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IMPLEMENTING VDC

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ABSTRACT

Norwegian construction clients are demanding the use of VDC in their projects. Contractors have thus implemented VDC on construction projects. However, little research has been conducted regarding how projects should implement VDC.

The study answers four research questions to provide a set of recommendations on how VDC should be implemented in projects: (1) How is VDC implemented in construction projects, (2) Which part of the implementation had positive effects on the implementation, (3) Which part of the implementation had negative effects on the implementation and (4) How should VDC be implemented in construction projects. Three general and five case-specific semi-structured interviews were conducted.

The contribution of the study is a set of recommendations concerning how projects should implement VDC. The recommendations are based on seven key elements for implementation, ranked from most influential to least: Anchoring, Communication, Vision, Plans, Project Team, Training, and Engaging.

KEYWORDS

Last Planner® System; Virtual Design and Construction (VDC); BIM; Lean Construction; Implementation

INTRODUCTION

Norwegian construction clients require their design and build-contractors to use Virtual Design and Construction (VDC) in many of their projects. VDC can be defined as "the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives" (Kunz and Fischer, 2012). Some clients have demanded using one or two of the working methods found in VDC (Bråten et al, 2021). More recently though, clients require using all the working methods within VDC in their construction projects.

The increasing demand for VDC in Norwegian construction projects has – as a natural response – resulted in contractors implementing the VDC framework in their projects (Alarcón et al, 2010). Implementing in this context is defined as "to put into practical effect" (NUBU, 2014). VDC is thus considered implemented in a project when VDC is in practical use.

Nevertheless, implementing new working methods successfully in construction projects is a demanding process (Alarcón et al., 2010). Sufficient attention must be given to the implementation. If the implementation is not prioritized, the result may be a waste of money, time, and effort (Alarcón et al., 2010). However, little research has been

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conducted on how VDC should be implemented in construction projects to implement the framework (Alarcón et al., 2013, Mandujano et al., 2017). Until now, the knowledge on how VDC should be implemented is pretty much based on anecdotes and experiences of individuals who have implemented VDC themselves (Alarcón et al., 2013). Moreover, it appears not to exist any formal guidelines on how to implement VDC (Mandujano et al., 2017). There is a need to document practical experiences of VDC implementation.

The lack of research on the implementation process of VDC, combined with more frequent requests for VDC, led to a study of the following research questions to provide a set of recommendations for the implementation of VDC:

1. How is VDC implemented in construction projects?
2. Which part of the implementation process has had positive effects on the implementation?
3. Which part of the implementation process has had negative effects on the implementation?
4. How should VDC be implemented in construction projects?

The study is limited to four Norwegian construction projects due to a limited time frame. Betonmast was the design and build-contractor for all four projects.

RESEARCH DESIGN AND METHOD

A qualitative research design was applied. First, an initial literature review provided a theoretical framework before data was collected. This was undertaken by using the search engines Oria, Scopus, and Google Scholar. Search strings such as “Implementing VDC” and “Implementation of VDC” were used. A pilot case study was conducted to understand how Betonmast had implemented VDC in their organization. The theoretical framework was used to form an interview guide consisting of questions for semi-structured interviews with three key personnel in Betonmast, each from different projects. The pilot study identified positive and negative effects of implementation on an organizational level. Throughout the pilot study, questions arose on how VDC was implemented at the project level.

Following the pilot study, a revised literature review regarding the project implementation of VDC was conducted. The same search engines were used, but search words changed and consisted of different compositions of “project”, “implementation”, “construction”, and “VDC”. After reviewing numerous publications concerning implementation, a collection of eleven articles, books, and reports were selected. A second interview guide became the basis for interviews with design and project managers. The initial plan was to interview the design and project managers in all four case projects. However, due to a lack of will to participate, only one project manager was interviewed, giving a total of five interviews. This lack of will was maybe caused by a lack of insight in the implementation of VDC among the project managers. All interviews were conducted digitally due to the COVID-19 pandemic. Each interview was filmed and later transcribed. The transcriptions were sent to the informants to review and verify before being analyzed against the theoretical framework.

