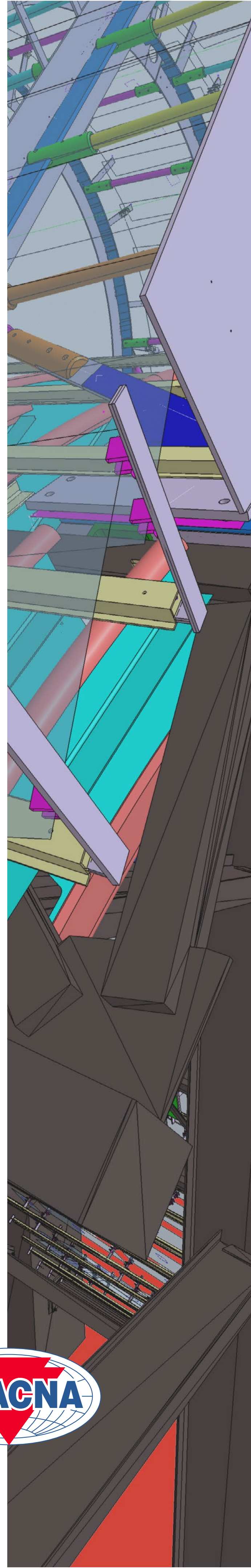
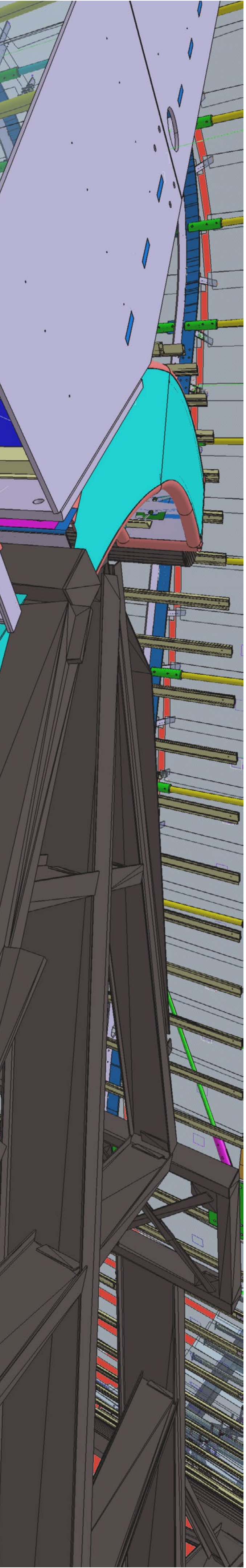
VIRTUAL DESIGN AND CONSTRUCTION IN PRACTICE

Benefits, Challenges, and Proven Strategies for AEC Teams

A concept paper developed in collaboration with A. Zahner Company for the SMACNA community.



SMACNA



VIRTUAL DESIGN AND CONSTRUCTION IN PRACTICE

Benefits, Challenges, and Proven Strategies for AEC Teams

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Leading members of the Architecture, Engineering & Construction (AEC) industry have begun championing the adoption of a Virtual Design and Construction (VDC) approach to projects—a change that is slowly but dramatically transforming the way projects are completed. VDC describes the process through which a design and construction team collaboratively simulates every step of a construction project before beginning work on the actual job site. It's a shift as dramatic as the industry once made from pen-and-paper blueprints to CAD drawings, but one that brings widespread efficiency and quality improvements across all aspects of a project.

VDC begins with the use of Building Information Modeling (BIM) solutions, but goes well beyond the adoption of new technology. Its focus is on data-driven project collaboration, where all members of the project communicate to produce a project that is on time, on schedule, and exactly as the owner expects it.

VDC allows project members to work in a common language, where all necessary information is transparent and instantly available. Challenges are solved proactively and cooperatively. Innovation is made possible by leveraging all team members' strengths and exploring creative solutions.

In many ways, VDC is about creating bridges among the many factions within the AEC industry at the earliest stage of a project, when the greatest benefit can be felt. In a synergistic environment, partners can make better decisions and define a more accurate budget.

Companies making the switch to VDC do face a number of obstacles, both in the industry and within individual companies. Among these challenges are:

- The misperception that information must be restricted to retain competitive advantages.
- The construction industry's deeply ingrained preferences, and resistance to new processes.
- The temptation to secure short-term project gains over long-term value.
- The need to invest in new technology solutions and retrain or enhance the workforce.

However, the case studies analyzed for this report demonstrate that even a portion of the project team's use of VDC, in even a late stage, can leverage this approach to secure impressive project improvements. For example, the contractors interviewed here benefited from the VDC approach through gaining greater insight into potential problems and by establishing a common understanding of how to communicate effectively as a team, reducing risk and significant costs.

On the larger projects outlined in this report, VDC helped project teams eliminate change orders—even for complex projects constructed in challenging winter conditions. This approach also helped project partners navigate necessary mid-project changes more effectively, to rapidly come to agreement on practical resolutions.

As these project benefits are becoming better known within the AEC industry, an increasing number of owners are demanding uniquely complex projects be completed within shorter timelines than ever. With these expectations, designers, general contractors, specialty trades, fabricators, and other partners will soon find that leading the shift to VDC, and adopting new strategies for approaching projects, will be the only way to survive the evolution.

WHY VDC IS IMPORTANT

Forward-thinking business leaders are always exploring ways to achieve new levels of profitability, and for design and construction professionals, profitability is dependent upon producing results on time and on budget. The AEC industry today is seeing a dramatic influx of varied technology solutions meant to drive improvements in efficiency to meet tougher demands over increasingly tighter deadlines. As business leaders sort through the myriad of new strategies, one thing becomes clear: the future of design and construction exists in a digital world.

VDC is rapidly proving to be the direction in which the AEC industry is headed. The digital world allows experts to more holistically manage every project, and serves as a basis for adopting dramatic efficiency improvements. Industry leaders have already shifted to a VDC approach, setting the pathway for a future where owners demand the dramatic results only possible through a collaborative virtual platform.

VDC is not about pursuing unique ways to communicate — it is about pursuing efficiency and clarity in communication.

That future is rapidly approaching. Business owners who don't put a strategy in place today for adopting VDC processes may find themselves struggling not only with profitability but with the very survival of their company. Within the next ten years, companies at every level of the AEC chain—from material fabrication to installation and beyond—will find this game-changing methodology is the only way to compete in the industry.

