CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

VDC Use in 2007: Significant Value, Dramatic Growth, and Apparent Business Opportunity

By

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Abstract

This study analyzes and compares data from surveys conducted in 2006 and 2007 on the use of Virtual Design and Construction (VDC) and Building Information Modeling (BIM) technologies in the AEC industry. The 171 respondents thus far to the 2007 survey represent a broad mix of geographic locations, business sizes, technical disciplines, and project types. The data suggest that VDC use is significant, expanding quickly and has entered mainstream use. Survey respondents report more and increasingly sophisticated use of the methods in their operations and many are reporting specific benefits in the areas of improved participant engagement, reduced risk and project contingency, improved latency, and cost and schedule conformance. While value of their work in practice is rarely measured quantitatively, the majority of users report qualitative value across all phases of the design and construction process as well as for all parties to it, which is growing in comparison with survey results of a year ago. A growing proportion of early adopters report plans to transform their organizational strategy, and, in addition, more early adopters are now shifting from individual pilot projects to broad scale use of the methods than in the previous year of the survey. The majority of veteran users now plan such organizational transformations, and, indeed, are attempting integration and automation phase implementation of VDC in a sign of ever-increasing sophistication of use.

An ironic finding of our study is that those organizations that respondents themselves and others consider most likely to find value from using VDC, namely architects and facility owners, are the least likely to use or require it on their projects. This result may now be changing for Architects, however, as the biggest annual reported increases in VDC use, implementation efforts, and perceived value occurred in the design phases of the construction process. As VDC use increases, reported impediments to its further adoption by new and existing users are shifting from technical issues such as contractual language and hardware and software to people issues such as training and availability of qualified staff. The survey data and information gathered during one-on-one phone interviews suggest that VDC programs are growing in extent and that once they start organizations grow their use of VDC. Since VDC staff training and availability have become bottlenecks in 2007, we infer that early adopting organizations obtain value at a lower cost than competitors that need to recruit, invest and compete in an established VDC marketplace. Later adopters may find themselves operating at a strategic disadvantage for significant periods of time while they need to offer low prices to overcome lack of perceived marketplace competence and simultaneously pay for their attempts to develop scarce people resources and institutionalize new processes.

Introduction

The Center for Integrated Facility Engineering (CIFE) at Stanford University has been a leading proponent of the VDC and BIM use in the design and construction process, and has helped numerous firms implement the technology on individual projects. This paper describes a survey, now in the second year of what we hope to be an annual effort to track the diffusion of VDC use industry-wide and to evaluate trends in its use over time. It is our belief that use of VDC methods is expanding and has now entered mainstream use, which we did not see in years past.

Adopting companies placed significant effort into implementing VDC programs across all phases of the design and construction process last year and many report reaping benefits from this effort. Many user companies report that they are shifting toward broad VDC implementation and overall organizational transformation based on its use. These users report value in qualitative terms as few measure value quantitatively.

Adoption is not universal, however, and slightly more than half the 2007 respondents say that they are not using VDC / BIM on any projects. The majority of non-users cite lack of need, lack of request by owners, and lack of qualified providers as the most common reasons for not implementing the technology. Those same respondents indicate they would use the technology if it could improve their process efficiency. Since the majority of current users seem to derive value in the use of VDC for precisely this reason we suggest that a profound disconnect exists between the perceptions and desires of non-users and those of users.

Notes on Survey Methods

This paper highlights the results from two versions of an annual survey that began in 2006. The 2006 survey was considered a beta version and several changes were made to the 2007 version based on experience gained on the earlier instrument. In particular, several new questions were added in 2007 in order to improve clarity or to provide information seen lacking in the 2006 version. Some questions seen as redundant were removed.

A particularly significant change between the two years was a modification in the treatment of respondents who reported having no projects using VDC methods at the time they took the survey. These non-users were diverted past all detailed or direct-experience related questions. Instead, they were asked why they did not use VDC and for what reasons they might begin doing so. From this we hoped to reduce the incidence of respondents skipping questions in the more detailed sections of the survey. In the 2006 beta version, users were not diverted in this manner, but rather they were advised to skip questions that did not pertain to them. We feel this modification has allowed the survey to gather better insight into the perspective of the significant numbers of non-user respondents.

The 2007 data are based on a combination of a web-based survey and individual follow-up interviews with respondents who volunteered to be contacted. As of the writing of this report there were some 171 respondents to the survey and 45 interviews conducted. The raw survey data is included in Appendix 4, cross-tabulations in Appendix 5, and a summary of all interview results in Appendix 3. It is worth noting that this paper compares the results of the 2007 survey with the relatively small population of respondents in the 2006 survey. The earlier instrument had 40 total responses. Since respondents were advised to skip questions that they did not have direct information to answer, many skipped large numbers of questions, thereby reducing the population size further for specific questions. Because of this small sample size, data based on percentages of total respondents to the 2006 version are often sensitive to fluctuation in the personal experience of individual respondents. The 2007 survey has larger sample sizes, so averages represent industry status more reliably then in 2006.

Findings

This section reports the findings of the 2007 VDC use survey and compares those findings with the earlier 2006 results.

Survey respondents represent all parts of the AEC industry

Survey respondents in 2007 provided a broad and representative cross-section of all parties in the AEC industry, as shown in Figure 1. Respondents operate throughout the US and the rest of the world, and frequently provide services in multiple phases of the design and construction process. The figure demonstrates the relative percentages of respondents specializing in the various roles and services that make up the process of design, construction and operation of buildings. With the exception of the specific subcontractors providing mechanical, electrical, and plumbing (MEP) and structural steel installation, at least 20% of respondents were involved in each of the specialties listed. Such broad involvement provides a balanced insight into all phases of the process.

The makeup of survey respondents in 2007 is similar to that of 2006 with a few noticeable exceptions. The 2006 survey did not allow a response option for MEP or structural steel subcontractors so these are new in 2007. There is an apparent reduction of between 4-18% in the proportion of respondents offering all other specialties except engineering which remains roughly the same. However, the relative proportions of each specialty and their ranking from greatest to least is similar between the two years. These are not considered significant shifts. We believe, therefore, that the similarity of response allows for direct comparison of data between the two survey years.

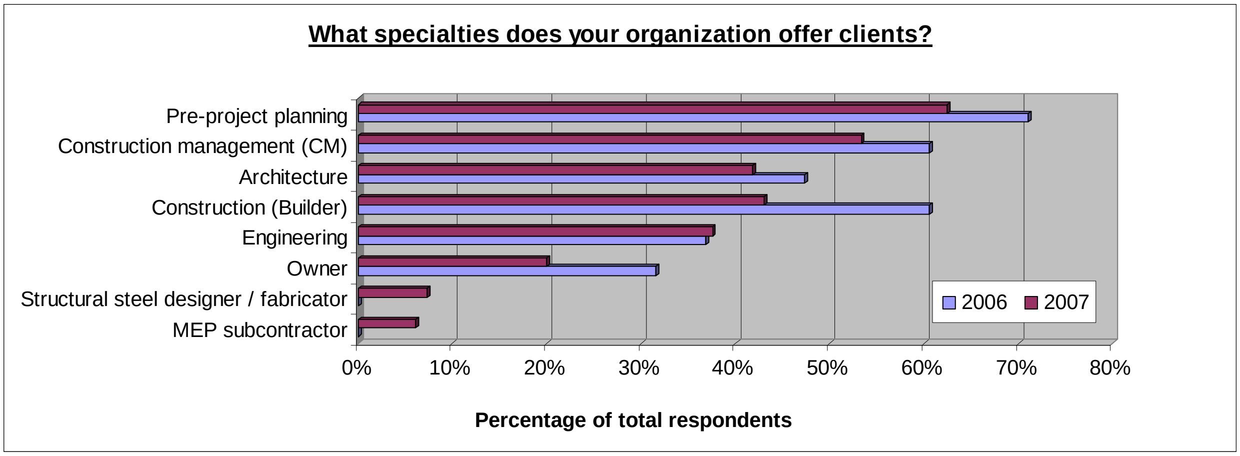

Figure 1: Respondents to the survey represent all specialties and disciplines of the design, construction and operation cycle for buildings, and most respondents reported offering more than one specialty. The relative proportions and ranking of respondents from each discipline are roughly the same in 2007 as in 2006 with the exception that there were slightly more architects and the significantly fewer contractors. Specialty subcontractors, structural steel and mechanical electrical and plumbing, were added options in 2007.

A significant shift in the demographics of respondents can be seen in the large increase in the number of non-users who responded to the survey as demonstrated in Figure 2 in the next section. In 2007, non-users were diverted past detailed project questions to a section of more general questions tailored toward their non-user status. In 2006 this diversion was not present so non-users saw the same questions as users. All respondents in that version were instructed to skip questions they did not have the information to answer, and, there was indeed a significant incidence of respondents skipping questions requiring information from VDC project experience. We infer this indicates non-users largely avoided those questions that did not pertain to them leaving the overall results comparable.

The use of VDC is broad and growing significantly

In Figure 2, respondents report a significant growth in the absolute numbers of projects in the past 12 months on which they attempted to use VDC. The figure shows these use increases by groupings of 0 total projects, 1-3 total projects, and more than four total projects. These results separate non-users, pilot users with few projects, and relatively advanced users that have adopted the technology on multiple projects. As stated above, the biggest increase since 2006 is in the number of VDC non-users, which we infer is a consequence of the much larger sample size in the 2007 survey in comparison with the 2006 version. The number of pilot users quadrupled, and the number of advanced users doubled.

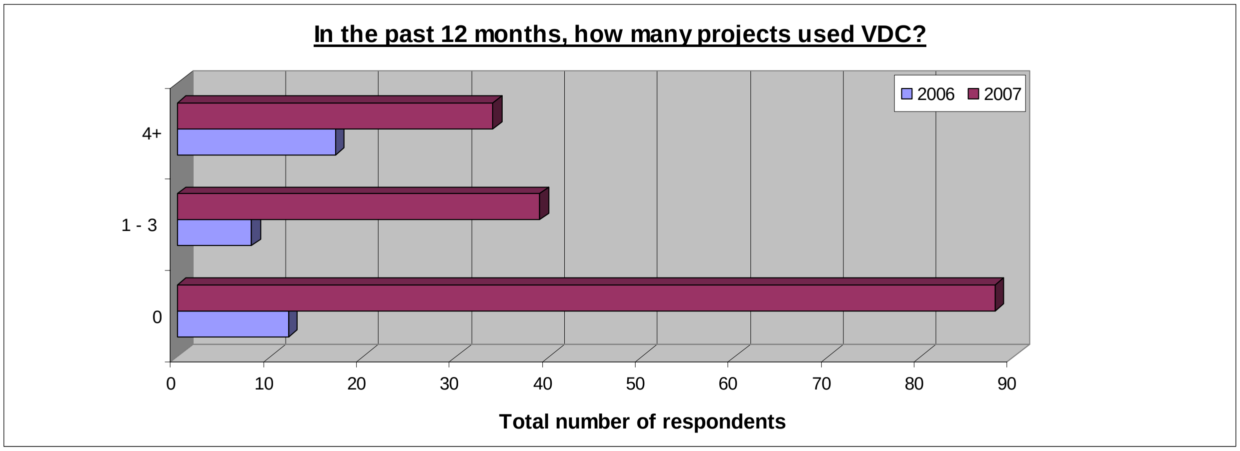

Figure 2: The number of non-user respondents, those reporting having no projects on which they used VDC, jumped from 12 to 88 demonstrating wider advertisement this year. Pilot users, those with 1-3 projects, quadrupled in absolute number, and established users, those with four or more projects, doubled. With a reasonably large and representative population we found 45% of respondents are VDC users.

Figure 3 shows that VDC-users placed significant attention to developing VDC capability in all phases of the design and construction process. Design phases received the most attention; between 67% and 75% of respondents reported they had paid significant attention to their VDC capability during these phases. Design phase attention increased 10-20% over the previous year. Attention paid to VDC capability in the phases of pre-project planning and field construction management stayed nearly the same between the two years, and the majority of users still paid close attention to these areas. Few respondents reported they paid significant attention to developing VDC capability during O&M that is typical of our findings in other sections of the survey for this phase of the cycle.

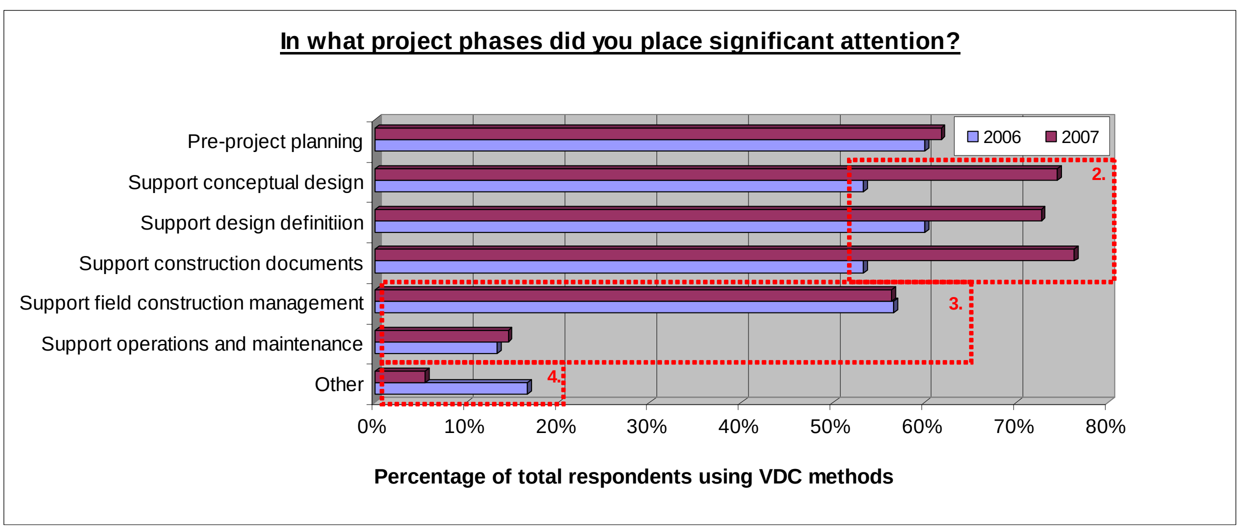

Figure 3: 1. The majority of VDC users reported placing significant attention in all phases of design and construction. 2. Users reported placing more attention in design phases than any other increasing this response by 20-25% over the previous year. 3. Users reported little change in attention placed during construction management or O&M. The latter lags the design and construction phases by a wide margin. 4. 75% fewer respondents report placing attention to VDC in Other phases of the construction process.

As shown in Figure 4, the majority or near majority of respondents report they are creating models in all phases of design and construction excluding operations and maintenance. Additionally, the largest percentages in 2007 occurred during the design process where it is more likely to have an impact on value. As shown in this figure, at least 67% of respondents reported creating models in all phases of design this year. Significantly more respondents reported creating models in all phases during 2007 than in 2006. Though the rate of respondents reporting they created VDC models during the O&M phase grew slightly in 2007 over 2006, these respondents are in the minority and the response rate lags far behind the other phases. A shift to creation of models during the design stage is of potentially great future significance given the procedural efficiencies inherent in having the entire design and construction team operating from a central 3D model created early in the process rather than from individual models created by multiple parties at later stages.