THEORETICAL FRAMEWORK

VIRTUAL DESIGN AND CONSTRUCTION (VDC) COMPONENTS

Virtual Design and Construction can be described as "the use of integrated multi-disciplinary performance models of design-construction projects to support explicit and public business objectives" (Kunz and Fischer, 2012). VDC consists of five main components: Building Information Modelling (BIM), Project Production Management (PPM), Integrated Concurrent Engineering (ICE), Client Goals and Project Objectives and Metrics (Rischmoller et al., 2018). Table 1 describes the five components of VDC.

Table 1: VDC components

VDC component	Explanation
BIM	The creation and use of 3D models. The model is an intelligent representation of the finished product. BIM is used for communication and is a tool to make informed decisions.
PPM	Organization and control of the physical work activities in the project. The methods stem from Lean, viewing the projects as a production system (Rischmoller et al., 2018).
ICE	Engineering the project collaboratively. Information is shared, actions are coordinated, problems are solved, and decisions are made in ICE sessions (Rischmoller et al., 2018).
Client goals and Project objectives	Project objectives support the client's goals. The project team defines project objectives considering the total cost and building performance (Rischmoller et al., 2018).
Metrics	Controls and monitors the project objectives. The client's goals are measured by metrics considering operations, use, sustainability performance, safety, schedule, and costs (Rischmoller et al., 2018).

VDC only occurs when the main components are used in an integrated approach, not when the components are used isolated (Rischmoller et al., 2018). The VDC tools and methods should therefore be integrated within the traditional work operations, and not exist as a parallel alternative (Andersson et al., 2016).

The Last Planner System, hereafter Last Planner, is a PPM technique described as a production planning and control system. It is based on lean principles, being a pull planning method where the project defines the project milestones and places the project's deliveries and activities according to them. The team plans its way backward, starting with the last delivery or activity. Last Planner is a good example of the strong synergy between Lean and VDC (Hamzeh et al., 2009; Belsvik, Lædre and Hjelseth, 2019).

Model Maturity Index (MMI) is a metric that measures the progress of the 3D model by determining the maturity level of its elements. The elements receive an MMI level from conceptualization (MMI 100) to as-built (MMI 600) throughout the design process (Garcia et al., 2021).

IMPLEMENTATION OF VIRTUAL DESIGN AND CONSTRUCTION (VDC)

After reviewing available literature, seven key elements for successful VDC implementation in construction projects were identified: *Anchoring, Communication, Vision, Plans, Project Team, Training, and Engaging*. These seven identified key

elements for a successful implementation of VDC in construction projects are described in the following.

The success of VDC depends on how well the VDC components are integrated with each other and thereby *anchored* within the organization (Kunz and Fischer, 2012; Andersson et al., 2016). To enable integration, VDC tools and techniques should be automated (Kunz and Fischer, 2012). In addition, routine work in the project should also be automated (Kunz and Fischer, 2012). A supportive culture within the organization is further crucial for successful implementation (Ling, 2003; Blayse and Manley, 2004). Both the contractor and the client should support the implementation (Manley, 2008a). In the same way, the contractor needs to support the sub-contractors for the implementation to be successful (Manley, 2008a).

BIM, PPM, ICE, Client Goals and Project Objectives should be implemented in the early part of the engineering and design phase. It's not clearly described when Metrics should be implemented, but since they are based on the Client Goals and Project Objectives, it is considered to be implemented at the same stage as the other components. (Khanzode et al., 2006; Aslam et al., 2021).

To implement VDC, the stakeholders should *communicate* according to standards (Kunz and Fischer, 2012). National BIM specifications should also be applied to the project (Andersson et al., 2016). In Norway, the standard NS-EN ISO 19650 defines information sharing in BIM (Kodjeykova-Merriman, 2020). The implementation requires the stakeholders to share data, which could be done with IFC files (Kunz and Fischer, 2012). IFC is a unified file format that applies to most programs in the construction industry (Kunz and Fischer, 2012). Communication in BIM results in transparency and contributes to collaboration between stakeholders (Khanzode et al., 2006). Good communication platforms combined with better technological software and hardware will increase project efficiency (Andersson et al., 2016).