As evidenced by the outcomes in the case studies included in the following paper, VDC produces results too dramatic to ignore, even when used by a single team in the AEC relationship. You'll find here examples of how VDC can help companies achieve higher levels of profitability by completing complex projects ahead of schedule and under budget. As you explore these examples, it will become clear that the future of design and construction is best served by the accuracy and early insight provided by VDC in action.

WHAT IS VDC?

Virtual Design and Construction (VDC) is the process through which design and construction partners collaboratively simulate all work on a construction project in a 3D virtual environment before performing any work on-site, in the real world.

VDC allows project partners to more effectively manage all areas of a project – from schedule to budget to material procurement and so on – to produce the optimal outcome.

The five elements that enable VDC are:

1. Building Information Modeling (BIM)

BIM is a process which facilitates collaboration on a consolidated 3D model. This 3D BIM model "is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward." (*National BIM Standard*, National Institute of Building Sciences)

A proper BIM model incorporates input **from all partners,** which is integral to the success of VDC. In practice, VDC gains efficiencies with the use of a single model, and reaps further efficiencies from a parametric model. Accordingly, within BIM Level 3—the highest level of BIM maturity and the industry's aspirational goal—all parties work collaboratively on a single, parametric BIM model.

2. Level of Development (LOD)

Not to be confused with Level of Detail (which indicates "how *much* detail is input into the model element"), Level of Development indicates the reliability of the output, or "the degree to which the element geometry and attached information has been thought through." (*Level of Development Specification*, BIM Forum)

The LOD Specification allows everyone working on a construction project to clearly understand the expected depth and quality of information within each model element.

The VDC process typically starts at LOD 100 and works toward LOD 350 or higher, ensuring the degree of specificity necessary to predict how systems will interact.

An element with **LOD 350** is where nearby or attached elements—such as supports, connections, and other parts necessary for coordination—are modeled. Also, "the quantity, size, shape, location, and orientation of the element as designed can be measured directly from the model without referring to non-modeled information such as notes or dimension call-outs." An element with **LOD 400** goes even further, adding detail and accuracy sufficient for fabrication of the element. (*Level of Development Specification*, BIM Forum)

Therefore, LOD 350 to 400 enables the project team to identify system conflicts and fabrication challenges before construction even begins—a key benefit of VDC.

3. Advanced Digital Tools

Augmented Reality or Virtual Reality (AR/VR) can improve communication among all project partners on matters ranging from safety training to logistics planning to occupant experience. AR/VR applications are becoming more sophisticated and widespread. They are helpful for advanced visualization elements of a VDC process, but are not an absolute requirement.

4. Collaboration Space

A "virtual project site" or online meeting room allows all partners to contribute to, modify, and simulate the construction process, particularly the handoff between trades. Together, the team plans in a virtual environment for a rapid and accurate real-world build. Cloud-based environments best facilitate this collaboration due to the large amounts of data that needs to be shared among all parties.

5. Collaborative Mindset

It is crucial to operate under the understanding that all design and construction partners are interested in the successful outcome of the project as a whole, and not simply in the result of their specific contribution. This is a key guiding principle for VDC.

Through a shared team mentality built on trust and mutual respect, VDC encourages a proactive approach to problems, promotes constructive criticism, and supports mutual accountability. VDC projects are most effective when there are no silos, and where each member of the team celebrates each other's successes.

These principles of trust and codependence are above and beyond any formal contract or Integrated Project Delivery agreement.

THE CASE FOR VDC: What Can Be Gained?

Clarity of Communication Through a Single Shared Platform

Using a single platform is as powerful as sharing a common language: it gets a community to a point of clarity faster. It also reinforces the concept of teamwork as each member is actively working with the same tools, opportunities, and limitations. This commonality allows team members to build upon one another's progress and achieve a level of success that the entire community celebrates.

While critics say this approach leads to a loss in innovation and a lack of opportunity for the unique solutions gained when each member take a different path to the same finish line, this argument is flawed. Consider that one of the most important success factors of a construction project is communication. VDC is not about pursuing unique ways to communicate — it is about pursuing efficiency and clarity in communication.

Each party continues to innovate at its own pace, however, through a common platform, innovation can be shared more rapidly and built upon to achieve new levels of advancement and overall project success.

Streamlined Exchange of Information via the Cloud

Cloud-based interaction is the next, and perhaps most important, step in the evolution of communications: First, hand sketches and balsa models were kept in a common location. Next, computer aided drafted drawings were sent around to various users via floppy disc. Then, 3D models of surfaces, lines and letters (essentially CAD drawings in 3D) were sent around to various users via zip drives and sometimes, very slowly, via Internet connections. More recently, 3D models of parts that interact with each other are transferred to other parties via email, shared directory, and zip drives; opened, downloaded, reviewed, and manipulated; and then sent back to the originator via the same email, directory, or zip drive method.

Today via the cloud, multiple disciplines can develop, improve, and maintain 3D models on a single platform at the same time, and with the capability for instantaneous reviewing, commenting, and version control.

A Stronger Extended Team: From Coordination to Collaboration

Coordination is about each person doing their job and timing everything out to allow others to do their jobs. Much like a relay race, each member of the team is waiting for a job to be completed so they can perform their part. Coordination is greatly impacted by the weakest link. The result is that many parties emphasize the value of "doing their job" over setting the team up to succeed.

*"**Large-scale collaboration is the new normal.** Your firm's Project Team is now working at various levels with parties who, just a few years ago, did not participate in the coordination process."*

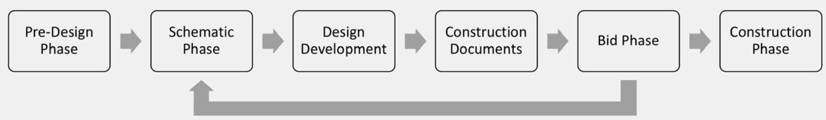
— David E. Quigley, Achieving Spatial Coordination Through BIM

Collaboration is about integrating each member's strengths into each stage of progress and allowing for influence to occur early. When done correctly, collaboration puts value on the overall end-product. On collaborative teams, there is less emphasis on individual success and more focus on group success.