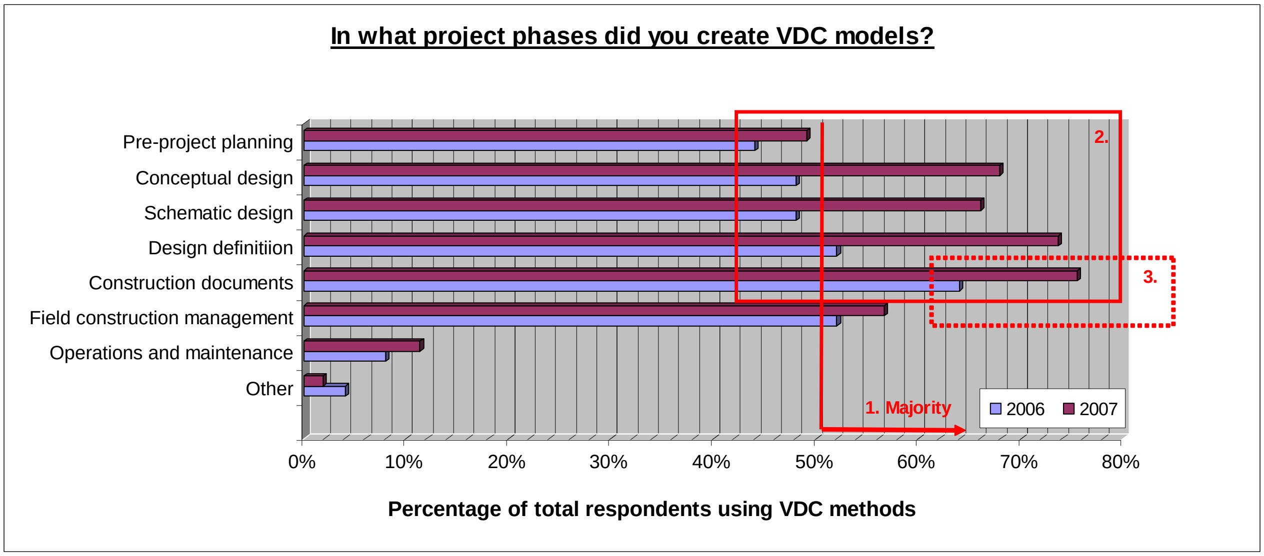

Figure 4: More respondents report creating VDC models in every phase of the design and construction process in 2007. 1. The majority of respondents reported creating models in every phase except pre-project planning and operations and maintenance. 2. The increase in model creation was particularly strong in the design phases with greater than 33% growth during the conceptual, schematic, and design definition phases. 3. Nearly 80% of respondents report creating or updating models during the construction documents phase. These results suggest a general, significant, and rapidly growing use of VDC models across phases and company types.

Creation of models earlier in the process allows users to take advantage of the lower cost of adding value or avoiding problems at these stages. Interviews indicate that some users are creating models in the pre-project planning stages to test the economic and technical viability of various concepts prior to choosing a specific direction or embarking upon an actual design. These exercises can yield surprisingly accurate forecasts of final cost, especially if done on design-build or design-assist contract structures where all parties are participating from the beginning. The most advanced users tend to automate the production of documents typically left until later design phases, as is the case with Design Atlantic, Inc. of Salisbury, MD. Design automation is has greatest impact in the construction documents phase and can allow designers to expend greater effort on the actual design rather than the packaging of their product. Design Atlantic's experience with this process is that they can reduce their time spent on the CD stage from between 40-50% of design effort to roughly 25% of total effort. A study of their effort on a municipal fire station in Salisbury is included in Appendix 1.

As shown in Figure 5, users reported making significant progress at implementing VDC across most design and construction phases. Again, the best progress was reported in the design phases, particularly in conceptual design and design definition, where a solid majority of respondents reported making headway developing VDC capability. Respondents reporting progress in the support of construction documents more than doubled over the previous year. Indeed, comments on several interviews indicated that automation of construction documents could greatly reduce the administrative effort of the design process. The large increase in progress made in this area, combined with the data from Figure 3 that more models were created during the design document phase than any others, indicates that designers may be capitalizing on construction document automation as true low-hanging fruit. Progress reported on pre-project planning retreated about 10% in 2006, however, there is not any indication from interviews or survey-respondent comments to reinforce or explain this.

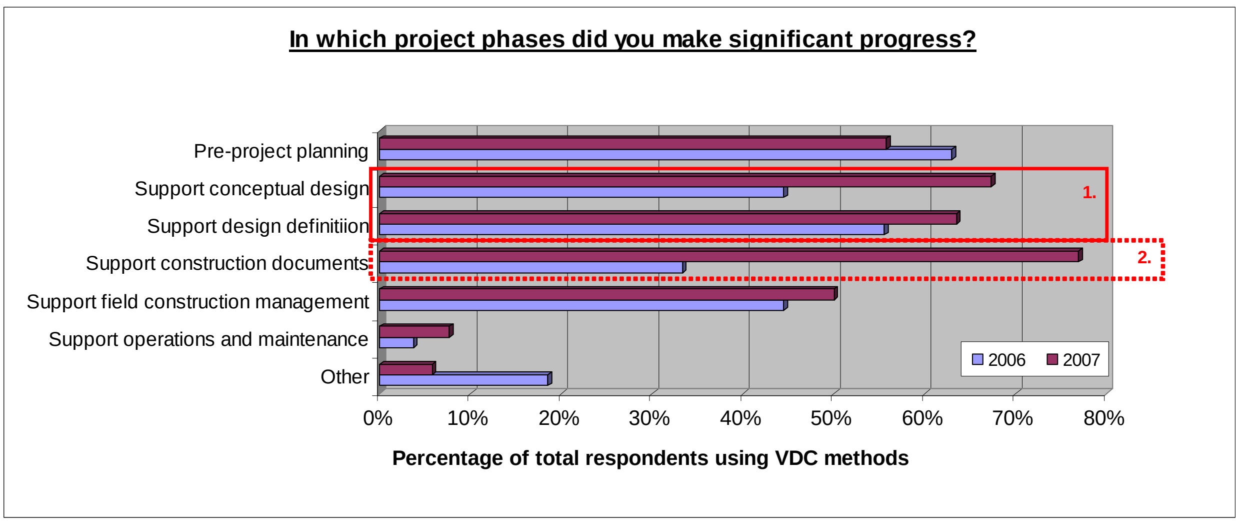

Figure 5: Respondents report dramatic progress across nearly all of the AEC process. 1: Design phases attention grew by 10%-20% over 2006, with the majority of users saying they had made significant progress. 2: Users citing significant progress in using VDC during the construction documents phase more than doubled in the past year indicating a new level of sophistication. There were only nominal gains in support of field operations and operations and maintenance and significant progress on pre-project planning decreased. The data suggest that designers increased their VDC use more quickly than construction, O&M or pre-project planning.

Figure 6 shows the numbers of projects VDC users reported planning for the 12-month period following the date on which they took the survey. It shows that while pilot and advanced users will remain in roughly the same proportions of total users, advanced users are moving toward performing more projects using VDC methods.

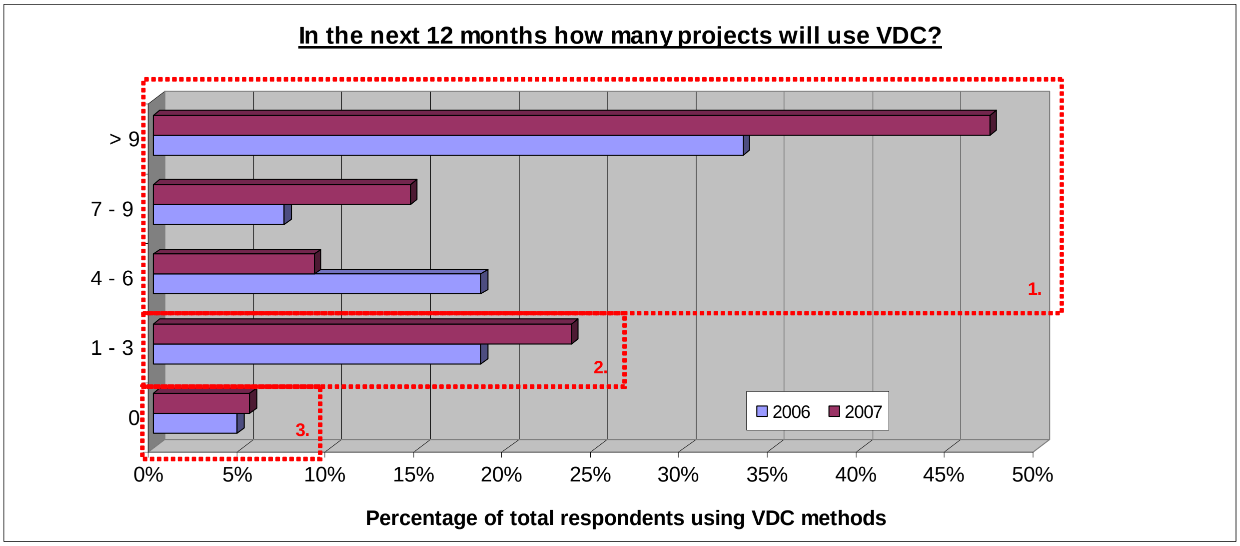

Figure 6: Planned VDC-use grew in scale during 2007. 1. Nearly the majority of VDC-users planned 9 or more projects for the coming year and the proportion of users planning 7 or more projects more than doubled. 2. Respondents in the pilot stage, those attempting between 1-3 projects grew slightly as well. 3. The proportion of respondents who tried VDC in the past year but planned no new projects in the year ahead stayed at the relatively small proportion of 5%.

We suggest that these data indicate that VDC use is well established and growing within a significant and representative segment of the construction industry. Further, we suggest that given the degree of attention paid and progress reported, especially earlier in the design phases of the process, this trend is likely to continue. Users report implementing VDC methods on greater absolute numbers of projects and the majority of survey respondents report creating models at all phases of the design and construction process. The majority of respondents report paying significant attention to developing VDC capability, and, they report doing so during the early design phases more than in the past year. Excluding O&M, the majority or near majority of users report making significant progress in all phases of design and construction. While the proportion of users in the pilot and advanced stages of implementation remained essentially the same between the two years, the majority of advanced users in 2007 report having 9 or more projects using VDC. We infer that the significant reports of attention paid to development of VDC capability and corresponding progress made in these areas, as well as the shift of advanced users toward increasing numbers of VDC-based projects indicates a trend toward continued broad operational VDC use. Interview data that indicate that as stakeholders gain experience and see benefits they consistently expand their use of the technology.

VDC users see significant value as well as a shift in the nature of impediments to progress

Figure 7 shows that advanced users of VDC technology find it qualitatively valuable and are starting to see fewer technical impediments and more personnel obstacles as they seek to capitalize on this value. We see a majority of survey respondents attest to the value VDC provides to the four key process players, namely, architects, owners, general contractors, and subcontractors. Figure 8 shows that respondents see value across all phases of the construction process, and report sizeable gains in qualitative value over last year in most of those phases.

Finally, Figure 9 shows that respondents are more likely to say they derived competitive advantage in winning new projects from using the technology. In broad terms respondents were more likely to see value in VDC use in 2007 and they saw this value in all phases of the process.

Figure 7 indicates the perception held by the various parties in the construction process relative to the key players in that process. Clearly, all parties perceive that architects and owners are deriving the most value from VDC. Subcontractors are consistently perceived as receiving the least. Subcontractors aside, the majority of respondents (50-100% depending on the point of view) saw themselves and all other parties as receiving "some" to "very high" value from VDC. Follow-on interviews with respondents report consistently strong perceptions of value as a result of effective VDC use. Interestingly, many report anecdotally that the highest monetary benefits probably go to the subcontractors due to reduced interferences in the field and correspondingly increased efficiency in their on-site work. Many advanced users report that the main value of VDC is in the ability to coordinate work closely enough to cause a meaningful reduction in the number of personnel and materials, which are on the jobsite at any one time. Thus VDC is seen by some as a direct contributor to the implementation of lean construction methods. The primary beneficiaries of this are MEP and structural steel subs and in some cases, interviews indicate that it can be they who drive implementation of VDC on individual projects. Indeed, Emcor Group, a mechanical contractor operating at the national level, has required the use of VDC on all its projects, even those on which other stakeholders make no use of it. A study of Emcor Group's perspective is included in Appendix 2.

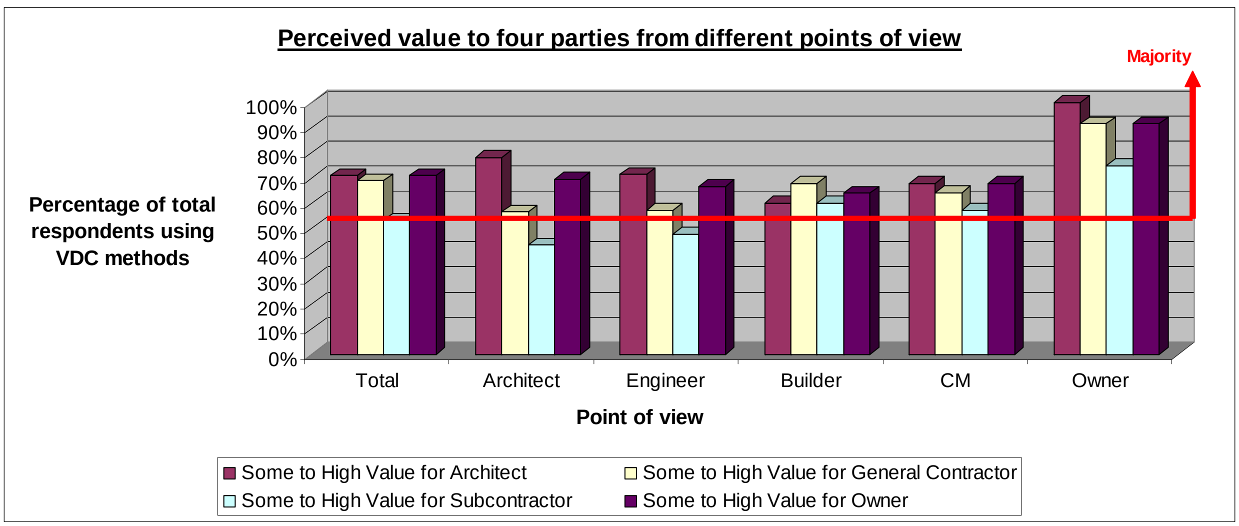

Figure 7: The majority of all parties to the construction process reported seeing qualitative value in the use of VDC. Regardless of the point of view, respondents tended see the primary beneficiaries of VDC as the Architect and Owner with the GC close behind. Respondents saw the least value going to Subcontractors. These data suggest that those who use VDC consistently see value for themselves and others in the process. Our individual interviews confirm the survey data but indicate that subcontractors may actually receive the most direct financial benefit.

Figure 8 shows that in 2007 respondents reported value in every project phase except operations and maintenance. The most significant use is in Design Definition, and the biggest increase in perceived value occurred during Conceptual Design. Interviews with advanced architect users reported that a primary source of value from VDC use was reduced effort to prepare

Construction Documents, which they significantly automate. They then increased time and percentage of effort in earlier design phases, which increased value to the client. These data suggest that the AEC level of influence curve [Paulson - 1976] applies to these VDC users, who report that VDC use helps them make design changes more effectively early in the project lifecycle.

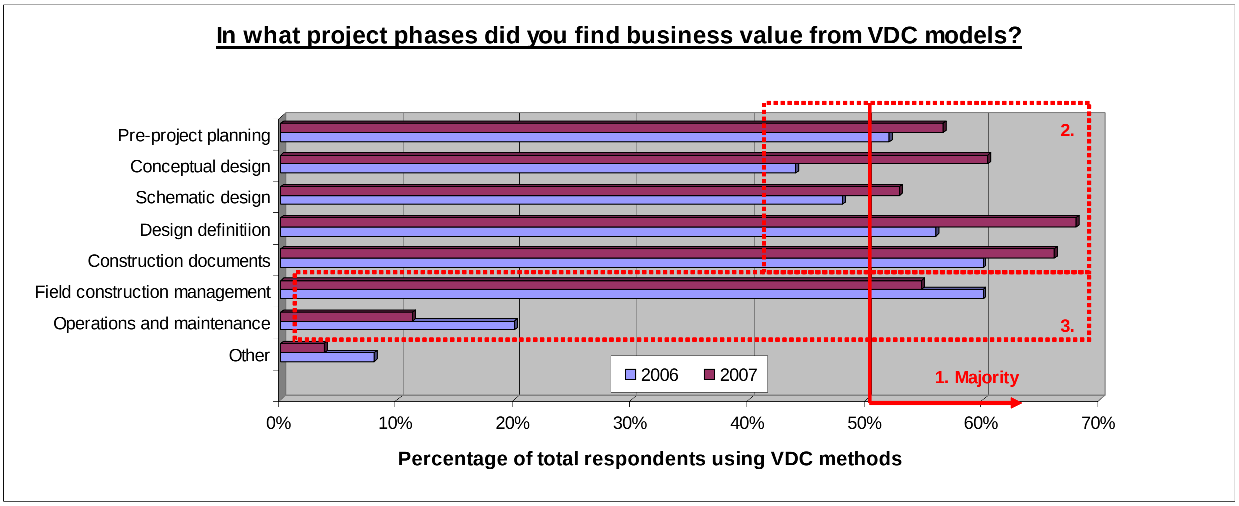

Figure 8: The majority of VDC users now find value in every part of the design and construction process. 1: The majority of respondents see value in every phase except operations and maintenance. 2: The biggest gains were in the design phases. The conceptual design and design definition phases in particular increased by more than 20% such that over 60% of respondents report seeing business value in theses phases. Both Field Management and Operations and maintenance decreased with the latter lagging far behind the rest of the survey. This point is supported by our individual interviews that indicate that owners rarely ask for VDC models to support their ownership even though those that do see great value in doing so.