Creating a *vision* for the implementation of VDC is essential (Kunz and Fischer, 2012; Andersson et al., 2016). A vision creates a direction for the project team (Andersson et al., 2016). Beyond the vision, the project should set two to three goals that are challenging, yet realistic (Kunz and Fischer, 2012). The stakeholders should be involved in the development of the goals (Kunz and Fischer, 2012). The project should establish metrics for the goals and vision (Kunz and Fischer, 2012). When goals or milestones are reached, this should be celebrated (Kunz and Fischer, 2012).

Several studies conclude that creating a strategic *plan* for the implementation is crucial (Kunz and Fischer, 2012; Andersson et al., 2016; Ling, 2003). The plan should be made by the stakeholders responsible for VDC – usually the design or project manager – and delegate the responsibilities to specific project team members (Kunz and Fischer, 2012). The contractor organization – which is accountable for the plan – should also be included (Kunz and Fischer, 2012). The plan should be flexible on project level and should be continuously updated (Andersson et al., 2016; Ling, 2003). It should also include the specifications for the project in question (Kunz and Fischer, 2012). The plans should be realistic with regards to the vision and the goals for the implementation. The implementation must not be rushed, and projects with a tight schedule should not conduct an implementation (Ling, 2003).

To create good relations within the *project team*, a kickoff meeting should be arranged (Kunz and Fischer, 2012). The project's VDC tools and techniques are presented to stakeholders at the meeting, as well as a 3D model of the product (Kunz and Fischer, 2012). The project team, client and subcontractors should be located together on-site to

ensure good relations throughout the project (Kunz and Fischer, 2012; Andersson et al., 2016). Members of the project team should not be chosen randomly but based on their knowledge of VDC, project type, size, complexity, client, and location, (Andersson et al., 2016). Further, a high level of interest in the implementation by team members is vital for the implementation (Ling, 2003). Lastly, the team members should receive feedback from each other and the organization (Andersson et al., 2016). The feedback becomes a quality control of the work and contributes to good relations between the team members (Andersson et al., 2016).

The stakeholders should be *trained* to interpret the visual models of the project (Kunz and Fischer, 2012; Andersson et al., 2016). Stakeholders need to understand how VDC works and have practical experience. Those responsible for developing and updating the 3D model need to be skilled users of the applied software (Andersson et al., 2016; Ling, 2003). Organizing internal training is a good way for the employees to develop and maintain useful knowledge (Ling, 2003). After VDC projects are completed, the stakeholders should reflect on lessons learned to improve VDC implementation in future projects (Andersson et al., 2016).

There are four main types of barriers that can hinder stakeholders to *engage* in the implementation of innovations, namely restrictive contract relations, disagreements concerning risk assessments, resistance between the contract partners, and lack of resources (Manley, 2008b; Rose and Manley, 2012; Rose and Manley, 2014). Restrictive contract relations concern choosing contractors based solely on price, a practice that gives few incentives to implement innovations (Manley, 2008b; Rose and Manley, 2014). Disagreement concerning risk assessments is regarding economic responsibility if the innovation fails (Rose and Manley, 2014). Distrust between the partners can prevent them from proposing and welcoming innovations (Rose and Manley, 2014). Enough resources are essential for the clients to evaluate the innovative ideas that are being proposed (Manley, 2008b). Beyond preventing barriers, one should establish incentives for the project team to engage in the implementation, and economic incentives are preferable (Rose and Manley, 2012).

RESULTS AND DISCUSSION

The main findings are represented by seven key elements for VDC implementation ranked from most to least influential: Anchoring, Communication, Vision, Plans, Project Team, Training, and Engaging. The following three research questions are answered: 1) how is VDC implemented in construction projects, 2) which part of the implementation process has had positive effects and 3) which part has had negative effects on the implementation?

ANCHORING

The results show that the many software used to anchor VDC tools and techniques are not well integrated, nor have a huge amount of automation. There is a lot of manual and time-consuming punching when using the VDC framework. This is surprising considering the importance integration and automation is given by the theory (Kunz and Fischer, 2012; Andersson et al., 2016). One would assume there exist software programs designed for the VDC framework, and questions are raised concerning the lack of effective VDC software.