Achieve Team Success (Not Individual Wins) with Aligned Incentives

Over time, each stage of design through construction has grown into its own unique business venture. Entire industries have grown around each element of the process. As a result, design and construction processes have become compartmentalized, and the bridges connecting each phase have become less robust.

Common Pre-BIM Process



Source: Associated General Contractors' BIM Education Program

Its common for each discipline to have a business plan for success that is disconnected from others' role in the process. Financial gains are not always dependent on one's ability to prepare successors for a positive project outcome. This becomes even more apparent, and problematic, on projects that extend over many months or years.

Without VDC: Connections between construction processes are tenuous.

The idea behind VDC is to draw the key disciplines and champions of the various stages of the building process to a common place at the earliest reasonable stage, and maintain connectivity throughout the building lifecycle. In a way, the bridges are gone and replaced by a continuous highway.

With VDC: Connections between construction processes are seamless.

A key advantage to this approach is the ability to focus on the end state, opening opportunities to innovate and create more value during the earliest stages of design and planning.

Trust Through Transparency

This may be the most important step and is by far the hardest to achieve. With the growth of the construction business to a point where a company can define its business strategy without considering its upstream and downstream partners, trust has become devalued.

"Sunlight is said to be the best of disinfectants."

— Justice Louis D. Brandeis

In a collaborative, single-source platform environment, all activity depends upon trust: trust that your partners have the same end goal in mind, trust that all stakeholders understand the need for collective success, trust that when conflict occurs (and it will… often) the collective goal is achieving agreement rather than legal representation.

Trust in this type of environment means sharing risk, and this is not a common condition in the construction world. Trust can be achieved through **the transparency of virtual construction.** Each party sees what the other is doing, all team members can ask for clarity the moment it is needed, and everyone holds each other accountable for keeping the principles of the construction activity on track.

It is much harder (and unwise) to ignore the importance of a trust-based relationship when you are relying on others to help you be successful. More open and meaningful communications lead to improved project outcomes.

An Environment That Supports Problem Solving

A creative idea for how to improve a design or process often lacks internal support due to an inability to prove a direct benefit. Too often within a project, an innovative solution is viewed as not adding value, and thus not worth exploring. Common reasons include, "We don't have enough time or resources," and "We cannot take a chance on a new approach, let's stick to the standard."

On a high-trust team, process improvements and creative ways to do something are more readily accepted. In a collaborative environment, innovations and process improvements are able to start small and grow with the project. Under these conditions, small experiments can happen as part of the standard design and construction process; innovations can be proven or disproven without leading to major setbacks or big risks with time and resources.

Greater Value from Early Value Engineering

When value engineering happens at the end of the design phase, aesthetic often suffers. Money becomes much more important toward closing, different decision makers with different motivations come in at the end, and factors that make a design stand apart may be removed or greatly diminished. Cost becomes the primary consideration.

It is easy to see how creativity is lost through value engineering, with such a gap between the unique and valuable participants on the project: when they are involved, their motivations, and their investments. This does not have to be the case.

In a collaborative effort, in which designers and builders influence all the various stages to better define the project early on, **smarter decisions can be made with a clearer and more accurate budget.** For instance, if a highly efficient concrete shell model is developed at the earliest reasonable point possible, the concrete supplier can give the design team a more accurate price at an earlier stage. This could free up contingency dollars to preserve the more interesting elements of the project. The value engineering thus happens earlier and can be used to remove non-value added components.

ROADBLOCKS & RISKS: What Must Be Overcome?

We are under no illusions that the adoption of VDC is an easy road. There are a number of obstacles we as an industry must overcome together.

The Misperception That Information Must Be Restricted

In today's construction world, powerful entities tend to dominate the process. One way this is done is through the tight control of project information. GCs often take on a large amount of risk, and to control that risk they may take actions which result in a restriction to the flow of information.

The result of this restriction looks like a traditional construction process with key design influencers disconnected from the early project stages. Unfortunately, there are those within the construction industry who see this as part of their business plan.

Traditions Have Deep Roots, and Change Is Tough

Prior to the information revolution of the late 1980s and early 1990s, it was nearly impossible to effectively gather and communicate in a collaborative way. But even as we are well into an age where it is simple to instantaneously transfer large amounts of data, the deep roots of traditional construction practices are still very much in place.

Change is not easy, and the sentiment "if it isn't broken, don't fix it" is an easy rebuttal. In reality, the advent of the information and computer age has resulted in unprecedented design advances. As boundaries between project stakeholders are removed, traditional methods are slowly becoming outpaced by collaborative approaches.

As with many industries, the keepers of tribal knowledge and individuals with many years of valuable hands-on experience are not the ones that naturally gravitate to new techniques and tools. The challenge is to retain all the great construction techniques developed and refined over time, and use them to develop a better, more efficient, more accurate product.

Engagement Is Easy, Continuous Engagement Is Hard

The application of VDC to a building lifecycle requires very early engagement by all key design influencers and builders. It also requires sustained engagement through the construction phases.

As designs become more complex and require many months to construct, the total phase of engagement must also be months. This is not an easy undertaking, especially if focus and motivation for the project are in flux. As with any endeavor worth doing, one must be disciplined, stick to the process, and see it through.

The Temptation of Short Term Gains over Long Term Value

A VDC approach requires a company to invest in infrastructure and resources which will not turn a single screw or create a single building element for quite a bit of time. Those not willing or able to participate directly may see this investment as unnecessary. There is a common school of thought that perception is everything, and in the eyes of traditional constructors, VDC is perceived as complicated and expensive.

However, companies that approach construction in a VDC fashion generate returns on the investment, clearly indicating the money spent in the early stages of design can greatly reduce fabrication expenses, increase material takeoff accuracy, and eliminate or mitigate costly risks.

CASE STUDIES

As VDC gains traction, more lessons such as these will be shared among design and construction professionals as peers in collaborative environments.

Rather than silence, sharing will generate a competitive edge for design and construction professionals who learn to build upon one another's innovations, and push the envelope of what is possible.

Project Details:
Zahner constructed interference-coated black stainless steel over aluminum substrate and HVAC system, supported by precast concrete pillars, and structural steel members.