Interviews also reported that operations and maintenance lags the rest of the functional phases in terms of perceived value, and only 20% of those interviewed said they were incorporating O&M data in their modeling effort. Service providers report that owners simply are not asking for facility maintenance information in BIM format, and owners indicate that they do not see a need for it. Since owners are the only party that would benefit from an operations and maintenance supporting model, and are the party least likely to use VDC, it is not surprising that this area lags the rest. Additionally, interviews with Fluor and Bechtel, parties to the process and power industries, which design, build and often own their projects, indicate that information required for the design and construction phases differs greatly from that needed to make a successful operations and maintenance program. These interview findings suggest that project models developed for design and construction will not be useful for owner operation without further definition and population with the specific information they need. The potential business opportunity or marketing edge for design and construction service providers who could provide viable (O&M) models to their owner clients is real. The fact that owners are not asking for them indicates that they find the cost to change their O&M process to create and use VDC remains prohibitive, that they are unaware of the technology, or that they are unwilling to take a risk on an unproven method. Some architect and construction companies, such as Design Atlantic, Holder Construction, and Emcor subsidiary Trautman and Shreve find that there is specific benefit in marketing O&M features to customers. Holder has developed a proprietary system for adding data attributes to their models which link their 3D VDC model directly to maintenance manuals, sequence of operations data, and warranty information. Trautman and Shreve have done the same and have been able to gain long-term guarantees of future work based on their 98% accurate digital as-built knowledge of the owner's facility. Studies of these three companies O&M efforts on two projects are included in Appendix 1.

Users indicated an increased sense of the marketing impact of VDC in 2007 in both a positive and negative way. From Figure 9 it is clear that nearly two thirds of respondents in 2007 saw significant value of new projects won based in part on competitive advantage gained through VDC use. The previous year, less than half of respondents reported an increase. Indeed, Holder Construction indicated that their success rate on winning bids using the technology was as much as twice as high as those on which they did not propose to use it. It is clear that the diversion of non-users past detailed questions had a dramatic effect on the rate of respondents saying they did not know the overall impact of VDC. In 2006 more than half the survey respondents said they did not know the marketing impact of their VDC use. Cross-tabulation with non-users shows this category to be close to a third of total respondents, which is similar to the 25% of respondents calling themselves non-users in 2007.

Nearly 17% of respondents indicate that the use of VDC *reduced* the value of new work won. None of these respondents agreed to be contacted for further information so we could not use interviews to explore the result. Interviews with other companies did not suggest any negative value. Data cross tabulation indicates that some respondents citing negative value also said that they saw value in VDC use and that it might allow them to reduce contingency on future projects. This inconsistency with reported reduced value of new work suggests that some respondents may have found the intent of the question confusing. They may also find that VDC provides benefits but that their cost to implement VDC puts them at a competitive disadvantage overall.

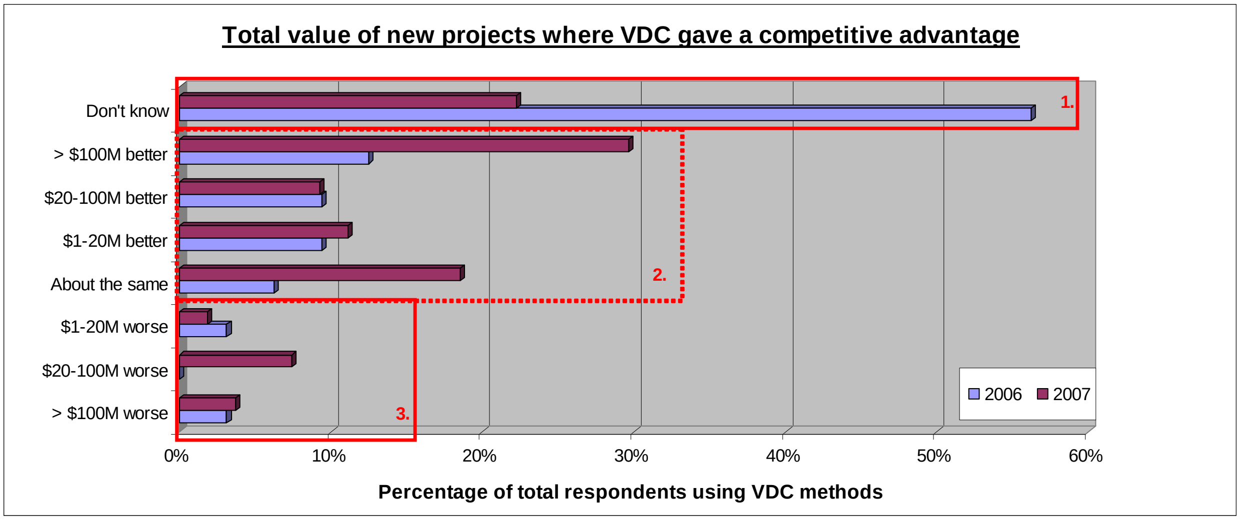

Figure 9: Respondents perceived a value to VDC as a competitive advantage for winning new work in 2007. 1. The number of respondents reporting they did not know the value of this competitive advantage shrank dramatically due in large part to the new survey structure that diverted non VDC-users past this question. 2. The proportion of respondents who felt that VDC gave them greater than $100M additional new work more than doubled and the near majority of respondents felt use of VDC gave them some advantage. 3. Those perceiving a disadvantage resulting from their VDC usage grew by a significant margin as well. Our individual interviews do not reinforce or provide explanation for the lost-value data as yet, however, and this survey question did not allow explanation of this loss.

The nature of impediments to realizing value from VDC use is changing. As the use of VDC increases, the need for qualified personnel and third-party firms to produce models is increasing as well. Perhaps the most significant signal of actual increased adoption of VDC is in the perception by users that staff availability is now a bigger obstacle to deriving value from VDC than are software and hardware issues. As can be seen from Figure 10 below, this perception has increased dramatically from the previous year and overshadows technical or cost impediments that have stayed consistent or decreased between survey years. Survey respondents saw a lack of training and availability of staffing as the two biggest issues, both surpassing lack of hardware and software tools that were the biggest concerns the year before. Additionally, contractual impediments, previously the second biggest obstacle, decreased dramatically in the past year. Interviews indicate that lack of qualified contracting parties and pre-trained personnel are limiting the ability to implement VDC on a wider basis. Companies are trying to move forward on implementation through on-the-job training and offsite 3rd party training which often results in less efficient first steps toward implementation.

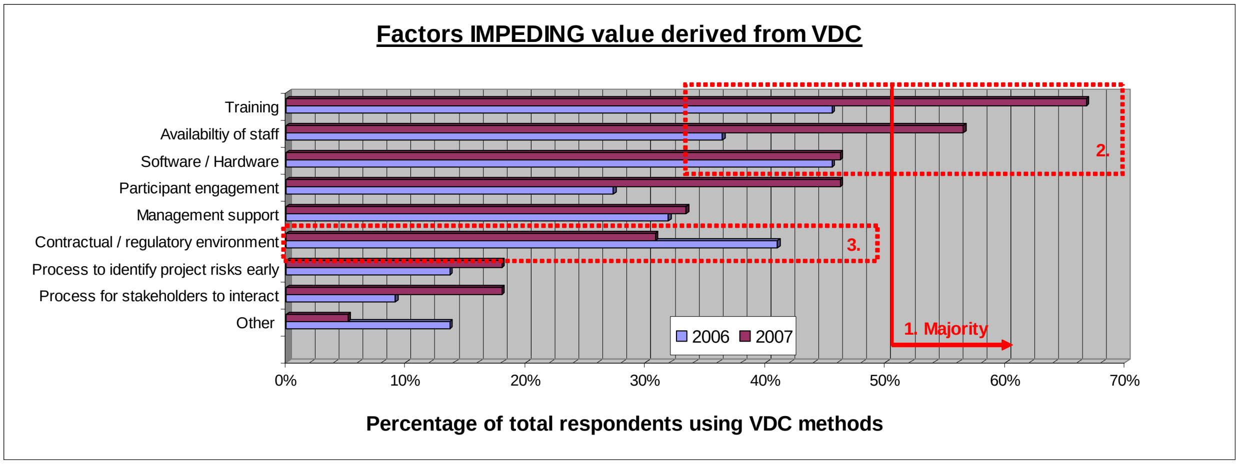

Figure 10: Respondents reported a significant shift in their perceptions of the principal impediments to deriving value from VDC. 1. The majority now see training and availability of staff as most limiting. 2. Greater growth in concerns over personnel issues pushed technical concerns with software and hardware from the biggest concern 2006 to a somewhat distant third position in 2007. 3. Contractual language dropped by nearly half from the 3rd to 6th most significant impediment. The data suggest that as VDC use grows an increasing scarcity of trained personnel is beginning to dominate contractual and technical issues.

As dramatic as the increase in perceived value was in Figure 9 and Figure 10, respondents only reported qualitative value. Indeed, more than 80% of respondents stated that they do not track performance on VDC projects separately from non-VDC projects and fewer than 20% of respondents said that their cost information was based on formal company records. In interviews, a minority indicate they quantify VDC performance data, and many interviewees indicate they find it difficult to track quantitative data for metrics on the impact of VDC. Interviews report that some do not know what data to track, and many do not know how to attribute or credit change in performance directly to VDC use on a given project.

We suggest that the perception of great qualitative value by VDC-users in the face of a general lack of quantitative data is a by-product of the complex nature of the construction process. There are simply too many variables for users to feel comfortable attributing success on a single project to one specific part of that process with any certainty. Results may not be replicable exactly from project to project for just the same reason. However, where well implemented, VDC allows for better mutual understanding of project requirements and helps avoid many problems by finding them virtually before they become actual problems in the field. Increased cooperation and trust between stakeholders and decreased pressure to handle problems when time is critical helps users see value even if they can't quantify it directly.

The data thus far show an overall trend toward a greater perception of value that both drives and is reinforced by significant efforts made toward implementation of VDC. This perceived value is shared by all parties, but seems to be especially strong for designers as shown by the growth in perceived value during the design stages and the dramatic increases in efforts and progress by designers reported in the last section. As growth in use increases, more pressure will be put on the relatively limited supply of qualified personnel and the need for training and the market for qualified individuals will grow as well.

VDC Users and quantitative value

While most value reported by VDC users is qualitative, we found significant data supporting quantitative value as well. In particular, reported benefits include increased participant and stakeholder engagement, reduction of risk and contingency, reduced cost, improved schedule conformance, and reduction in latency, or the time that stakeholders wait between asking a question and receiving an answer that enables them to proceed with their work. Many users who report specific quantitative impacts track numbers of issues caught using VDC methods that would normally be found in the field, the number of RFIs, or cost of change orders, between a given VDC project and other projects of similar size and scope on which VDC was not used. Some assign estimated costs to interferences avoided virtually based on past costs for similar issues or estimating the cost of delays avoided. One interviewee, DPR Inc., provided a detailed analysis of quantitative benefits on a medical office building project in Mountain View, CA on which they performed extensive clash-detection and elimination and prefabricated 90% of mechanical materials off-site. They tracked actual labor-hours in the field and total hours of rework on HVAC duct and pipe installation and compared these with their bid estimate that was based on traditional methods that did not include clash detection or assembly of materials on site. A case study for DPR's Camino Medical Building project in Mountain View, CA is included in Appendix 1.

Figure 11 shows some of the principal benefits reported by users of VDC methods. Survey data indicate, and interviews support the finding, that use of VDC methods provides a medium for improved participation by project staff and engaged stakeholders in general. This benefit can lead to both improved productivity and decreased latency by improving the quality and timeliness of communication on projects using VDC. Specifically, several interviewees stated that working from a common 3D model improved all stakeholders' understanding of the scope and intent of the design. Designers, owners, and builders alike said they gained a better appreciation of each others' due diligence, better understood their concerns, and had increased trust in them as a result. Turner Construction, in particular, reported that resolving conflicts in complicated hospital MEP systems during design detailing that might have taken months in a traditional process, took a collocated team using a common 3D BIM only hours to resolve. Increasing the engagement of key project stakeholders is a key area for improvement on most construction projects as shown in Figure 12. The data on improved stakeholder engagement and reduced risk and contingency benefits shown in this figure are reinforced by the results of other survey questions as well. Figure 13 – 16 demonstrate that a significant population of users sees reduction in risk as a key benefit of VDC use. Figure 17 shows that some users can quantify the actual improvements in latency that they enjoyed from using VDC methods on their projects.

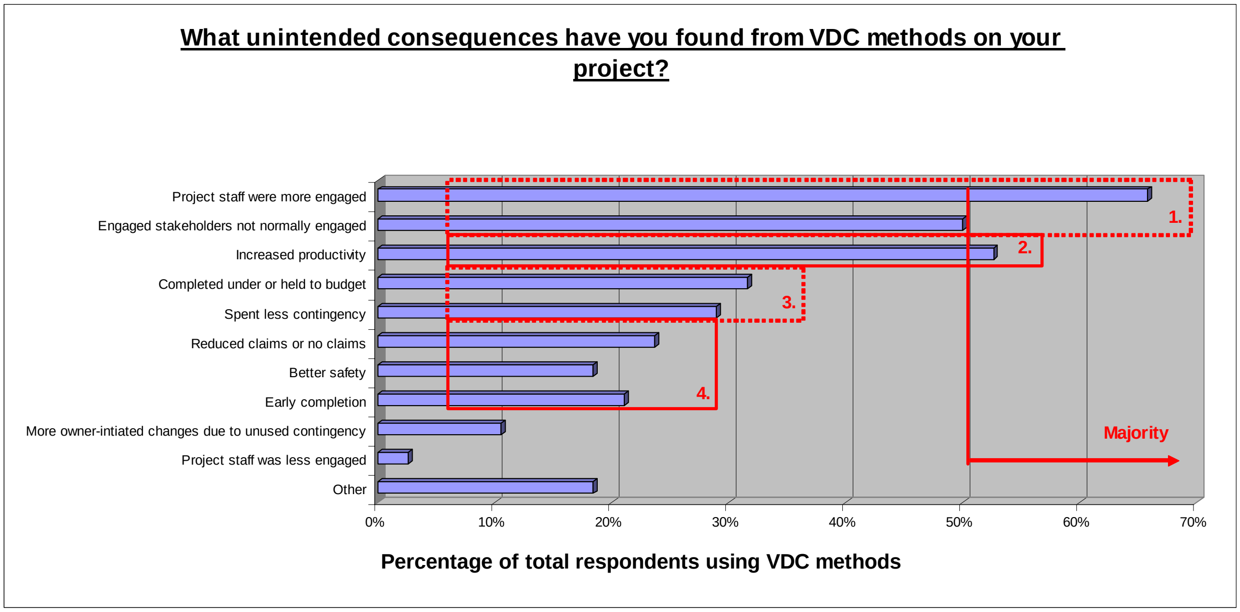

Figure 11: VDC users reported many specific benefits. 1. The majority of respondents reported that VDC helped improve project staff and other stakeholder engagement. 2. The majority of users report increased productivity. 3. Roughly 30% of users report benefits to maintaining budget and reducing contingency as a result of VDC use. 4. Significant numbers of users report improvements to claims, safety and schedule.

Of particular interest given the data in Figure 11 are the data indicating that participation by key project stakeholders is low on current design projects. Figure 12 indicates that for over half of all respondents it is common to have only 20% or less of these stakeholders involved in design reviews. Indeed, less than a quarter of projects engage the majority of stakeholders in these reviews. This finding represents a major need for improvement in the design and construction process, and, as shown above, VDC methods can provide an important tool for improving such engagement.