One informant says the engineers and designers were forced to use VDC instead of the “the traditional way” of working. This push positively affected the implementation,

which resulted in the use of VDC, as Andersson et al. (2016) suggest. The remaining informants were unsure how crucial it was that participants actually used the VDC framework besides from the ICE sessions. However, all the informants ensured that the VDC tools and techniques were used during ICE sessions.

Three informants received support from the company during the implementation, and according to the literature, this should affect the implementation positively (Ling, 2003; Blayse and Manley, 2004). One informant claimed that support from the project manager was important, even though the literature does not seem to mention support from the nearest leader as crucial.

The 3D models were implemented early in the design phase of the projects, unsurprisingly complying with Khanzode et al. (2006) and Aslam et al. (2021). One project introduced MMI and a Last Planner Software halfway into the design phase. This was too late, and the project spent resources without achieving the potential benefits. One project stopped the ICE sessions towards the end of the design phase, when most of the BIM was finished, since they were time consuming. Continuing the ICE sessions was considered as waste. The theory does not recommend stopping ICE sessions, making the finding unexpected.

COMMUNICATION

National BIM standards were not used in the projects, and one design manager didn't know they existed. This is fascinating considering the vital position standards are given in the literature (Kunz and Fischer, 2012; Andersson et al., 2016). One project created its own BIM manual describing, among other things, file formats for the project. Another developed a manual for communication to avoid information being wasted. These BIM manuals affected the VDC implementation positively.

The projects used 3D models for communication purposes, as suggested by Khanzode et al. (2006). To prevent all team members from attaining business secrets, one of the projects used email when communicating project costs.

Three of the projects used software for Last Planner instead of post-it notes on a wall due to the COVID-19 pandemic. One informant manually rewrote the activities from the Last Planner software to a 3D model software with – obviously – limited functionality. The manual rewriting was time-consuming and affected the implementation negatively.

An interesting finding is that two of the informants deliberately did not call the framework VDC. This helped implementation, as the project team accepted the new ways of working without complaining about dealing with a lot of new terms. Descriptions of similar experiences were not found in the literature. One states this "sold" the working methods to the project team. The positive effect is not enhanced in the literature. When the intention is to implement VDC, it seems counterintuitive to not make the stakeholders familiar with the term, making the finding interesting. Another informant deliberately exaggerated the potential benefits of VDC to the client to create high expectations. This pressed the project to deliver what they had promised and is also not investigated in examined literature.

VISION

Two projects had no vision for the implementation. The implementation of VDC was still successful, so a vision may not be as essential as Kunz and Fischer (2012) and Andersson et al. (2016) state. A supporting finding is that closer investigation revealed that the two projects had not formulated visions, but goals. A vision should create a direction for the

implementation rather than being an achievable goal (Andersson et al., 2016). However, the goals had a positive effect on the implementation since they were accomplished. A vision for the implementation might create positive effects without being critical. One informant specified that including the client when setting the goals positively affected the implementation. Time was spent understanding the client, resulting in excluding objectives that were nice to have but not needed. Including the stakeholders and creating realistic goals are supported in the literature by Kunz and Fischer (2012).

One informant observed that goals prioritized by the project team were achieved, while those neglected were not. This is interesting since it's not established in the literature. One can argue that it's not enough to establish goals for the implementation, the project team must work targeted to achieve them. Metrics targeting the goals and visions would enable this Kunz and Fischer (2012). However, none of the projects used metrics to target the goals. Yet, it did not affect the implementation negatively. This raises questions as to whether creating metrics to achieve goals and vision is critical.

None of the projects were celebrated when goals were accomplished during the COVID-19 pandemic. They usually celebrate with cake, but the finding indicates that this may not be as important as the theoretical framework states.

PLANS

None of the projects created an implementation plan, even though it is recommended in the theory (Kunz and Fischer, 2012; Andersson et al., 2016; Ling, 2003). Implementation was not believed to suffer, hence implementation plans may not be critical for success. The implementation plan should be continuously updated (Andersson et al., 2016; Ling, 2003). Therefore, it's no surprise that even though no projects created implementation plans, other dynamic plans allocating responsibilities had positive effects. One project had a too complicated plan, and they believed the reason was the inclusion of too many project specifications, as suggested by Kunz and Fischer (2012). One solution for future projects could be to not include too detailed project specifications. One informant experienced that prioritizing one detailed specification, and neglecting others, caused negative effects. Another negative effect of the lack of implementation plans was too few milestones. It made it challenging to identify when deliveries were due. Theory does not point out the number of milestones to include in an implementation plan, making the finding interesting. A tight schedule is considered unfortunate for implementation (Ling, 2003). Therefore, it was surprising that the projects ascertain that their tight schedules affected the implementation positively. One stated: "The tight schedule created an opportunity for VDC". Questions arise about whether a tight schedule could benefit the implementation, but experiences from other projects imply that pressure on time, results in the returning to well-known routines.