Collaborators: 8
Area: .... 1,500 SF
Skins: 256
Cost: $850,000
Duration: .... 5 months
Completed: 10/2015

VDC ON A SIMPLE PROJECT

Transit Center HVAC System

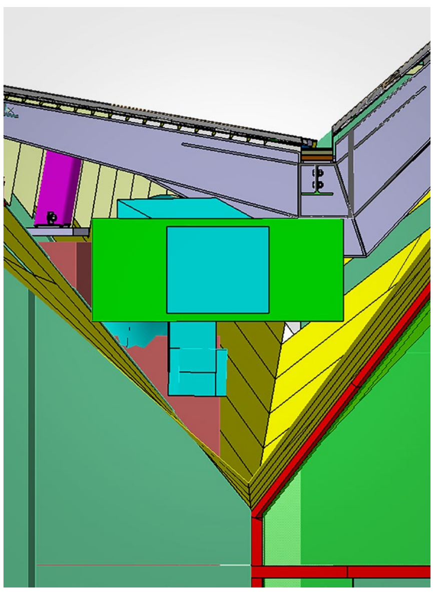
VISUALIZATION

VDC is a valuable method for installation sequencing and preventing challenges where trades or systems intersect.

After construction began on this project, it was quickly evident that the architect's Revit model for this project was insufficient in providing the context necessary to identify a major conflict, let alone resolve it.

Likewise, the 2D shop drawings could not effectively demonstrate the incompatibility of the building decorative cladding with the specified air handling unit (AHU): Standard HVAC units are rectangular. However, in this design, the space above the cladding system was not rectilinear—a factor that severely limited positioning for the AHU.

A "digital twin" model was developed to provide a clear understanding of the interface between these two systems, identify the primary risk points, and help stakeholders examine solutions including positioning and rotation options.



An early digital representation showing where the AHU would intersect with steel and facade systems.

Ultimately, the VDC model was also provided to external stakeholders as a visualization tool, helping simplify coordination among various trades.

ISSUE AVOIDANCE

Mid-construction, it was determined that the team would need to select a different AHU. While the structural support system and overall volume were adequate, the team could not effectively overcome clashes with the cladding support structure.

Installation of the AHU was not the only challenge. The AHU had to be accessible for maintenance and replacement when necessary. The cladding and support systems had to account for these eventualities. Virtual design tools helped the team to recognize the long-term needs of the facility and to create a working solution.

The model was central to the construction phase of the project, and clearly demonstrated the value of using VDC to mitigate system conflicts. By using the model for collaboration in the design phase, the team could have developed a method for removing the AHU without destruction of the cladding surface. It could have also improved the integration of the cladding support structure with the structural support system.

SUMMARY OF PARTICIPATION

Architectural Metals Team: Use of VDC was driven by the architectural metals team. The architect's model was used as a base for developing a functional model with real and constructable components. The functional model established real space requirements for each component, and enabled the team to collaborate with the HVAC subs in modifying the elements to adjust to the unusual geometry. This effort by the architectural metals team subsequently allowed them to efficiently generate manufacturing directives.

Field Personnel: In advance of executing the work, the GC's field superintendent and field engineer, and the subcontractor's project manager were most engaged with the model. Engagement was most prevalent at the point of field coordination.

Architect: The original model was based on the architect's Revit model, however, while the design team was regularly updated on the progress of the collaboration, they were not active participants in the VDC process.

Subcontractors: The primary steel and precast concrete subcontractors used 2D drawings to complete their scope of work, and while the HVAC subcontractor engaged in the model review and interface issues, it did not actively participate in the modeling process.

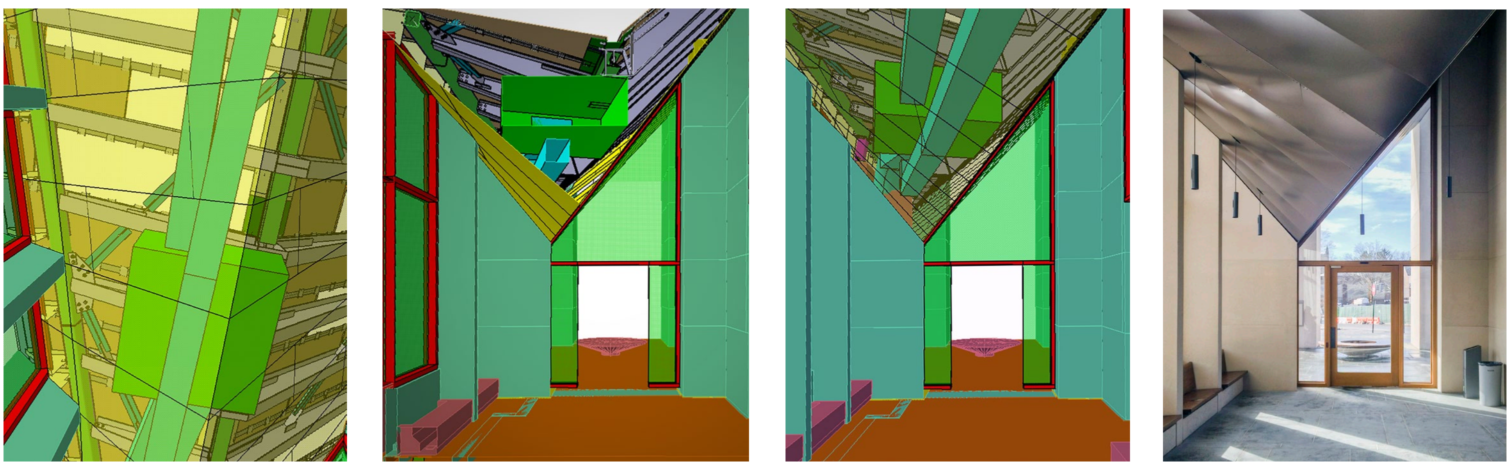
General Contractor: Similarly, the GC maintained a field engineering level of participation in the process, but did not actively engage in the model.

PROJECT OUTCOMES

Despite the system change midway through, the project was completed on time, with only minor delays in schedule.

Delays might have been further mitigated with earlier usage of the model, a key takeaway the project team can apply to future usage. Early usage of the model also could have helped eliminate redundancy and unnecessary back-tracking, which could have further shaved time off the schedule.

