloting evaluation metrics for sustainable high-performance building project delivery." *Journal of Construction Engineering and Management*, 136(8), 877-885. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000195

Kunz, J., and Fischer, M. 2012. “Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions.” *CIFE Working Paper*, <http://www.stanford.edu/group/CIFE/online.publications/WP097.pdf>.

Ma, Z., Wei, Z., and Zhang, X. 2013. “Semi-automatic and specification-compliant cost estimation for tendering of building projects based on IFC data of design model.” *Automation in Construction*, 30:126-135. https://doi.org/10.1016/j.autcon.2012.11.020

Reed, D., Ashcraft, H., Khanzode, A., Fischer, M., Rischmoller, L., and Berg, P. 2017. “Integrating Delivery of a Large Hospital Complex.” *Proc. 25th Annual Conference of the International Group for Lean Construction*, K. Walsh, R. Sacks, and I. Brilakis, eds., Heraklion, Greece, 201-208.

Rischmoller, L., Reed, D., Khanzode, A., and Fischer, M. 2018. “Integration enabled by virtual design & construction as a lean implementation strategy.” *Proc. 26th Annual Conference of the International Group for Lean Construction*, V.A. González, ed., The International Group for Lean Construction, Chennai, India, 240-249.

Sacks, R., Koskela, L., Dave, B.A., and Owen, R. 2010. “Interaction of Lean and Building Information Modeling in Construction.” *J. of Construction Engineering and Management*, 136(9), 968-980. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203

Taboada, J.A., and Garrido-Lecca, A. 2014. “Case study on the use of bim at the bidding stage of a building project.” *Proc. 22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production*, S.T.A. Kalsaas, B.T. and Koskela, L., ed., Oslo, Norway, 1473-1482.

This page was intentionally left blank.

This page was intentionally left blank.

This page was intentionally left blank.