PROJECT TEAM

Two projects arranged kickoff meetings that positively affected the relations in the project team, an experience that is supported by Kunz and Fischer (2012). An informant that did not arrange a kickoff meeting said this had a negative effect on the project team. However, another informant stated that they established a good group without a kickoff meeting, so the latter finding suggests that kickoff meetings are not necessary for the implementation.

Team members in two projects were put together after careful consideration. The combination of knowledge positively affected the implementation. In two projects where the teams were composed randomly, one informant says it affected the implementation

negatively. This aligns with the prescriptions for team composition proposed by Andersson et al. (2016). Regarding required knowledge about VDC, the findings show that two projects had two members with VDC knowledge while two had one. Two members with knowledge had a positive effect on the implementation since these two members could support each other's efforts. Even if it's not specified that projects should have two members with VDC knowledge, the finding is not regarded as unsurprising.

In one project, the client and the project team decided not to be co-located. According to the theoretical framework, the client and project team should be co-located in VDC projects (Kunz and Fischer, 2012). However, the decision positively affected the implementation since both the client and the project team could discuss economic matters without being overheard. This suggests it may not be as crucial for the project team and client to be co-located.

Two informants experienced feedback from the organization. This had a positive effect on the implementation, just as described by Andersson et al. (2016). Two other informants received almost no feedback. On the surprising side, they stated this had a positive effect since the organization did not "surveillance" the project. However, the fifth informant experienced a lack of feedback as a problem. The project did not get the needed support from the organization. In sum, feedback from the organization might be favorable.

TRAINING

Three informants had attained VDC training, which, unsurprisingly, affected the implementation positively. The informants without training stated however that this did not negatively affect the implementation, since other team members contributed with VDC knowledge. It's interesting since the literature claims stakeholders need to know VDC (Kunz and Fischer, 2012; Andersson et al., 2016; Ling, 2003). The finding implies that some stakeholders should understand VDC, but it doesn't have to be the design or project manager. The training focused on the practical implementation of VDC, and the informants implemented VDC on projects as part of the course. This both positively and negatively affected the implementation. One said: "You're in a VDC bubble during training and it's beneficial to implement VDC while in that bubble". He admits though that VDC needs maturation, and that one is not ready to implement VDC under training. Nevertheless, practical training is viewed as positive by the literature (Andersson et al., 2016; Ling, 2003). After training, the informants got professional input from their instructors which positively affected the implementation. Further, they all will arrange internal training in the company, supported by literature (Ling, 2003).

It varies how much training the subcontractors have. However, their skills in 3D modeling software positively affected the implementation. This correlates well with literature (Kunz and Fischer, 2012; Andersson et al., 2016; Ling, 2003), which states that all the stakeholders should be able to use the program for the 3D model.

One informant said the organization will evaluate the projects ex-post for learning purposes, as suggested by Andersson et al. (2016). Another informant added that their continuous project evaluation had a positive effect on the implementation, even though this does not seem to have been studied in the existing literature.

ENGAGING

Two projects based their contracting on the lowest price. According to the literature, this will negatively affect the implementation (Rose and Manley, 2014). It's therefore surprising that it's not considered negative by the informants. There have not been any

disagreements concerning risk assessments between the parties since the contract provides the contractor with most of the risk. The finding is in line with the theoretical framework (Rose and Manley, 2014). There have emerged good relations between the clients and the project teams as they used collaborative contracts. The positive effect on the implementation is stated by the literature (Rose and Manley, 2014). The projects had enough recourses for the implementation, positively affecting the process, correlating with the theoretical framework (Manley, 2008a).