Key Takeaway: *VDC allows teams to address points of conflict prior to installation, which gives the project team more options for problem solving.*



Various sections of the digital twin: a virtual fabrication model showing three coordinated systems (AC, structural, & facade), and the completed Transit Station as-built, showing metal facade system.

VDC ON A COMPLEX PROJECT

“The Chrysalis” Amphitheater

Project Details:
Zahner produced and installed custom painted aluminum cladding on an aluminum substructure, supported by curved, hollow steel shapes.

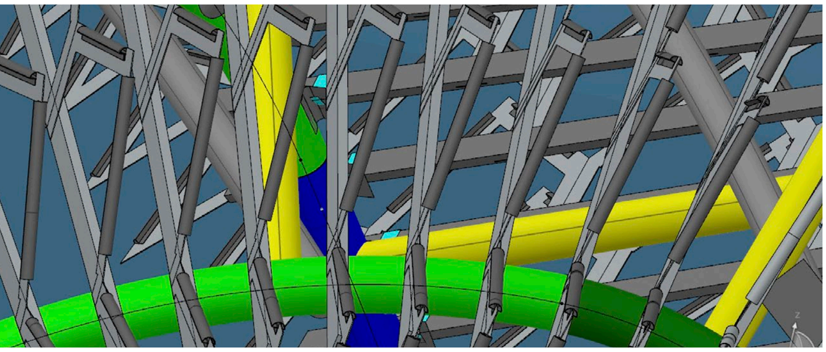
Collaborators: 12
Area: .... 12,000 SF
Skins: 7,500
Substructure panels 107
Unique steel parts: $850,000
Duration: .... 18 months
Completed: 4/2017

VISUALIZATION

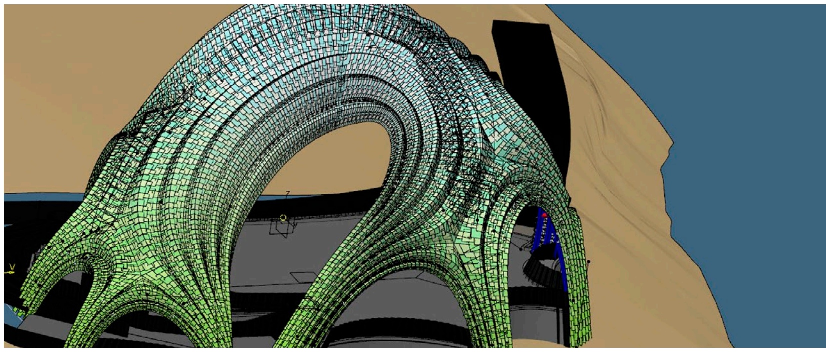
The Chrysalis is part sculpture, part amphitheater, part performance space, and entirely unique in its construction. The structure is a distinctive assembly of geometric aluminum tiles which, when assembled over steel supports, create a smooth, curved shell.

VDC was instrumental in ensuring the individual pieces were accurately installed to create a flowing end product. The project team leveraged the 3DEXPERIENCE® platform from Dassault Systèmes to generate a visual representation of the concrete, structural and architectural models.

In addition, the project owner had direct access to the status of Zahner’s ongoing development. This helped gain owner confidence in the progress of the project, which helped speed conflict resolution during the project. For example, two new scopes were introduced midstream of the project: stage support steel and light support steel. The client did not want these elements to impact the visual impact of the exposed structure of the main canopy. Through modeling, the owner was assured that the desired outcome could be achieved.

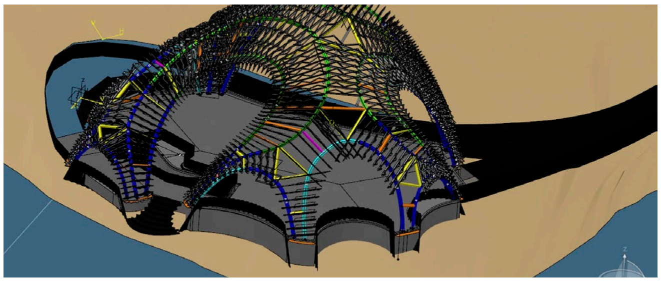


Model showing coordination between the structural steel and skin support system.



Final model showing comprehensive view of all systems including external shingles.

These visual representations were shared with external stakeholders to facilitate coordination of the various disciplines. The model was central to every design meeting and was used to focus the stakeholders on specific areas of development. For instance, the texture of the exterior surface was a key point of emphasis for the design team and owner’s representation. The team was able to reach a decision on what physical prototypes to build following simple digital manipulation of how the skin elements overlaid each other.



Model showing coordination across 3 systems: concrete, structural steel & skin support. This model was used throughout the building process.

ADVANCED COORDINATION

The coordination process was integrated within the platform so all stakeholders could provide their real-time status and identify and track potential issues. There were three key interfaces which had to be closely coordinated: primary steel to concrete foundation, substructure to primary steel, and skin to substructure. In addition, there were hundreds of different structural load paths which had to be identified, and each demanded development of a custom solution.

Flexibility drove the design and structural control elements at the majority of the connection points. For example, concrete slab limitations drove the primary steel configuration, while wind loading at a specific location on the cladding surface drove development of the primary steel footing at the concrete slab. While this might have once meant days before designs could be updated, use of this single-source platform reduced the time for key drivers and other information to be identified and communicated to stakeholders—from days to mere hours.

AUTOMATION IN ACTION

Panel definition automation provided parameter-based changes of the underlying structure and other design variables. Within a tight schedule, the design team was able to evaluate returns on investment from simplifying certain elements of the panel substructure and could move to the best practice early.

Automation was also used to reconcile the design intent of the shingle pattern with manufacturing constraints. The original model exercises resulted in more than 7,000 skins entirely unique in both color and shape. By constraining certain parameters, and presenting a detailed visual representation for review and approval, the design team could limit the final cladding system to three standard shingle types produced in three different colors.

SUMMARY OF PARTICIPATION

Each stakeholder had varying levels of familiarity with the VDC process. Therefore, those leading the process had to educate players on VDC benefits and ensure total buy-in.

Engineers: Zahner took on the responsibility of managing the platform and managing the consolidated model. They also established the collaboration process that was enabled through the platform. In addition to architectural metal, the model included structural steel and concrete.