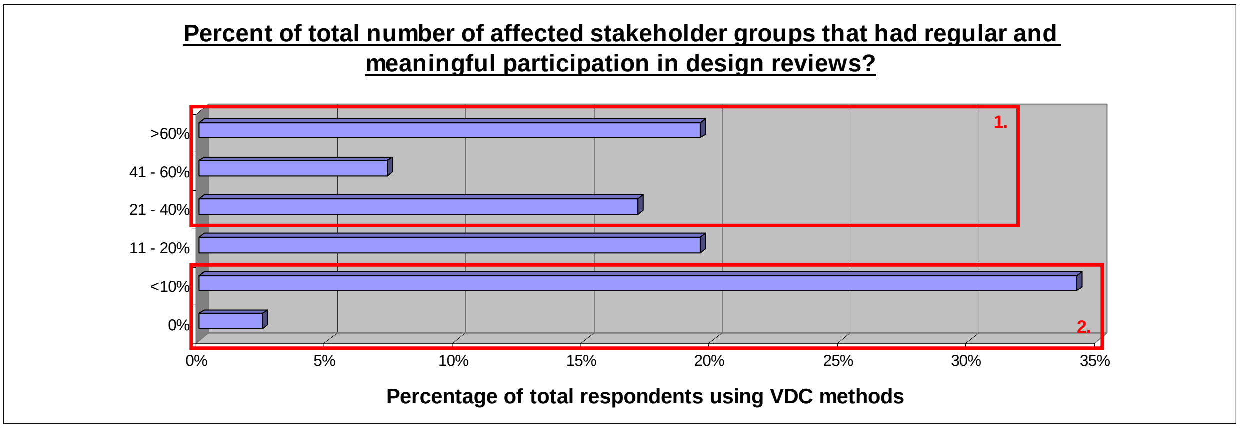

Figure 12: Participation by stakeholders is currently a great potential area for improvement in the design process, and users report that VDC helps improve participation. 1. Roughly half of respondents said they saw more than one in five affected stakeholder groups had meaningful participation in design reviews on their projects. 2. More than a third said fewer than one in ten affected stakeholders participate in design reviews.

A significant portion of respondents indicate that they already allow less contingency on current projects using VDC as compared with projects that do not, and nearly a third say they will make this shift on future projects using VDC methods. Figure 13 shows that approximately 18% allow less contingency now, and Figure 14 shows that 24% will allow less in the future. Interviews with subcontractor entities in particular, related that their main reason for assigning contingency was the risk of labor productivity in the field. They indicated that performing extensive clash detection and off-site material fabrication helped remove the uncertainty of this productivity by reducing or eliminating field conflicts and shifting assembly to the field where productivity is both higher and more certain. Some interviewees said that they covered the cost of BIM modeling out of their contingency costs believing that they would always at least cover this investment in avoided problems. One subcontractor reported reducing his bid by over 5% upon signing a scope of services agreement with the GC and owner that all parties would use a common VDC model for clash detection. Indeed, one subcontractor entity, Emcor Group, related that their company will use BIM even if they are not compensated and no other stakeholder agrees to use it. They create their own 3D building model, including work to be done by other contractors, simply to provide themselves protection in the case of changes or clashes once work commences. Thus, the modeling cost is made up by a guarantee that either they will not have to change their plan of work or they will be able to use the model to justify full compensation in the event they are asked to change. These perspectives allow a great potential for competitive advantage, and the fact that so many more stakeholders plan to allow less contingency in the coming year as did so this year indicates that the industry is catching on.

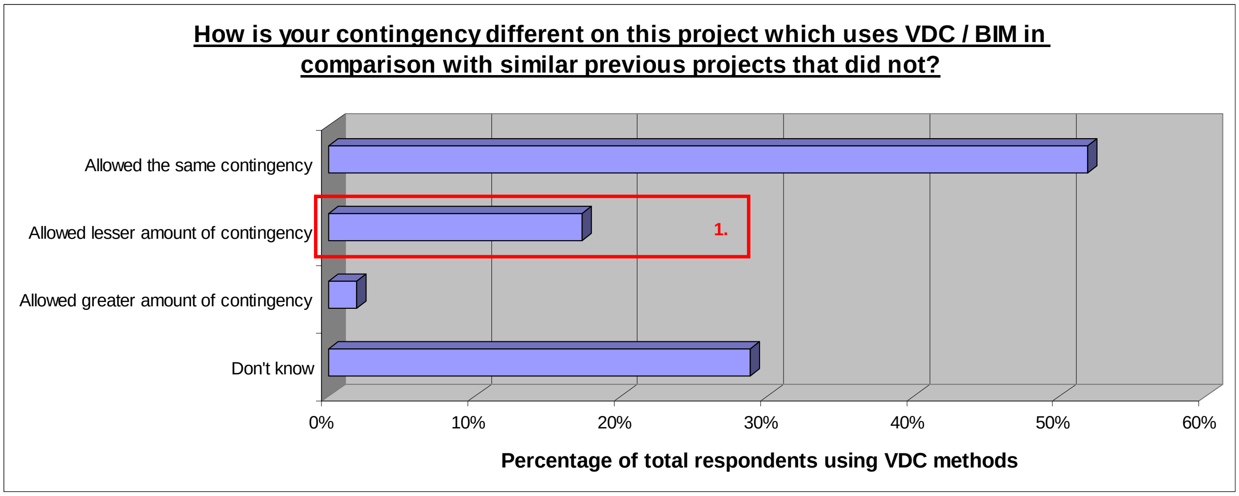

Figure 13: 1. 17% of VDC users report they reduced their contingency on projects using VDC as compared to projects that did not use it. Many interviews support these data and indicate that while VDC users see the potential for the technology to greatly reduce their project risks, they have not typically quantified this benefit and choose to maintain their contingency as a hedge.

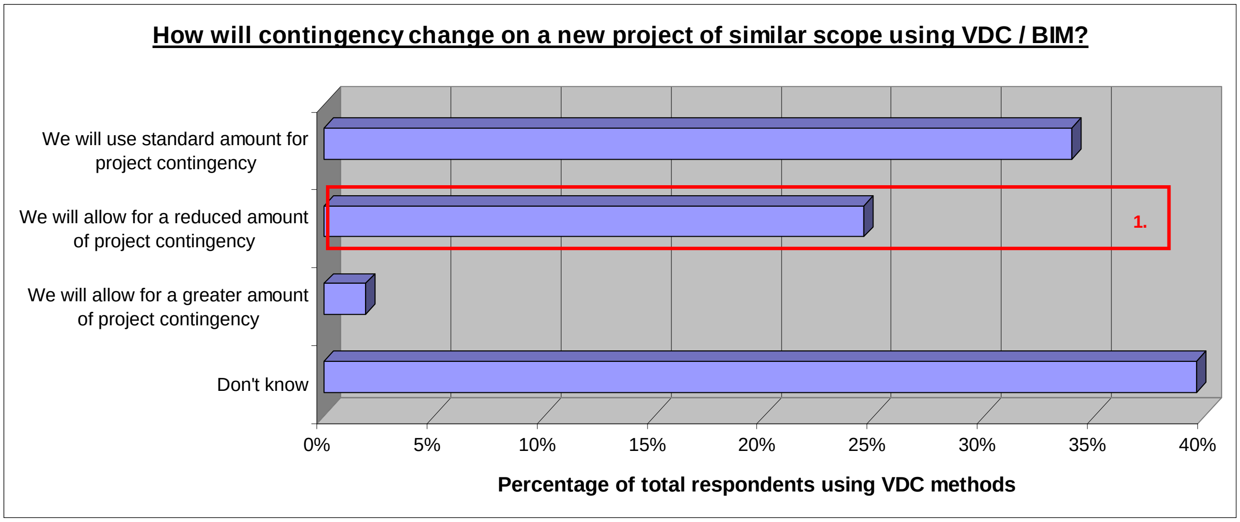

Figure 14: 1. 24% of VDC users reported that they will allow less contingency on future projects using VDC. About double the rate of those who have already reduced contingency, this finding suggests that users are gaining confidence with the technology.

In Figure 15 it is apparent that significant numbers of users see reduced risk from VDC use or from contractual shifts made in conjunction with VDC use. The majority sees less overall risk even with the same contract structure. 30% of respondents report reduced risk associated with using contractual alliance structures associated with VDC use to distribute it across the various parties to the process. Interviews support the notion that contract structures involving VDC use and distributed risk alliance structures are becoming more desirable to project participants given the potential benefits involved in cooperative work. Of all interviews, over 60% said that they had signed some form of VDC scope of services agreement to define what work would be done and by whom, and over 75% said they had some form of collaborative contract delivery method such as design-build, design-assist, or use of a common model by all project stakeholders during design detailing. One interview with a general counsel at a general contracting firm indicated that traditional views of the risks of sharing information between stakeholders was flawed in that liability is no more and probably much less with stakeholders working together collaboratively from a common understanding of scope than at arms length. Indeed, owner Sutter Health in California has determined that collaborative delivery methods (which they call "Lean Delivery") combined with use of VDC by all parties from the initial design stages will be the future for all their projects. Two Sutter Health Projects, Camino Medical Building and Mills Peninsula Hospital, are included as case studies in Appendix 1. We suggest that these data imply a dramatic shift in the view of the benefit of collaboration and the enabling role of VDC.

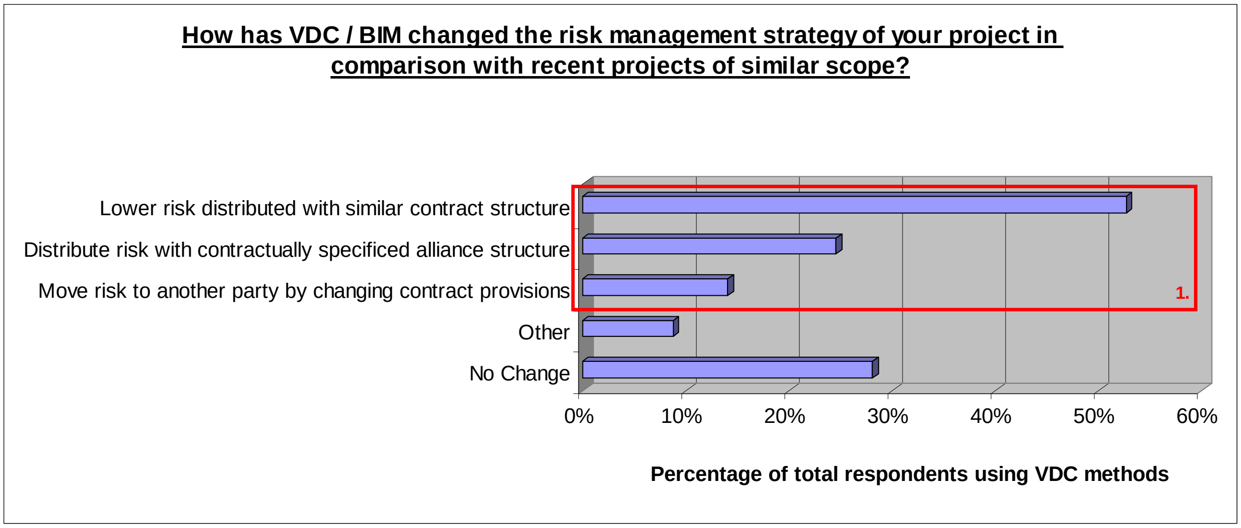

Figure 15: The majority of VDC users see some reduction in risk associated with projects on which they used VDC. 1. The majority of users saw reduction with similar contract structures while significant numbers of users used structured alliances or contract provisions to distribute or shift risks among the contract parties.

The cost and number of unbudgeted change orders provide a good measure of risk to project participants. Figure 16 shows that a significant proportion of respondents see improvements in unbudgeted change orders in association with use of VDC methods. 20% see greater than 10% improvement, while roughly 8% see improvement between 2-10%. These numbers improve somewhat when cross tabulated for Architects, Builders, and Owners who have four or more projects using VDC. Roughly 33% of these veteran users report 10% or greater reduction in unbudgeted changes. These data are reinforced by interviews, which indicate that VDC is especially important in the avoidance of clashes between trades in the field, and in avoidance of changes requested by owners who are able to test their reactions to designs virtually prior to start of construction. Architects such as Design Atlantic of Salisbury, MD report using automation-phase VDC in the pre-project and schematic design stages in order to accurately define their customers' needs and to test both the function and cost impact of their designs at that early stage. On a current project building a fire station for the city of Salisbury, they feel they have been able to use VDC to avoid all unbudgeted change orders and are on track to complete construction of the project at within 0.6% of the original programming budget for the project. Design Atlantic's experience on the Salisbury Fire Station project is included as a case study in Appendix 1.

Despite such successes, the majority of current-user interviewees, and even veteran users, are still hesitant to tie VDC use directly to any specific cost savings. Figure 16 indicates that nearly 60% of all respondents do not know the impact of VDC on unbudgeted changes, and even 50-67% veteran users report they do not know. Interviews indicate few stakeholders have methods in place to track changes in cost and associate them directly with VDC use. These interviewees are often hesitant even to tie VDC use to a specific reduction in the number of clashes or conflicts as they cannot be sure how many of those would have been caught in the traditional design-review process. We suggest that a major reason for the high proportion of users showing such hesitance is the fragmented nature of the construction process that makes each project a unique situation not readily reproducible even between projects that are similar in scope.

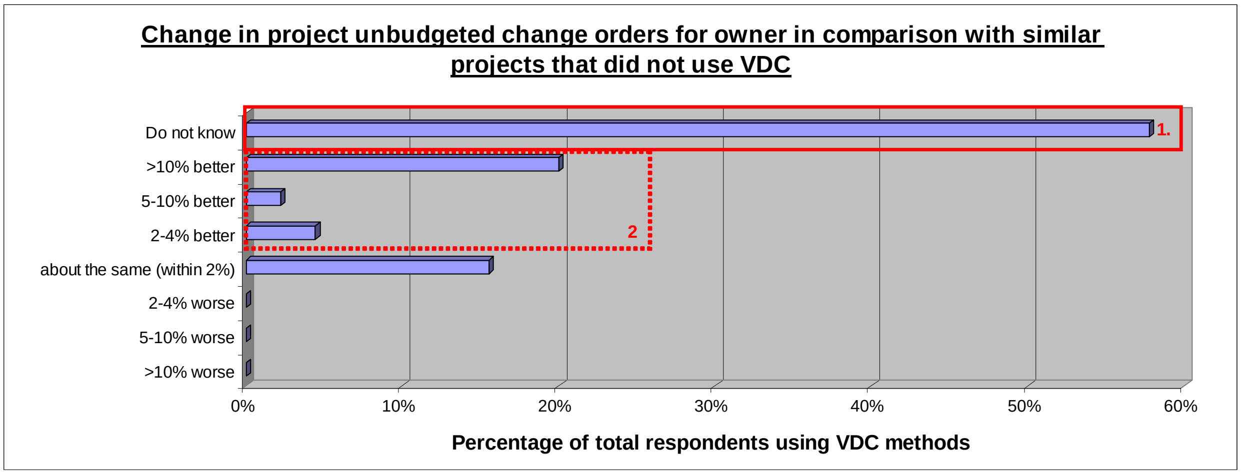

Figure 16: Unbudgeted change orders are often less on projects using VDC and represent another aspect of reduced risk. 1. The majority of users do not know or are hesitant to tie the impact of VDC to reductions in unbudgeted changes. 2. However, more than 25% of users see some significant reduction in these changes on projects using VDC.

Latency is a readily measurable quantitative metric of effectiveness of stakeholder participation and communication. Since the majority of respondents see improvements to participant engagement as a main benefit of using VDC methods we expect significant reductions in latency as well. Figure 17 shows that, indeed, 40% of respondents see some improvement in latency resulting. While roughly half of VDC users reported that latency remained the same, half reported improvements of more than a day, and 15% saw better than a week of improvement. Latency improves among veteran respondents, 60-80% of whom report two days or better improvement with VDC use. Interview data support this correlation of latency improvement to VDC use. Many interviewees tied the improvement to a combination of removing the need to interpret the intent represented in 2D drawings, a typical source of misunderstanding, and the use of a common model which removes a potential for discrepancies between the details from which each party works. These improvements are further magnified when the improved communication medium offered by VDC is combined with collaborative contract structures such as design-build or design-assist, especially involving collocation of personnel either physically or via regular on-line meetings. Indeed, trust and cooperation both enable and follow improved latency, and interviews consistently indicate that all three improve markedly with VDC use.