An unusual barrier to the implementation was the COVID-19 pandemic. The literature does not enlighten crises; however, it has understandably affected the implementation negatively. Nevertheless, the project team has learned to work remotely. Even though crises are not welcome during implementation, they can reveal new effective ways of working. Another barrier was getting the stakeholders on board with the VDC mindset. The theory does not address this, but it has presumably affected the implementation negatively. Finally, the projects did not establish incentives supporting the implementation. Surprisingly, this did not affect the implementation negatively, contradicting the literature (Rose and Manley, 2012). According to the informants, it's enough motivation that VDC reduces costs and increases efficiency.

CONCLUSION

The conclusion answers the fourth research question about how VDC should be implemented in construction projects and fulfills the purpose of the study by providing a set of recommendations. The following table 2 presents seven key elements of VDC implementation identified through literature and findings in the four investigated cases.

Table 1: The seven key elements of VDC implementation

VDC implementation element	Recommendations for implementation, gathered from findings and literature
Anchoring	• Tools, techniques and new software • Demolish the traditional way of working • Use of 3D models from project start • ICE sessions eliminated towards the end
Communication	• Manuals for project communication (e.g., platforms used in the project) • Communicate in 3D models • Client and sub-contractors have access to 3D models • Platforms enabling VDC • User friendly platforms
Vision	• Achievable goal • Inclusion of client when setting goal • Realistic goal • Focus on reaching goal • Use of metrics to reach goal
Plans	• Dynamic plan at project level • Specify responsibility of project members • Milestones clarifies the projects deliveries • Projects without tight schedule
Project team	• Put together carefully • Some members with VDC knowledge • Feedback from organization
Training	• VDC training with practical approach • Internal VDC-training within organization • Subcontractors trained in 3D models • Feedback from instructors
Engaging	• Stakeholders • Have responsibility for the risk • Contract that encourages collaboration • Resources

The results indicate that projects should *anchor* their VDC tools and techniques in the organization. The current software is not sophisticated enough for VDC. New software should be developed, providing leaner methods to execute VDC. The project should demolish the "traditional" way of working, only offering the VDC tools and techniques. The project manager – and the organization as well – must support the implementation. 3D models, MMI and Last Planner should be implemented early in the design phase, including the software which will enable the processes. ICE sessions should be eliminated towards the end of the design phase. All software anchoring VDC to the project should be user-friendly. This to make sure time is not wasted when using the software.

The study has revealed that project-specific BIM manuals for *communication* should be created, informing what platform the communication should take place on (e. g. 3D model, mail, IFC file format, etc.). The project should communicate in the 3D model, and both the client and the sub constructor should have access. The communication platforms should be user-friendly and sophisticated enough to conduct VDC activities.

The project can use an achievable goal instead of a *vision* for the implementation. The client should be included when setting the implementation goals. The goals should be realistic, and the project team should work targeted to reach them. Metrics should be

created to achieve the goals. In the case projects, they managed well without celebrating accomplished goals.

The case projects were managed well without specific implementation *plans* for VDC. However, there should be dynamic plans that delegate responsibilities between the project team members. The plans should contain detailed enough milestones for the project team to identify the project's deliveries. Projects with a tight schedule should not implement VDC for the first time, as it is tempting to return to old habits when under pressure.

The project team should arrange a kickoff meeting. The *project team* should not be composed randomly. Two or more of the members should know VDC, but all the team members do not need to have a high interest in the implementation. The client and the project team could be co-located, but they do not have to be. The project team should receive feedback from the contractor organization to enable continuous improvement.

The project team should have members that have attended VDC *training* with practical implementation. The contractor should arrange internal training for employees in the organization. The subcontractor should be trained in the software for the 3D model. After the training, one should get professional feedback from the instructors.

There was a need for *engaged* stakeholders to implement VDC. The projects based their contracts on the lowest price, but that worked since the contractor carried the main risk related to the VDC implementation. The contract between the client and contractor should encourage collaboration, and enough resources to implement VDC are necessary. A global pandemic was a barrier to the implementation but fostered new working methods that could be useful for implementation. There were no contractual incentives for the implementation of VDC, but that was not considered to be necessary since the contractor earned profit from using VDC anyway.

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