Owner and GC: The owner's representative was very engaged in the process and seemed to quickly understand the long-term benefits of using the 3D platform to design, engineer and manage the construction process, as well as the marketing/communication opportunities presented by this early use of VDC on a complex project. The GC also accepted this approach and actively used the shared platform portals for model review and communication.

Architect: The designer and architect were less familiar with the use of a 3D platform to manage the construction process and often reverted to more familiar traditional paper documentation techniques, such as paper RFIs. It is an understandable reaction, given the extent these individuals were impacted by a change in approach. Through continual reinforcement, the designer and architect were ultimately supporters of the VDC method. Through this real-time education process, these individuals gained experience and familiarity with the 3D environment, which they can now translate to improvements on future projects.


Chrysalis as-built: close-up views of aluminum shingled skins.

Trades: The steelworkers were more varied in their reception of the process. The primary steel manufacturer accepted the 3D platform as the mode of communicating and used it to work closely with the engineering team to minimize interface issues. The steel subcontractor used the platform as a model reviewing tool. Lighting design was developed from the 3D model as well.

PROJECT OUTCOMES

Due to the frequency of updates received throughout the project lifecycle, the owner exhibited a high degree of **confidence** in the project's process and outcome. He also viewed the **on-time, on-schedule** creation of this community asset as a public relations success.

The **elimination of change orders** was a leading goal for the owner. This goal was met for the pavilion primary structure, substructure, and cladding. Plus, although field installation had been scheduled during the winter, the VDC preparation ensured the pavilion structure and cladding were completed on time. The owner was able to use model updates to **communicate** these significant successes to the community.

Early expectations were that there would have to be conflicts and overruns because it was an atypical project. Even so, the team stayed on time and on budget.

While conflicts did still occur, the VDC process helped reduce the amount of effort to get to resolution. Because all **stakeholders were already tuned in** to potential issues, problems were quickly solved.

Chrysalis as-built. Photo © Jeffrey Totaro.

The **single-point collaboration** which kept everyone on the same page also generated confidence and trust in the process. Process confidence was crucial in the project's overall outcome. Given the complex nature of this structure, stakeholders might have easily come into the project with a preconception that it was a scheduling disaster in the making. Yet the project stakeholders had confidence the VDC process would help them **mitigate conflicts early**, and rapidly and cost-effectively erect a highly unique structure.

Trust in the process also helped mitigate issues before they became problems. For example, if one stakeholder saw a potential change order item on the horizon, the understanding was that flagging the issue would not be viewed as criticism of their peer's approach. Instead, the team accepted it as a hurdle to be overcome for the full project team to succeed. This level of trust and sense of **working as a team** contributed to the project's successful outcome, and led to dramatic reductions in RFIs and late design changes.

Key Takeaway: *Single-point collaboration keeps everyone on the same page, generates clarity, confidence and trust in the process, improved accountability, and a better overall project outcome.*

While the project was successful in encouraging new companies to embrace the VDC approach, it also presented **opportunities for future improvements**. For example, in retrospect, the model could have been used to manage site logistics. The project site is surrounded by protected vegetation, which restricted equipment movement and material storage. These issues could have been incorporated in the model and managed earlier to the benefit of all participants.

Chrysalis as-built. Photo © Jeffrey Totaro.

A Complex Geometric Building

CALIBRATING MODELS AND EXPECTATIONS

Zahner was invited to participate in a design-assist engagement for a large, geometrically complex project. Early-stage discussions were held among a number of project stakeholders, including:

- 2 different design groups
- 1 general contractor
- 1 steel subcontractor
- 1 concrete subcontractor
- 1 structural consultant

Project Details:
Zahner was hired to consult on the design of a custom support structure with custom cladding to define a unique geometry.

Collaborators: 17
Area: .... 50,000 SF
Cost: .... Est. $12MM - $15MM for cladding/support structure
Duration: .... Est. 20 months
Completed: .... Late 2018

In preparation for an early project review meeting, Zahner overlaid the design architect's geometry model with the steel subcontractor's model. Because the two models were not constructed using the same parameters or basis of origin, it took some guesswork to determine the overlay. Even with a best fit, matching the models as close as possible, structural steel elements stuck out of the geometry surface in many locations, in some cases by several feet.

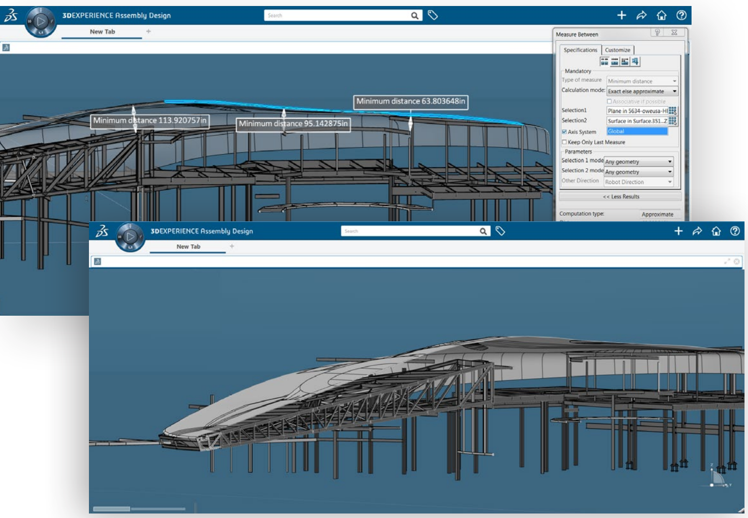
Zahner convened a conference call to discuss the state of the models and determine the best path forward. Four external stakeholders, conferenced in via four separate lines, weren't able to view the model illustrating the problems due to incompatible web interface platforms.

After Zahner's representatives described the visible issues, the response was simply that the steel had already been purchased, and Zahner would need to "tweak" the geometry to get a constructible relationship with the steel. It was clear a better approach was required.