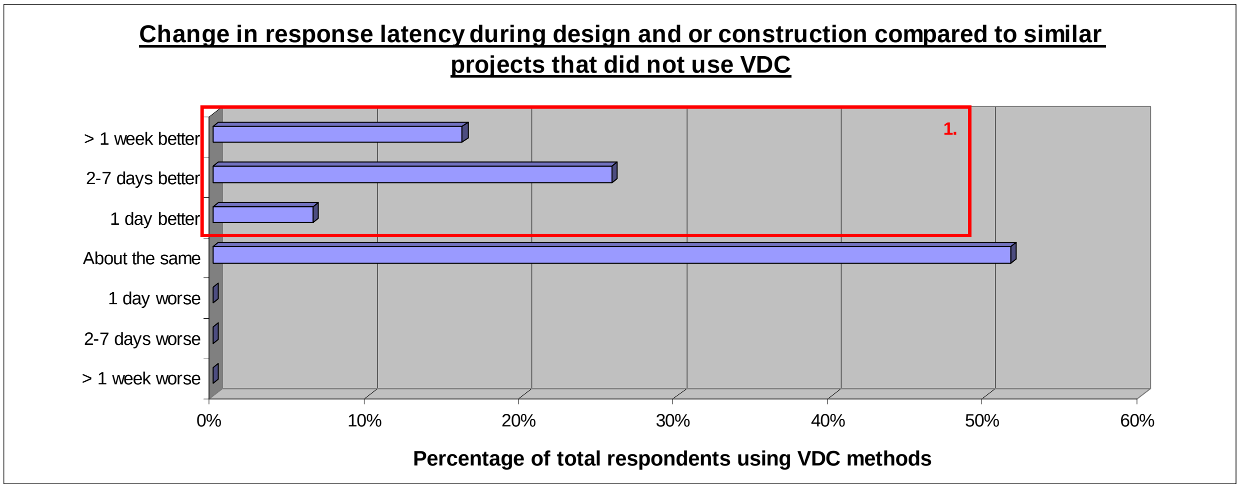

Figure 17: VDC users report dramatic improvements in Latency on projects using VDC, a finding that is also supported by interview data. 1. Roughly 40% of users report improvements of two or more days in response latency over projects on which they did not use VDC.

Users in the areas of cost and schedule reported less dramatic, though still significant, improvements. Figure 18 shows that while the great majority of VDC users do not know the cost impacts of their use of VDC methods, roughly 15% see some significant improvement. As discussed above, interviews suggest that VDC users lack a good tracking method for cost impacts and therefore do not quantify them. We suggest that even though respondents are uneasy assigning a quantity to this metric they are likely to feel cost benefits in qualitative terms. For example, Figure 11 data indicate that nearly a third see budget conformance as a benefit of VDC use. Interview responses overwhelmingly say that increased participation and communication, clash detection, and visualization techniques prevent problems normally encountered in the field that lead to increased cost.

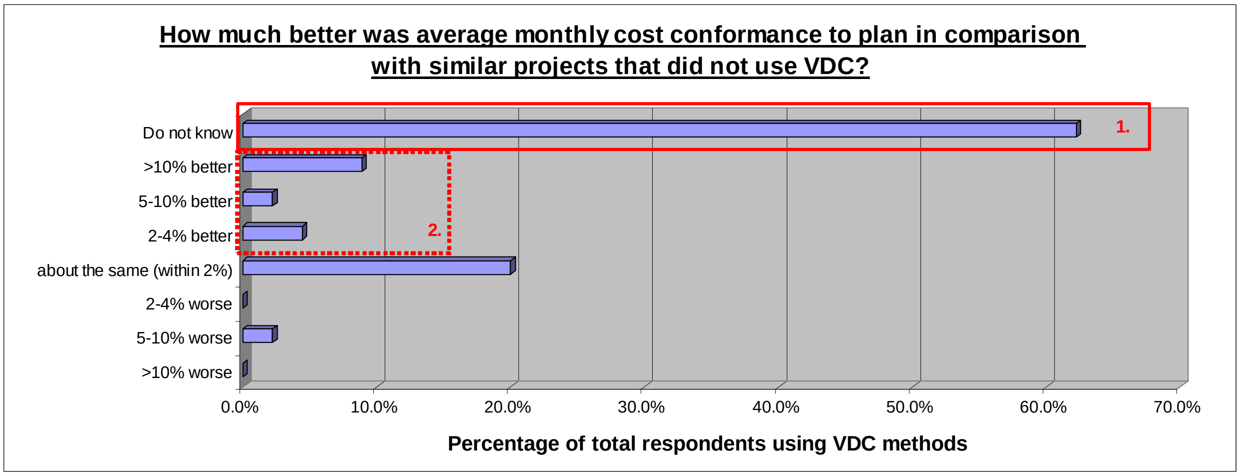

Figure 18: Many VDC users attribute some improvements in cost conformance to VDC use. 1. The majority of users do not know the impact, or, as found in interviews do not feel comfortable attributing cost conformance changes directly to VDC. 2. However, roughly 15% of users do attribute significant improvements in cost to VDC use.

Similar to cost benefits, users do not routinely quantify schedule benefits. Survey data indicate less than 20% of VDC-user survey respondents track final schedule performance quantitatively. Figure 19 shows that of the users who do not track such data quantitatively, 45% say they do not know the schedule impact of VDC at all, and nearly 30% could not comment since the project was ongoing. 12% say they see some improvement in schedule due to its use, and roughly 7% see some worsening in schedule conformance. Neither the survey data nor interview responses provide explanation or support for any negative impact of VDC on schedule. We suggest that these negative data are likely due to issues attributable to the specific project and not necessarily related only to VDC use.

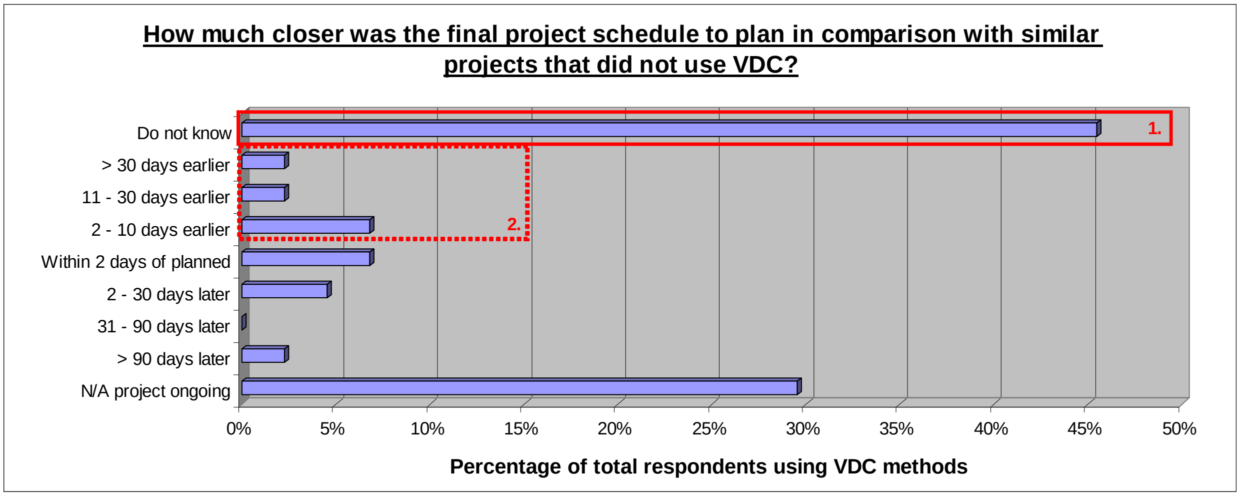

Figure 19: VDC users report some improvement in final schedule performance on projects using VDC methods. 1. 45% of respondents do not know the impact of VDC on schedule conformance, and less than 20% say they track this issue quantitatively. 2. However, roughly 10% of VDC users attribute use of VDC methods with some improvement in final project schedule conformance.

VDC Users show sophistication

Survey respondents show distinct strata in the level of sophistication of their VDC programs, as demonstrated by the phase of VDC implementation they achieve. We compared results between the total population of VDC-user respondents and veteran users with more than four VDC projects and note a general trend toward increasing sophistication. The majority of all VDC-users are working with visual and predictive phase methods such as 3D design presentation and clash detection, while fewer than the majority use it for more integration or automation methods such as direct-generation of cost estimates and automating shop drawings for fabrication from 3D models. The numbers of veteran users achieving these later phases of VDC implementation are much greater. Whereas the majority of users today may not be optimally sophisticated in their activity, experience shows, and the data suggest, that as their proficiency with individual technologies and their interoperability improves their use will grow in sophistication.

Figure 20 shows the business purposes for which VDC was used in 2007. The data demonstrate the range of sophistication of respondent VDC programs. A majority of users conduct 3D visualization and clash detection. Users report significant use of 4D scheduling and visualization of design as well as enhancement of field processes such as submittals, shop drawings, safety management, and cost estimation. Some automation of engineering analysis and shop fabrication can be seen. While these rankings vary slightly by community of respondent (architect, general contractor, owner, etc.) they are generally consistent across them.

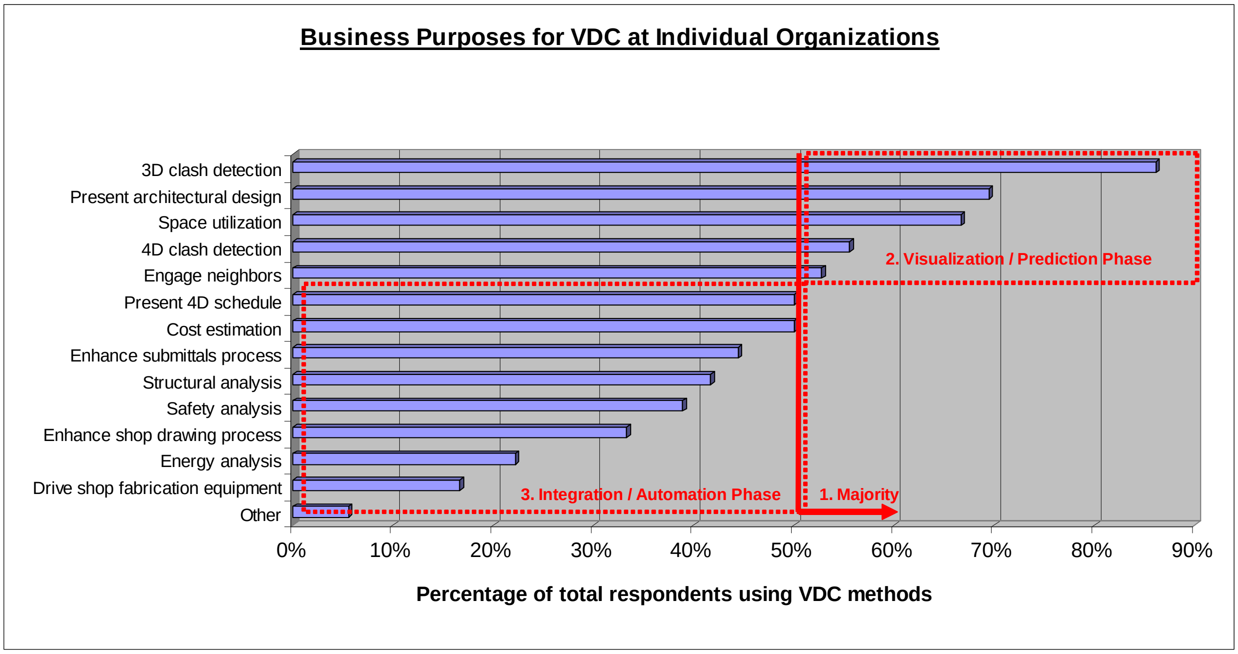

Figure 20: Respondents reported a wide range of purposes for VDC models. We classify the top four purposes as "Visualization", which is the first phase of implementing VDC. The vertical line representing a majority of respondents falls on the boundary between purposes supporting Visualization and the next phase of Integration and Automation. The data indicate that users first reach the Visualization and prediction phases, and the majority of respondents have this level of implementation and sophistication. 3. The data then show that less than the majority of users now reach the more advanced and sophisticated phases of VDC implementation, namely Integration and Automation. These data are supported by interviews in which the majority of users seek first to use visualization and predictive methods such as clash detection next, while a smaller number begin to use automation to fabricate materials off-site or generate design documentation automatically.

Of particular note in Figure 20 is the use of 3D clash detection, which almost 90% of respondents report as a business purpose of their VDC use. Interviews indicate that this may be the easiest and most productive use of 3D VDC models in field construction management. Most interviewees who successfully use VDC indicate that they achieve great success at avoiding field coordination problems by eliminating conflicts virtually before ever breaking ground. Indeed, more advanced users begin to trust this coordination enough to perform off-site fabrication and assembly of materials such as ducting, piping and structural steel. Companies at this level report, for example, report as much as 90% offsite fabrication of pipe and ducting as a result of their 3D VDC modeling. The ability to fabricate offsite to a specific design increases the proportion of labor done at the shop where it is more consistently productive and less impacted by uncontrolled events. Interviews suggest that the biggest cost savings from VDC come from pre-fabrication. Emcor Group now regularly fabricates its material off-site and indicated that they assume a 10-15% reduction in labor costs as a result of shifting assembly work from the field to the shop. Emcor subsidiary Trautman and Shreve (T&S) now assembles sections of duct and piping to the larges size they can fit on a delivery truck and handle in the field. In another example, DPR Inc., indicated reductions in field labor hours of between 30-50% in the mechanical work resulting from offsite fabrication on a medical office building project in Mountain View, CA. Case studies of the T&S and DPR projects are included in Appendix 1.

As indicated above, the implementation of integration and automation phase VDC is higher by respondents who use VDC on more than four projects. Figure 21 demonstrates that the majority of these users are implementing tasks associated with these more advanced phases such as cost estimating from intelligent 3D models, automating and improving the submittal and shop drawing process, and enhancing off-site shop fabrication. Additionally, veteran designer and builder users of VDC are 100% likely to perform clash detection. Interviews indicate that all implementers of Integration and Automation phase VDC are veteran users, and that most veteran users interviewed are attempting to perform at least the off-site material fabrication process.

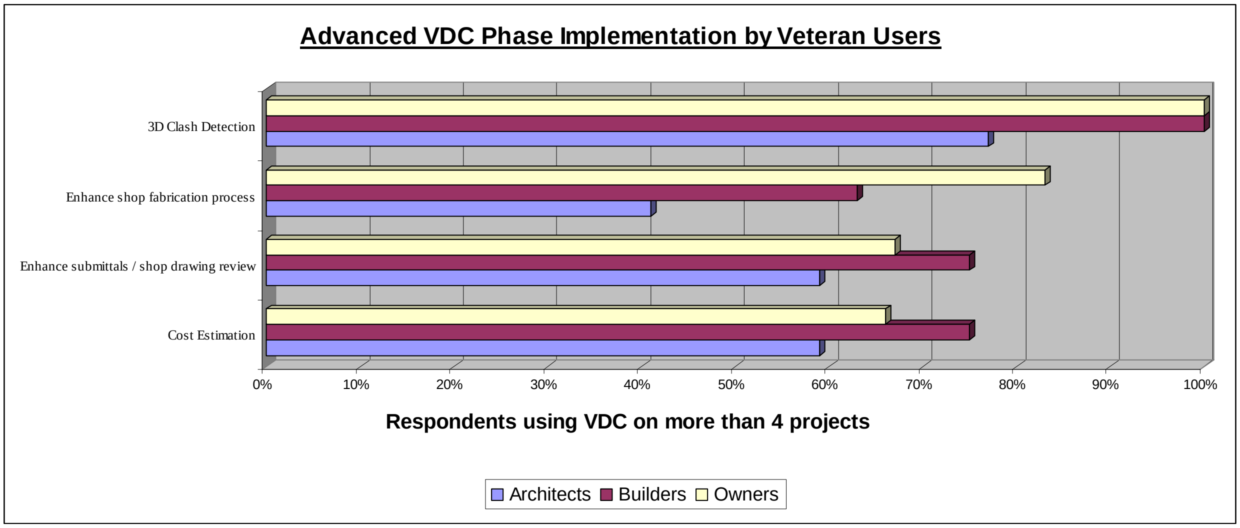

Figure 21: Integration and Automation phase VDC implementation is much more likely among key stakeholders who have four or more ongoing VDC projects than those with less experience. The data here clearly show that the majority of these respondents had achieved more sophisticated phases of VDC implementation.