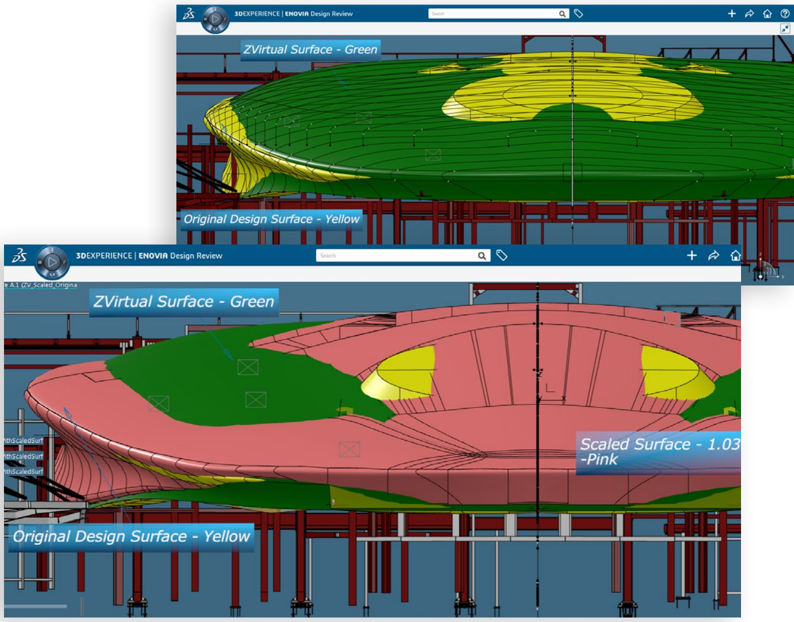
The Zahner team presented the GC with a proposal for model federation and development so that a common platform and communication method could be established. The goal was to determine the most cost-effective way to construct the structure. The contract was accepted, and Zahner produced a model representation of the current design with the steel model overlaid. (Subsequently, the GC approved a change order for Zahner to model an additional portion of the structure.)

Two alternatives for adjusting the geometry were proposed:

- adjust the geometry to overlay the steel and maintain an 18-inch zone for cladding support, or
- adjust the geometry by scaling the architect's surface so that it encapsulated all of the structural steel.



Cross-section views of the model showing intersections between the original surface and the top of steel.

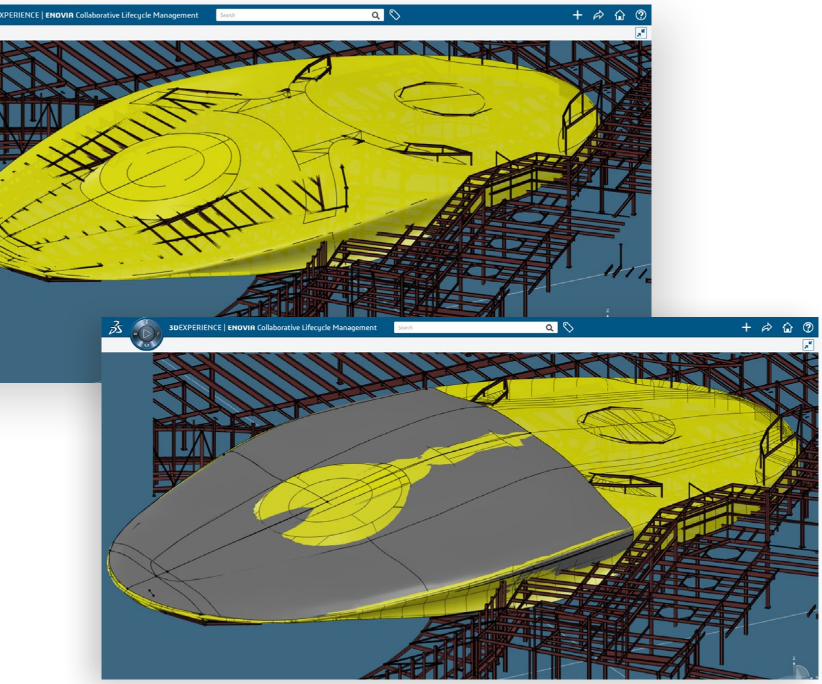


Design Review: Comparing the original surface (yellow), Zahner's proposed surface (green), and a scaled-up version of the original surface (pink).

VISUALIZATION

Earlier in the project, all information was exchanged via 2D drawings and written communications. It was only after communication had completely broken down that a federated model became the primary visualization tool.

With the completion of a federated model and options for geometry modifications, all meetings became centered around the model and the modeling platform.



Views of original surface (TOP) highlighting problematic areas where major structural steel sections are intersecting with the surface, and Zahner's proposed modifications (BOTTOM) which maintain the architect's surface as closely as possible.

A cautionary note: Decision latency improved with the introduction of a federated model on a single platform, however, early use of 2D communication had already negatively impacted the project. The longer it took to define the model to the LOD necessary to execute—for an operational plan to be created, for materials to be purchased, and for manufacturing to begin—the tighter the schedule became. The deadlines were not moving, but the timeline to achieve sufficient clarity took longer than anyone had accounted for.

PROJECT OUTCOMES

At the time of this writing, the project is still in progress. Fortunately, the team has already benefited greatly from the use of a single platform and federated model. Visibility of risks and needs have greatly improved. The VDC approach successfully revealed the project's problems areas, and established an effective method for communicating effectively and moving forward as a team.

Moving forward, integration and automation will play a significant role in the successful completion of this project due to its size, complexity, and tight schedule.

LESSONS LEARNED

There remains today a segment of construction professionals who avoid VDC until it is too late to take full advantage of its benefits. That said, it's never too late to see *some* gains from applying VDC—even at a late stage in design development, under a tight schedule, or for a discrete portion of the project. There are advantages to this approach that will benefit the construction team at any phase.

***Key Takeaway:** It's never too late to take advantage of the benefits of VDC on a project.*

IMPLICATIONS

Let's assume the above VDC benefits and risks are thoroughly considered, and the implementation of VDC processes are well-paced, accepted by project contributors, and governed effectively. What are the downstream consequences of VDC in practice?

What VDC Means to Your Business

Your business will have greater visibility into each project.

Among the chief benefits of VDC is its ability to give players at every level visibility into a large data set. This deep dive into project information helps all contractors **identify and plan for risks early in the design process**, rather than on the job site. Early planning helps projects go as precisely as possible, which can significantly reduce rework, time spent on RFIs, and many other challenges that too-often cause schedule delays and cost overruns.