Interviews also suggest that while it is preferable that advanced-phase VDC be implemented by all or most stakeholders on a project, there can be benefit even when only one does so. As stated above, Emcor Group requires the use of VDC on all projects, even those on which they are the only stakeholder creating 3D models. Emcor subsidiary Hansen Mechanical performed the HVAC and plumbing work on the Palazzo Hotel and Casino in Las Vegas from a 3D model where the only other project stakeholder involved was the structural steel designer and fabricator. From this nearly unilateral effort they were able to automatically generate take-offs of their material requirements, pre-order these in bulk for just-in-time delivery, and fabricate off-site all materials that involved only their coordination. The latter was especially important given the extremely large size of HVAC equipment required for a 50-story structure located in the desert. Emcor Group does not disclose specific cost savings data on their projects, but interviewees related that even where coordination problems occurred with non-user stakeholders, their approved model provided them liability protection and ensured that either their work was left in place, or that they were paid for any changes required. A case study of the Palazzo project is included in Appendix 1.

In addition to showing sophistication in the applications for which VDC was being used, the 2007 survey shows that users increased their reuse of information between VDC and other application platforms. Figure 22 demonstrates this trend. Of particular note was the high rate of information reuse between programs. Indeed, nearly 80% of respondents indicate they share their VDC models with 2D CAD, and roughly 64% say they generate their 2D drawings from their 3D models. There was a corresponding reduction in the numbers of respondents reporting that they recreated information, or manually created 3D models from 2D drawings between 2006 and 2007.

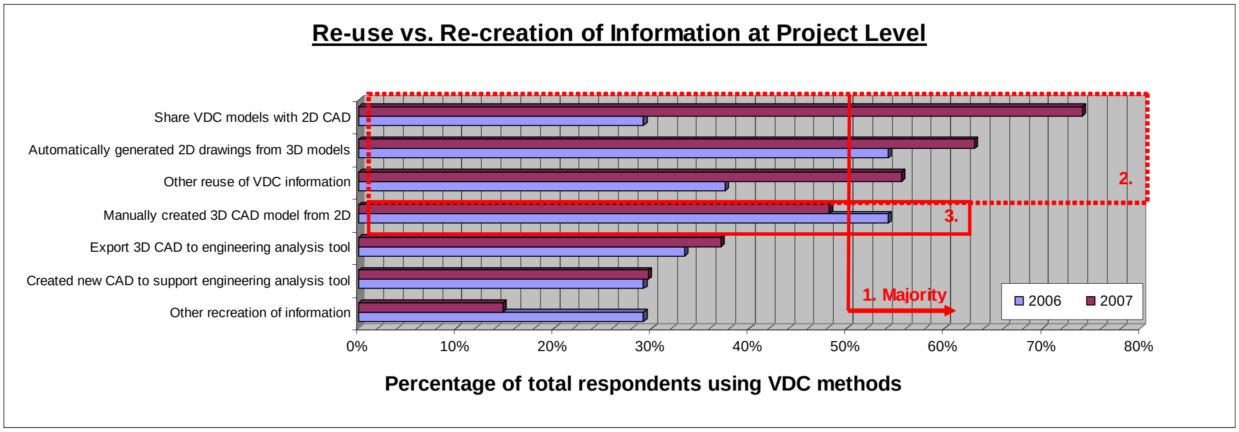

Figure 22: Another indication of VDC sophistication is the degree to which information is shared with non-VDC platforms such as engineering analysis tools and 2D CAD. 1. The majority of VDC users are now sharing and reusing key information rather than recreating it. 2. Sharing of 3D model data, generation of 2D drawings from 3D models and general reuse increased at a rapid rate, the former more than doubling since the 2006 survey. 3. Manual creation of 3D models from 2D drawings showed a slight decrease over 2006 and general recreation of information decreased by about half from the previous year. These data suggest that VDC-user capability and sophistication in model creation and information sharing is improving with time.

As in the past, many individual stakeholders require diverse information, and they must themselves provide unique and critical inputs to any effective VDC project. VDC both enables and requires that information to be developed in more detail and then shared and evaluated much more collaboratively and quickly than in the past. Thus, each project and participant must carefully support vertical (between functions such as operations and engineering), horizontal (between disciplines such as process piping and electrical design), and longitudinal (over time) integration of model creation, evaluation and use. For this reason certain contractual and team structures that allow for early sharing of information, such as design-build and design-assist, and the adoption of strict format and process controls tend to perform better. Additionally, interviews suggest that users find benefit in assigning maintenance of a single central model to one party and also defining the processes to share information between parties and between programs. Thus, management of the processes discussed in Figure 20 is critical to the successful implementation of VDC especially those that involve novice users or stakeholders that have not worked together previously. As stated above, more than 60% of those interviewed involved projects for which a signed agreement between the stakeholders defined the VDC process to be implemented. In the words of one interviewee, “VDC is not a Panacea…” Users must learn how their many business processes will work and manage well in order for VDC or the processes to be of value. Mismanagement of these processes can lead to frustration and missed-opportunity.

Established VDC users are expanding their focus

We see in the data a shift in early VDC adopters in 2007 toward both broader scale VDC use and organizational transformation based on VDC. This shift is very much consistent with the increasing perceptions of value and sophistication among VDC users noted in previous sections. As projects are attempted, users gain experience, overcome technical impediments and see greater value. This greater perception of value shows itself in breadth of use and shifting of organizational and project strategy to capitalize on that value.

Current users demonstrated a significant shift in their use of the technology from a focus on pilot projects toward broad scale use and even organization transformation. As Figure 23 indicates, the number of companies saying they would make broad scale use of VDC grew from approximately one quarter of respondents in 2006 to nearly 40% in 2007. Similarly, users saying they would transform their organizational strategy grew by a third from 28% to 38%. The number of pilot projects planned by respondents fell significantly, likely due to the structure of the survey that guided current non-users past this question. Though it is not possible to say with surety, we suggest that the reduction in pilot projects below the frequency of broad-scale use also indicates a shift toward more sophisticated capability and is driven by the reported perception of value on the part of the user-community.

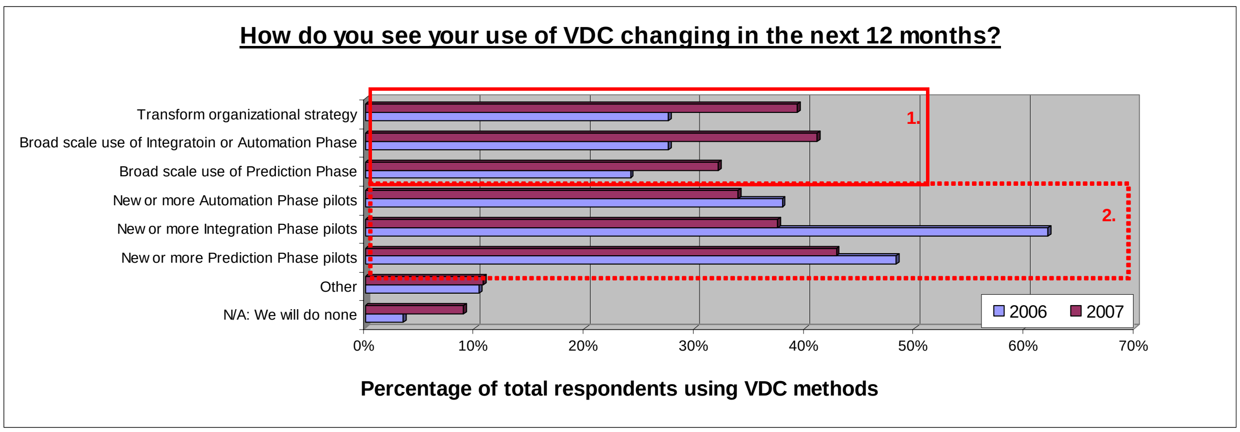

Figure 23: VDC users are shifting toward broad scale use and transformation of corporate strategy from simple pilot projects. 1: Users showed a 10-15% increase in likelihood to make broad scale use of VDC or to transform their organizational strategy based on VDC use. Cross tabulation of this question against large-scale users, those with greater than four VDC-based projects, showed that the majority are planning broad scale use of integration or automation phase VDC. 2: Users showed small to large decreases in plans to launch new pilot projects, including a nearly 50% drop in planned Integration Phase pilots. These data suggest that long-term users of VDC tend to move away from pilots and toward broad scale use of the technology.

The trend toward broad-scale implementation of advanced phase VDC and organizational transformation based on its use is more profound for veteran users than for the population of all VDC user respondents. Figure 24 shows that more than two thirds of veteran builders and owners plan organizational transformation versus less than 40% for all VDC users. It further shows that the majority or near majority of veteran architects, builders and owner plan broad-scale implementation of advanced phase integration and automation phase VDC versus roughly 40% for all users. We suggest that this higher rate is shows that with increased experience VDC users tend to expand their capabilities and that this is indicative of future growth in use and sophistication among current users today.

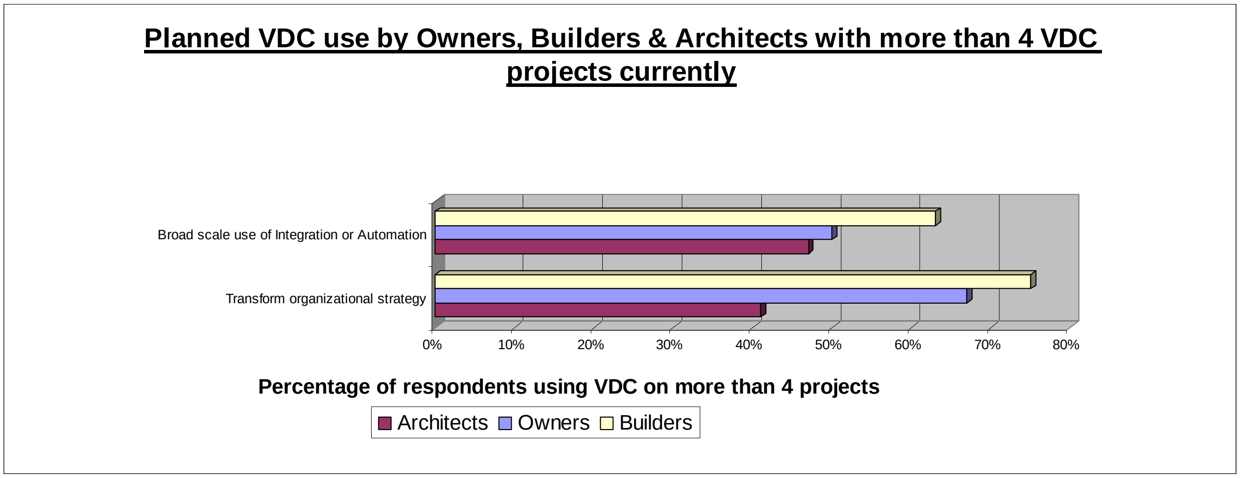

Figure 24: Veteran users, those with more than four ongoing projects, are more likely to attempt integration and automation uses, and they are also more likely to be planning organizational transformation using VDC in the near term than are pilot users. Broad scale integration or automation phase implementation is planned by more than 60% of builders and nearly 50% of owners, while more than 60% of owners and 70% of builders plan transformation.

Non-users are numerous but show signs of interest

Figure 25 indicates that roughly half the respondents to the 2007 survey said they did not make use of VDC / BIM in the previous year. 65% of owners said they were non-users and were therefore the least proficient respondent category. The rest of the groups have a roughly 40% rate of non-use of VDC. Slightly more than half of 2007 respondents -- including a clear majority of facility owners -- indicated that they were current non-users. These respondents also indicated that they would try VDC methods if it would improve process efficiency or if owners began asking for it. However, VDC users report that they find value in its use. That VDC users report finding new business and changing their basic business strategy indicates that these early adopters are exploiting a business opportunity given in part by non-user indecision and resistance.

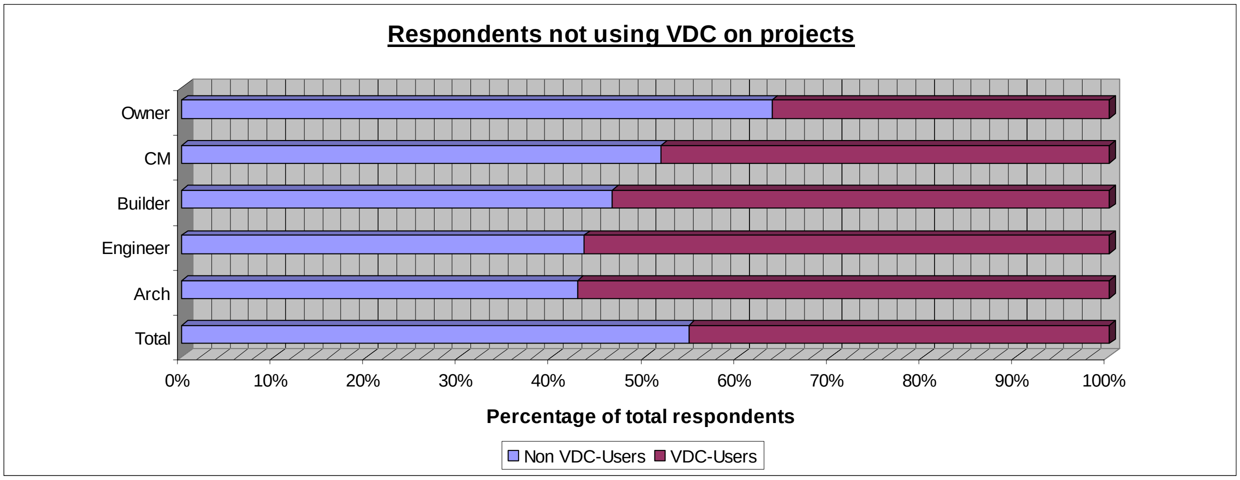

Figure 25: Owners are more likely to be non-users than the other parties to the design and construction process. In all, slightly more than half of respondents to the survey indicated they had not made use of VDC on a project.

As can be seen in Figure 26 below, nearly half of non-user respondents cited lack of need or request from owners as the primary reason for their not making use of the technology. In contrast, relatively few non-users, only 15% in all, say their non-use is due to being unfamiliar with the technology. Only 12% say it is too costly.

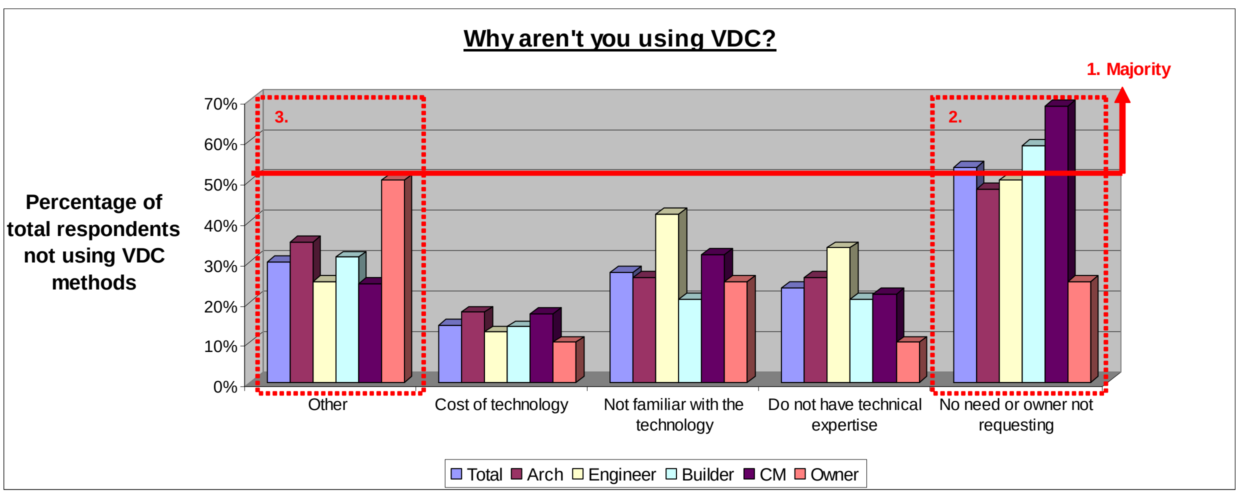

Figure 26: 1. The horizontal majority line indicates that there are several reasons that significantly contribute to non-users hesitance regarding VDC. 2. The most common single reason, cited by the majority or near majority of all parties, are lack of need or owner request. 3. The comments associated with the "other" response indicate that many non-users are in the process of starting a pilot project now, or did not have access to a designer or contractor with enough VDC experience to risk a first attempt.

Figure 27 shows that the majority of these same respondents said they would use VDC if they felt it would improve the design and construction process or increase overall efficiency. In particular, we cross-tabulated this information and found that 56% of owners say they see no need for VDC but 90% would use it to get more efficient projects. Similarly, while half of AECs said they don't use VDC because owners don't request it, fully 60% said they would use it if it would improve the process. The results indicate that Owners, who are least likely to be using

VDC technology, are the group most likely to start using it if a process or efficiency benefit were seen from doing so. Likewise, nearly half the respondents from the groups who would implement such programs on their behalf say they are looking to owners to make the first request. We see this situation as a classic case of a business opportunity where a proven solution is seeking a pool of potential beneficiaries who have only to be shown its existence and importance in order to be convinced.

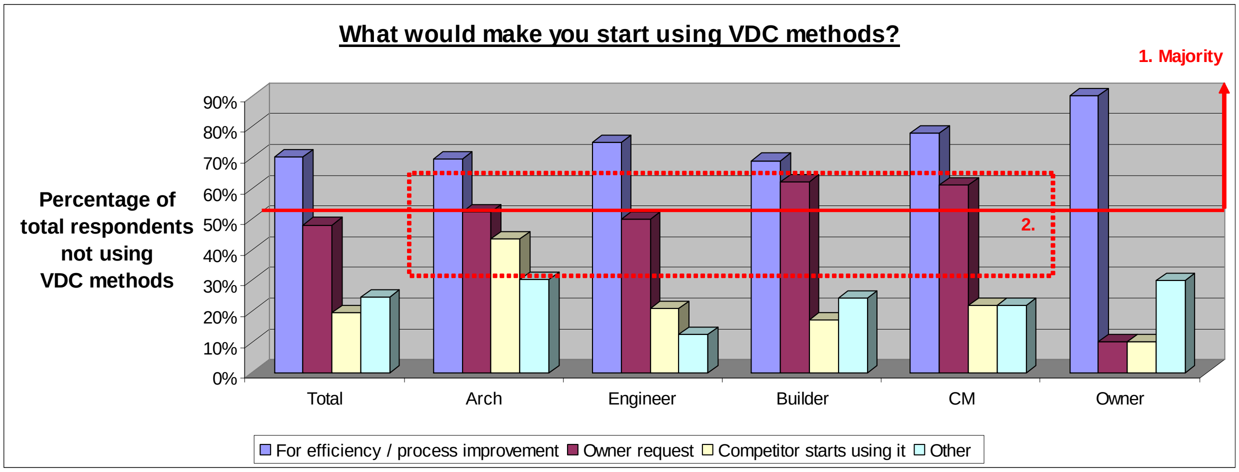

Figure 27: Improved process and efficiency and owner request are the leading reasons for VDC use. 1. The majority of all non-users, and nearly 90% of owners, say they would use VDC methods to improve process and efficiency. 2. The majority or near majority of all architects, builders and construction managers say they would use the technology if owners requested it. The data suggest an ironic logical disconnect given that most users see the value that non-users say they would begin using VDC to obtain value. This disconnect represents a potential business opportunity given that most professional service providers would use the technology if their clients requested it, and those clients indicate overwhelmingly that they would use the technology to gain the exact benefits experience shows they would get.

We suggest that a latent demand exists for VDC technology that will become more apparent as time goes by and VDC-capable companies become more sophisticated. Owners and other parties who are current non-users of VDC overwhelmingly say they would use the technology to get better results, and data from VDC-users tend to indicate that these results are being attained. Where providers demonstrate the potential value to owners it will ever more frequently be accepted and those who can provide the service early on will benefit most.

Conclusion

The VDC Value Survey data indicate that VDC has very significant use in practice; users find significant value, and its use is growing in both numbers of users and intensity of application. As the intensity of VDC use proceeds and advanced users become more proficient, they are more perceive increasing value and now have started to make significant organizational and strategic shifts in their operations. This process may already be driving a shift in the nature of impediments to progress. Where in the past difficulties were encountered more with technical issues such as hardware and software or contractual terms between the parties involved in a project, they are now more aligned with finding qualified people and providing training. This shift represents emerging acceptance by organizations that their own professional development and retention practices are fundamental bottlenecks, not the practices of their business clients and partners. The bottlenecks become more difficult to overcome as time goes on and will cause early adopters, those who establish capability and procedures before a personnel crunch, to operate at both a value and cost advantage over those who try to come on board later. Non-users who may find themselves in this position are still very numerous. However, our data show that they would overwhelmingly adopt the technology if they felt it would help them create process improvements or increase their efficiency. These are exactly the results that advanced users report and indicate an important business opportunity for those who can provide VDC-based services early on. Owners, in particular, represent a client base largely unaware of the potential benefits that VDC provides.

Appendix 1: Project Case Studies

- ***Salisbury Fire Station & Headquarters – Design Atlantic Inc.***
- ***Atlanta Hilton Aquarium – Holder Construction Company***
- ***Camino Medical Office Building – DPR Construction, Inc.***
- ***Mills Peninsula Hospital – Turner Construction Company***
- ***Palazzo Hotel & Casino – Hansen Mechanical Company***
- ***Honda Data Center – Trautman & Shreve Company***
- ***Texas & Ohio Data Centers – Holder Construction Company***

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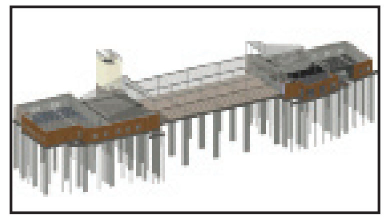
Salisbury Fire Station - Salisbury, MD

Owner's rep uses BIM to execute its client's first design-build project flawlessly

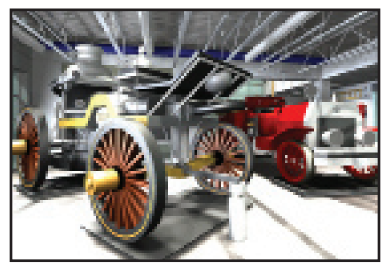
Project Scope: $9M, 37,000SF Fire Station and Headquarters Building
Project Duration: 18 months, design and construction overlap 7 months
Delivery Method: Design - Build
Contract Type: Guaranteed maximum price
BIM Scope: Project programming, budgeting and design coordination
File Sharing: ArchiCAD used by owner's rep to enable visualization with other project stakeholders
Cost to Project: $6,000
Cost Benefit: Project ongoing, total cost benefits not estimated as yet
Schedule Benefit: Project ongoing, schedule benefits not estimated as yet

The City of Salisbury provided Design Atlantic with a conceptual rendering of their proposed building by a specialist architect

The city of Salisbury, MD, hired architecture firm Design Atlantic, Inc. (DA) to manage their first-ever design-build project. The city wanted to ensure that the process was conducted in a manner that the public would trust given a historically volatile political atmosphere and difficult fiscal constraints in the city budget. DA took a proposed floor plan and conceptual rendering provided by another firm specializing in fire station design and generated a full 3D ArchiCAD model of the proposed facility. Using the model and the requirements development program Mindmanager they then conducted a design validation process that thoroughly captured the needs of their client and used it to justify the required costs to the public. Extracting quantities from the model, as part of the validation process, they produced an estimate which they used to manage the design-build process on the city's behalf. The model enabled a complete understanding of the project by all stakeholders and allowed true collaboration which helped the team virtually eliminate conflicts and design problems prior to breaking ground. Despite building the facility on a contaminated brown-field, at 72% complete (as if 9-30-07), the project remains within 0.6% of the budget established from the prototype model with zero error & omission changes. Indeed, the project has proceeded so well, that the city has now started to spend approximately $692,000 in unused project and contingency funding on its other needs and will soon move into a first-rate facility.



Design Atlantic produced a model which automatically generated a cost estimate accurate to within 0.6% of the guaranteed price



Design Atlantic's detailed models enabled everyone to fully understand the scope of the project

Stakeholder Implementation of BIM Across Project Lifecycle

Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation	O	O	O	
Technical Integration	O	O	O	
Automated Prediction	O	O	O	
Visualization	O D GC	O D GC S	O D GC S	

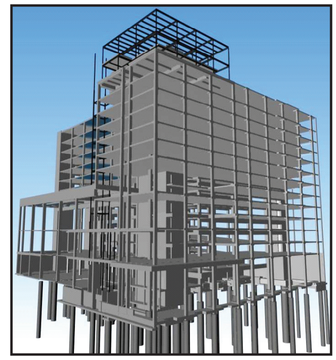
O **Owner**: City of Salisbury (Rep: Design Atlantic) - ArchiCAD (Expert - Model Creator)
D **Designer**: Cole & Russell Architects - AutoCAD 2D (Novice - Model User)
GC **General Contractor**: Gillis Gilkerson Construction - AutoCAD 2D (Novice - Model User)
S **Subcontractors**: Electrical - Tomey Electrical Inc - AutoCAD 2D (Novice - Indirect Model User)
Mechanical/Plumbing - Wilfre Co - AutoCAD 2D (Novice - Indirect Model User)
Structural Concrete - D. W. Burt Concrete Construction Co - AutoCAD 2D (Novice - Indirect Model User)

Hilton Aquarium - Atlanta, GA

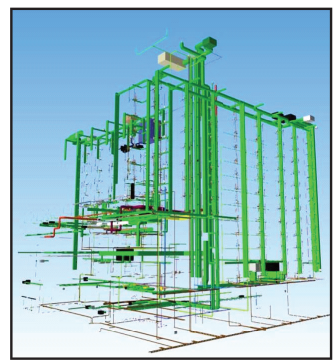
Novice Team Achieves BIM Success Through Leadership by BIM-Savvy GC

Project Scope: $46M, 484,000 SF hotel and parking structure
Project Duration: 21 months design and construction with 9 months overlap
Delivery Method: Construction manager at risk
Contract Type: Guaranteed maximum price
Design Assist: GC and subcontractors on board at design definition phase
BIM Scope: Design coordination, clash detection, and work sequencing
File Sharing: Navisworks used as common platform
Cost to Project: $90,000 - 0.2% of project budget ($40,000 paid by owner)
Cost Benefit: $600,000 attributed to elimination of clashes
Schedule Benefit: None directly attributed to BIM use

Architect's rendering
Stevens & Wilkinson



Structural model
Holder Construction



Plumbing Model
Art Plumbing

Atlanta-based General contractor Holder Construction made the jump to BIM easy on the Hilton Aquarium project in Atlanta, GA. Holder got on board during the design development phase and created 3D models of the architectural, structural and MEP systems of the proposed building. Holder's centralized, corporate modeling staff created an integrated 3D model of the building using detail level information from subcontractors based on drawings from the designers. This method allowed project team members to perform their work in the comfort of their traditional 2D, drawing-based delivery process and eliminated the potential risk that is often associated with open sharing of digital models across stakeholder lines. Through frequent 3D coordination sessions, the project team was able to quickly identify and resolve system conflicts, saving an estimated $600,000 in extras and avoiding months of potential delays. Non-BIM-savvy stakeholders made visualization use of Holder's model through a Navisworks viewer obtained for free over the internet. The collaborative 3D viewing sessions also improved communications and trust between stakeholders and enabled rapid decision making early in the process. Finally, Holder's commitment to updating the model to reflect as-built conditions provided the owner, Legacy Pavilion, LLC, a digital 3D model of the building and its various systems to help aid O&M procedures down the road.

Stakeholder Implementation of BIM Across Project Lifecycle

Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation				
Technical Integration				
Automated Prediction		GC S	GC S	
Visualization		O D GC S	O D GC S	O D GC S

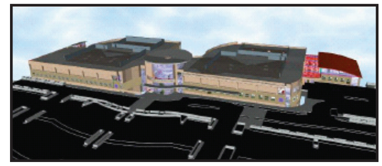
O **Owner**: Legacy Pavilion, LLC - AutoCAD/Navisworks Viewer (Novice - BIM Model User)
D **Designer**: Stevens and Wilkinson - AutoCAD/Navisworks Viewer (Novice - BIM Model User)
GC **General Contractor**: Holder - ArchiCAD/Navisworks (Expert - BIM Leader & Model Creator)
S **Subcontractors**: Electrical - Dyna Electric - AutoCAD/Navisworks (Novice - BIM Model User)
Mechanical - Shumate Mechanical - AutoCAD/Navisworks (Novice - BIM Model User)
Plumbing - Art Plumbing - 3D CADduct/Navisworks (Novice - BIM Model Creator)
Structural Concrete - Precision - AutoCAD/Navisworks (Novice - BIM Model User)

Camino Medical Building - Mountain View, CA

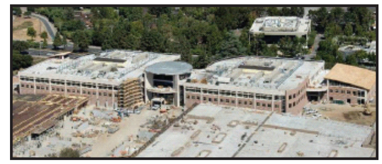
GC and Subs Save Owner $3M+ Maximizing Field Productivity and Off-site Fabrication

Project Scope: $98M, 250KSF Medical office building and 410KSF garage
Project Duration: 24 months design and construction with 12 months overlap
Delivery Method: Construction manager at risk
Contract Type: Guaranteed maximum price
Design Assist: GC and major subs on board at start of schematic design
BIM Scope: Clash detection, lean delivery and off-site material pre-fab
File Sharing: AutoCAD and Navisworks used as common platforms
Cost to Project: $410,000 - 0.5% of project budget (fully paid by owner)
Cost Benefit: Estimated at $3M+
Schedule Benefit: Estimated at 6+ months

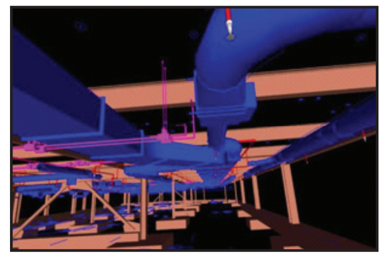
General Contractor DPR and its subcontractors built an integrated 3D model of the Camino Medical Building from conceptual 2D MEP drawings and used it to maximize clash elimination and field productivity. The mechanical subcontractor, Southland Industries, was able to use the process to fabricate and assemble over 90% of its duct and piping materials in production shops off-site. This resulted in a requirement for 30% fewer sheet metal and 55% fewer pipe fitter hours in the field than would have been necessary on typical projects and saved that sub over $400,000 in project costs. Across all trades a 20-37% increase in productivity was recorded and mechanical sub Southland Industries recorded only 43 hours of rework on more than 25,000 hours of total labor. The BIM effort cost an extra $410,000, but, for that initial investment the owner, Sutter Health, bought a project with zero change orders due to field conflicts, nearly 6 months earlier completion than would otherwise have been possible, and nearly $3M in avoided costs. Additionally, early interaction between the design and construction teams driven by Owner Sutter Health's Lean Construction delivery process used 3D models to capitalize on true value engineering worth nearly $6M. The owner's representative remarked that the project had proceeded better than any he had ever seen in his 30 years of experience and that Sutter Health will now be requiring the use of BIM from initial design on all future projects.