This early insight into a project also can help specialty contractors see additional areas of the scope where their expertise can add value, opening **access to new opportunities** and new markets. In this scenario, project stakeholders gain valuable solutions, while contractors earn additional opportunities to contribute to the project.

Your business will be involved much earlier in each project.

Use of VDC demands contractors to rethink certain processes and adjust to a new level of collaboration. While VDC adoption can help contractors secure more high-level work, it also impacts the length of time spent on any single project. Early involvement demanded by VDC means **longer gestation periods** for projects. As a result, companies may find they need to establish a different system for filtering projects and securing work that meets their adjusted timelines and capabilities.

Longer project durations may also impact management processes and systems. For example, contractors may find they need a different data management plan to support their communication channels for this longer period. Contractors also need to be aware of **changes to resource allocation** and adapt their processes accordingly.

Your team will need to develop new skills.

The tools required to work effectively within a VDC platform are likely different than those that most contractors currently have in place, so this shift will demand new systems. Beyond the investment into VDC technology solutions and experts versed in managing these systems, contractors may also find they need to adopt new support systems. For instance, computers may need to be upgraded to be capable of **handling and processing data** in a different way, and allow them to take full advantage of deeper project insights.

Staff, too, will need to view data in a different way. As a result, contractors may also find they need to **retrain their workforce**, or bring on new professionals with skillsets that meet these new needs.

On a broader level, the entire company will need to **rethink how data is collected and valued**. In many ways, information will be at the heart of the company's services, but rather than viewing data as proprietary differentiator, contractors will need to approach data as a shared tool for driving project success.

> *"The biggest change is that the **demand for information begins much earlier in the project.** Instead of identifying issues (coordination or design) through the construction cycle, they are now identified in the coordination phase."*
>
> **— David E. Quigley, Achieving Spatial Coordination Through BIM**

What VDC Means to the Industry as a Whole

Early adopters have an opportunity to lead.

Owners are demanding that our industry improve our processes. Implementing technology to adopt collaborative VDC processes is the low hanging fruit to start **addressing owners' concerns.**

The HVAC market is slightly ahead of the rest of the AEC industry in implementing VDC. Many HVAC designers and contractors have been drawing in 3D for 15 years or more. Otherwise, no other manufacturing or subcontractor sector has presented itself as the early adopter.

There is an opportunity to become an expert on this approach, and to be in high demand as **an asset to the overall construction process.** Plus, the barriers to entry into VDC are being lowered significantly faster than in the past.

Late adopters are putting their business at risk.

VDC has the extreme potential to change the way the construction world operates. Late adopters run the risk of falling so far behind that they eliminate themselves from the market. This is already a reality in several markets. Investing in VDC training is a must for contractors looking to position themselves for success in the ever changing industry.

Legal structures will require VDC as the norm.

IPD is becoming more prevalent as owners turn to alternative project delivery methods in frustration with the cost, time, or quality of their building. According to Matt Cramer, president of Dee Cramer, a Michigan-based HVAC and sheet metal contractor, VDC is a baseline requirement for IPD projects, and is also commonly expected on large HVAC design-build and design-assist contractual arrangements. With HVAC at the leading edge of VDC adoption, we can predict these contract trends will continue to expand to other trades, and eventually to the entire project team.

Projects will demand more labor hours—but the work will look different.

The nature of work across the industry will change in fundamental ways. Contractors will spend more time collaborating on a single, integrated model than they will reproducing drawings, creating separate fabrication models, and working on site.

Early involvement will pay dividends to the industry as a whole in both exposing a larger set of opportunities, and reinforcing value so that cost reduction agents are not looking our way. Lean principles enable the team to design it once and design it right, eliminating useless RFIs and change orders caused by vague drawings.

VDC's Major Implications:

- Greater visibility
- Earlier involvement
- New skills
- Opportunities for early adopters
- Risks for late adopters
- Contractual requirements
- More (but different) labor hours

ADVICE FOR GETTING STARTED WITH VDC

1. Engage with others in the VDC community. Consider taking a training course from a contractor in a related field to understand not only VDC tools, but also the adaptations the contractor has made to their business processes. Invite a solution provider to speak to your company to demystify the VDC process. Exposure to this new way of working is a good first step for understanding how you can apply specific benefits to selected projects.

2. Get involved in a construction project at the earliest stage possible. A good way to learn more about the internal changes you'll need to make is by observing the early stages of a VDC-driven project. Not only is this observation a good strategy for learning, but it also demonstrates to potential partners that you're aiming to provide a new level of value to future projects.

3. Explore how other groups within AEC have used VDC. Mechanical, electrical, and plumbing (MEP) trades are a good place to find insights on making this switch. Many designers of complex MEP systems saw early on how VDC could help them improve designs and reduce clashes among systems. Reviewing trade journals and case studies for others' perspectives and project insights may be the inspiration you need to transform your next project.

4. Consider hiring an engineer or architect trained in BIM. This professional can help get the company started on its VDC journey and educate others within your organization on what further training and resources might be needed to gradually transform your company to a data-driven services company and VDC advocate.

ACKNOWLEDGEMENTS

This paper was written by:

Tom Zahner, PMP, Chief Operating Officer, A. Zahner Company

Tom Zahner has been involved in constructing complex, cost-efficient art and architectural structures for more than 20 years. His family firm, Zahner, is an internationally acclaimed engineering and fabrication company at the forefront of digital definition for manufacturing and construction.

Ed Huels, Director of IT and VDC Services, A. Zahner Company

Ed Huels has spent the majority of his professional career in Information Technology with a focus on infrastructure and back office systems. Zahner's extensive use of technology and advanced modeling software allowed him to develop an understanding and interest in its use as a tool in the overall BIM/VDC process.

Tom Soles, Executive Director of Member Services and Market Sectors, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)

Tom Soles is responsible for SMACNA's four Market Sector Councils: HVAC, Architectural Metals, Industrial, and Residential. He directs all business management programs, educational programs, non-technical member services, and liaison programs with industry and federal regulatory partners. Tom has served on the NIBS buildingSMART alliance® Board of Direction, the NBIMS-US Vision Task Force, the NBIMS Planning Committee, and the SMACNA, NECA, MCAA BIM Coordination Task Force, and chaired the NBIMS Assemble Task Force.

Special thanks to Matt Cramer,
President of Dee Cramer, for his perspectives on industry implications.