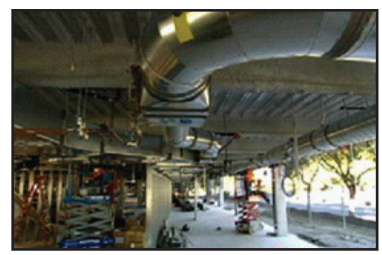
3D Model - DPR



Project under construction



HVAC Ducts in BIM, accurate and coordinated detailing allowed 90% off-site fabrication



HVAC Duct installed exactly as shown in model

Stakeholder Implementation of BIM Across Project Lifecycle

Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation			GC S*	
Technical Integration			GC S*	
Automated Prediction		GC S	GC S	
Visualization		O D GC S	O D GC S	

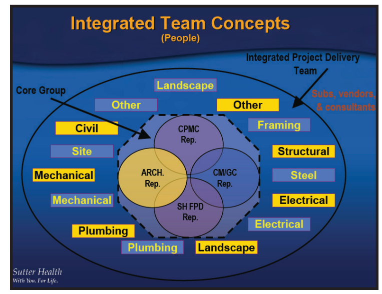
O **Owner**: Sutter Health & Camino Medical Group - AutoCAD/Navisworks Viewer (Novice - Model User)
D **Designer**: Hawley Peterson & Snyder - Architectural Desktop (ADT) 2004 / Navisworks Viewer (Novice - Model Creator)
GC **General Contractor**: DPR Construction - Architectural Desktop 2004 / Navisworks Jetstream (Expert - Model Creator)
S **Subcontractors**: Electrical* - Cupertino Electric* - PD3D / Navisworks (Intermediate - Model Creator)
Mechanical* - Southland Industries* - CADDuct / PD3D / Navisworks (Expert - Model Creator)
Plumbing - JW McLenahan* - Architectural Desktop 2004 / CADMech / PD3D / Navisworks (Expert - Model Creator)
Structural Steel - AFCO* - Architectural Desktop 2004 / Navisworks (Expert - Model Creator)

Mills Peninsula Hospital - Buringame, CA

Owner hires BIM-Savvy GC to convert 2D hospital design to 3D to improve project delivery

Project Scope: $350M, 500,000SF 335-bed hospital and parking garage
Project Duration: Design: 6 years, Construction: 3 years, Overlap: 2 years
Delivery Method: Construction manager at risk
Contract Type: Cost plus guaranteed maximum price
Design Assist: GC and major subs on board at 50% construction documents
BIM Scope: Design verification, clash detection, and material prefab
File Sharing: AutoCAD and Navisworks used as common platforms
Cost to Project: $1.5M, <0.5% of project budget (fully paid by owner)
Cost Benefit: Not quantified, job still in progress
Schedule Benefit: Not quantified, job still in progress

Project rendering by architect Anshen and Allen



Sutter Health's Lean Delivery and Integrated Teams collocated key players during design

Collocated team using Turner's project-site i-room for a design coordination meeting

Owner Sutter Health used its Integrated Project Delivery process on the Mills Peninsula Hospital, requiring collocation of a core group of stakeholders at the project site during design verification and use of a 3D BIM model as the tool of collaboration. Compliance with OSHPD, California's rigorous hospital facility construction regulations, was a major issue. Permit approval takes months and changes require complete re-submission with huge schedule impacts. Turner's expertise and role leading and training the stakeholders inexperienced with BIM was key to giving the novice team confidence to handle coordination of this complicated hospital design. Turner held weekly collaboration meetings between the core group stakeholders in a large i-room presenting issues using the 3D model on smart boards. The team was able to work through design and coordination problems in a matter of hours that had taken weeks on past projects given their disparate locations, lack of cooperation and problems interpreting intent from 2D drawings. In the words of Turner's MEP coordinator, "*We had 25 people in a room with a lot of tough issues and in 3 hours we would have a 2 page document saying exactly what needed to be done.*" In the end, the team produced a clash-free design from which the bulk of MEP and structural materials will be prefabricated off-site improving cost and productivity. Though not yet quantified, stakeholders feel that they are on the way to significant cost and schedule savings and a smooth project.

Stakeholder Implementation of BIM Across Project Lifecycle

Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation			GC S*	
Technical Integration			GC S*	
Automated Prediction		GC S	GC S	
Visualization		O D GC S	O D GC S	

O **Owner**: Sutter Health & Mills Peninsula Healthcare - AutoCAD / Navisworks Viewer (Novice - Model User)
D **Designer**: Anshen and Allen - ArchiCAD / Navisworks Viewer (Novice - Model Creator)
GC **General Contractor**: Turner Construction - AutoCAD 5.0 3D / Navisworks Viewer (Expert - Model Creator)
S **Subcontractors**: Electrical - Morrow Meadows - CADMEP / PD3D / Navisworks (Novice - Model Creator)
Mechanical* - ACCO* - CADMEP / PD3D / Navisworks (Expert - Model Creator)
Plumbing* - Broadway Mechanical* - CADMech / PD3D / Navisworks (Novice - BIM Model Creator)
Structural Steel* - Herrick Steel* - Revit Structural / Navisworks (Novice - Model built by design consultant)

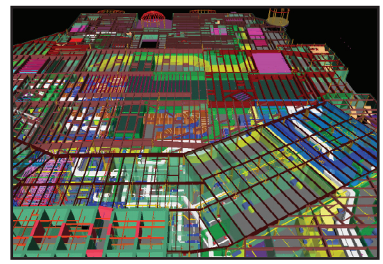
Palazzo Hotel & Casino - Las Vegas, NV

Novice Mechanical & Structural Subs Go it Alone Using BIM to Improve Coordination

Project Scope: $1,6B, 3,000 room hotel, casino, and convention center
Project Duration: 38 months design and construction, no overlap
Delivery Method: Design - Bid - Build
Contract Type: Fixed price, low bid for GC and all subcontractors
Design Assist: No design assist services included in project
BIM Scope: Clash detection, and off-site fabrication for mechanical only
File Sharing: AutoCAD and Navisworks used as common platforms
Cost to Project: Undisclosed, however costs taken from project contingency
Cost Benefit: Undisclosed, estimated to exceed cost to mechanical sub
Schedule Benefit: None attributed directly to BIM

The complex facility profits from mechanical and structural coordination even without the other stakeholders

Hansen Mechanical, a subsidiary of Emcor Group, proved the value of using BIM on the Palazzo project even through the majority of other stakeholders did not do so. Hansen had no experience with BIM at the outset of the project but was directed by their parent company to make it their first use of BIM. The only other stakeholder to participate in the modelling process was the structural steel designer. Lacking experience, Hansen turned to fellow Emcor subsidiary Trautman & Shreve for their expertise and the 3D models were built remotely from the T&S Denver office from 2D design and 3D structural steel detailing drawings. Given the complex nature of the mechanical and structural steel systems on this 50 story high-rise building there were still large benefits to be enjoyed from coordination and reduced conflicts between these trades during construction. This was especially true in areas where these systems represented the majority of work such as on the second floor mechanical zone and most vertical pipe chases. Even though they were not participating in the conflict coordination, the GC and owner approved Hansen's model and agreed to give them protection from rework in the event of conflict. Hansen was thus able to pre-order 95% of its materials in bulk, prefabricate large assemblies off-site, and deliver them to the site as needed. As a result they enjoyed a significant discount on material costs and improved field productivity. They were confident enough in this process to reduce their contingency cost to the GC by an amount equal to the modeling effort.



Hansen Model of 2nd Floor shows extensive interaction of mechanical systems alone

Piping installed per detailed 3D coordination model

Stakeholder Implementation of BIM Across Project Lifecycle

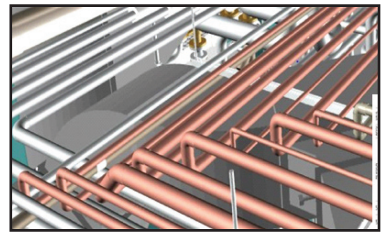
Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation			S*	
Technical Integration			S*	
Automated Prediction			S	
Visualization			S	S

O **Owner**: Lido Casino Resort, LLC - AutoCAD 2D / Revit (Novice - No Model Use)
D **Designer**: HKS Architects - AutoCAD 2D / Revit (Novice - No Model Use)
GC **General Contractor**: Taylor International - AutoCAD 2D / Revit (Novice - No Model Use)
S **Subcontractors**: Electrical - Mojave Electric - AutoCAD 2D (Novice - No Model Use)
Structural Steel* - Schuff Steel - Revit Structural (Experienced - Model Creation by Walter P. Moore Engineer)
Mechanical* - Hansen - CADDuct / CADPipe / Navisworks (Novice - Model Creation by Trautman & Shreve)
Plumbing* - Hansen - CADDuct / CADPipe / Navisworks (Novice - Model Creation by Trautman & Shreve)

Honda Data Center - Longmont, CO

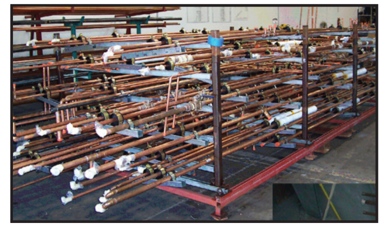
Mechanical Sub Automates Fabrication and Links BIM Across a Project's Entire Life-Cycle

Project Scope: $22M ($68M including equipment), 60,000SF Data Center
Project Duration: 9 months design and construction with 3 months overlap
Delivery Method: Construction manager at risk
Contract Type: Guaranteed maximum price
Design Assist: Yes, GC and subcontractors on board from 70% DDs
BIM Scope: Clash detection, off-site fabrication, and BIM O&M data
File Sharing: AutoCAD and Navisworks used as common platforms
Cost to Project: $200,000 - 0.03% of project budget (fully paid by owner)
Cost Benefit: Not quantified
Schedule Benefit: Not quantified



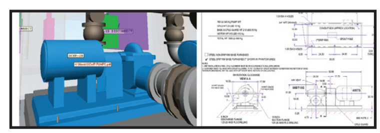
Piping Model - T&S

Mechanical subcontractor Trautman & Shreve (T&S) used BIM to provide owner Honda America a clash-free installation and a 98% accurate digital as-built model of their new facility. T&S' centrally-located, corporate modeling staff took a mixed set of 2D and 3D design drawings and led design coordination and conflict elimination using a series of weekly online-meetings. Separately located stakeholders from the designer, GC and MEP and structural subcontractors participated in this process from the 70% DD stage and completed the clash detection and design coordination prior to breaking ground. The team's confidence in the accuracy of these models allowed extensive off-site fabrication. T&S maximized this, performing 75% of required welding in their shop where productivity is double that which is possible from their typical crews in the field. The only thing limiting the pre-fabrication work performed off-site was the size of individual pipe and duct assemblies that could fit on a delivery truck and be handled by crews at the site. Overall the project team estimates that productivity increased by nearly 30% though they did not track quantities in detail. The final as-built model is fully linked to all operations and maintenance, warranty, and sequence of operations data for the major building systems equipment providing operating efficiency benefits to the owner that will last the life cycle of these systems. Based on successes like these, T&S parent company Emcor Group has required the use of BIM by all its subsidiary companies on all projects.



Shop Pipe Assembly - T&S

Field Installation - T&S



Building Information Model linked to O&M data, original design drawings and approved submittals - T&S

Stakeholder Implementation of BIM Across Project Lifecycle

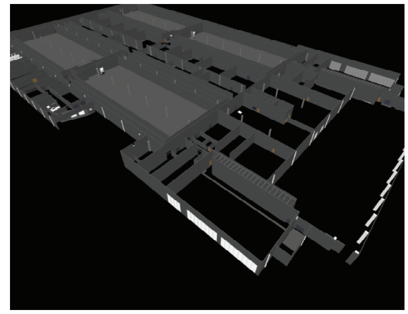
Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation			GC S*	
Technical Integration			GC S*	
Automated Prediction		D GC S	D GC S	O D GC S
Visualization	O D	O D GC S	O D GC S	O D GC S

O **Owner**: Honda America - Revit 3D / Navisworks Viewer (Experienced - Model User)
D **Designer**: Crosby Group - Revit 3D / Navisworks Viewer (Experienced - Model Creator)
GC **General Contractor**: Saunders Construction - AutoCAD 5.0 3D / Navisworks (Experienced - Model User)
S **Subcontractors**: Electrical* - ???* - PD3D / CADMEP / Navisworks (Experienced - Model Creator)
Mechanical/Plumbing* - Trautman & Shreve* - CADDuct / PD3D / Navisworks (Expert - Model Creator)
Structural Concrete - ???* - Revit Structural / Navisworks (Experienced - BIM Model Creator)

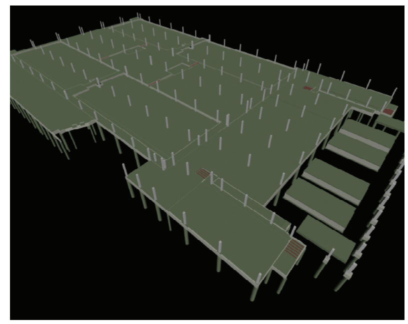
Datacenters - Georgetown, TX & Delaware, OH

Project team improves BIM process and provides O&M tool on a repeated datacenter design

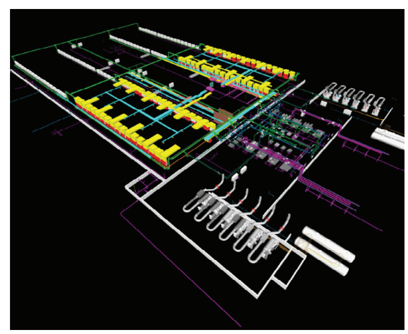
Project Scope: Two individual $150M, 300,000 SF data centers
Project Duration: 22 months design and construction with 1 month overlap
Delivery Method: Construction manager at risk
Contract Type: Guaranteed maximum price
Design Assist: None, clash detection started at 75% CDs on 2nd project
BIM Scope: Clash detection and 3D digital as-built linked to O&M data
File Sharing: Navisworks used as common platform
Cost to Project: $75,000 & $35,000 - 0.01% of combined project budgets
Cost Benefit: $220,000 combined savings on 450 avoided conflicts
Schedule Benefit: None directly attributed to BIM as yet



Architectural / Interior Model
Corgan Associates



Structural Layout Model
Holder Construction



Mechanical / Plumbing Model
Brandt Engineering

Holder Construction led a core design and construction team in the creation of BIM for two data center projects in Texas and Ohio of nearly identical scope. By leveraging a similar design, training the other stakeholders during the first modelling effort and applying lessons learned, Holder was able to produce the second model at a reduced cost and transfer an increased amount of the modelling effort to the other stakeholders. Both projects involved clash detection and greatly reduced RFIs or change orders in the field by eliminating over 450 clash and coordination issues. However, an earlier start and the benefit of experience allowed more stakeholder involvement on the second project. In particular, the illustrations at right show that several stakeholders added key elements to the model leading to a more collaborative and cheaper overall process with less re-creation of 3D models from 2D drawings. The majority of Holder's BIM effort, however, went into the development of the model as an accurate 3D representation of the completed facility with links to operations and maintenance data such as approved submittals, manufacturer maintenance requirements, sequence of operations, and warranty information. Cost benefits from clash detection alone will cover the entire cost of the modelling effort including this O&M feature which will benefit the client financially and operationally throughout the entire life cycle of these facilities.

Stakeholder Implementation of BIM Across Project Lifecycle (Ohio/Texas)

Level of BIM Implemented	Programming & Schematic Design	Design Definition & Pre-construction	Field Construction & Coordination	As-Built / O&M Documentation
Automation			S*	
Technical Integration			S*	
Automated Prediction			D GC S	O D GC S
Visualization	O D	O D GC S	O D GC S	O D GC S

O **Owner**: Confidential - AutoCAD/Navisworks Viewer (Novice - Model User)
D **Designer**: Corgan Associates - AutoCAD/Revit for arch/interior drawings / (Novice - Model Creator)
GC **General Contractor**: Holder - ArchiCAD/Navisworks/Revit (Expert - BIM Leader & Model Creator)
S **Subcontractors**: Electrical* - (Hunt / Walker) - 3D AutoCAD / Navisworks (Intermediate - BIM Model Creator)
Mechanical & Plumbing* - (Brunner / Brandt) - CADPipe / Navisworks (Intermediate - BIM Model Creator)
Fire Protection - (Dalmation / Automatic) - AutoCAD / Navisworks (Novice - BIM Model User)
Structural Concrete - Coreslab - AutoCAD / Navisworks (Novice - BIM Model User)