CHALLENGES AND BENEFITS OF IMPLEMENTING VIRTUAL DESIGN AND CONSTRUCTION TECHNOLOGIES FOR COORDINATION OF MECHANICAL, ELECTRICAL, AND PLUMBING SYSTEMS ON A LARGE HEALTHCARE PROJECT

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ABSTRACT: This case study presents the challenges that the project team faced and the benefits they realized in implementing virtual design and construction technologies to coordinate the Mechanical, Electrical and Plumbing (MEP) systems on a $95M healthcare project in Northern California, USA. These challenges include creating a work structure for the MEP coordination process, organizing the project team consisting of designers, engineers, contractors, and subcontractors, determining the handoff of information between the team members, creating guidelines for the most efficient use of virtual design and construction technologies, creating the process of conflict identification and resolution between the MEP subcontractors, and aligning the contractual interests of the coordination team to meet the overall project schedule.

We also discuss the benefits that the project team achieved by using the virtual design and construction tools for the coordination of the MEP systems. These benefits include labor savings ranging from 20 to 30 % for all the subcontractors, 100% pre-fabrication for the plumbing contractor, only one recorded injury throughout the installation of MEP systems over a 250,000 square feet project area, less than 0.2% rework for the whole project for the mechanical subcontractor, zero conflicts in the field installation of the systems and only a handful of requests for information for the coordination of the MEP systems. The overall benefits to the owner include about 6 months' savings on the schedule and about $9M in cost for the overall project.

1 INTRODUCTION

The MEP systems on technically challenging projects like those focused on the high technology, healthcare, and biotech industries, can sometimes comprise of as much as 50% of the project value. Therefore, the coordination and routing of the MEP systems on these types of projects is a major endeavor. The MEP systems need to be routed in limited space under the design, construction, and maintenance criteria established for the systems (Barton 1983, Korman and Tatum 2001). The Camino Medical Group project in Mountain View, California, is a new Medical Office Building (MOB) facility for the Camino Medical Group (CMG) that fits the bill of a technically challenging project. The negotiated contract for this project is about $95M. The construction for this fast track project started in January 2005 and completed in early April 2007, and the facility is now open for business. The project scope includes a 250,000 square foot, three-level MOB and a two-level 1,400 space parking garage. The MOB includes patient exam rooms, doctor's offices, surgery and radiology rooms, public spaces, a cafeteria, numerous conference rooms, etc. This building is designed as a steel structure with the following parameters:

- floor to underside of metal deck height is about 14 feet (4,260 mm)
- floor to ceiling height in most rooms is 9 feet (2,740 mm) or 9.5 feet (2,900 mm)

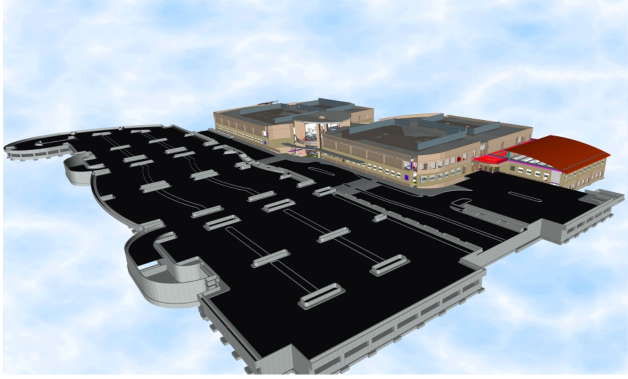


Figure 1. 3D rendering of the three-level MOB for the Camino Medical Group Project in Mountain View, California. Image courtesy DPR Construction, Inc., CA, USA.

This means that all the complex MEP systems supporting the facility need to be incorporated within the 4.5 (1,370 mm) to 5 feet (1,520 mm) of interstitial space on all floors. The Camino MOB project team adopted Virtual Design and Construction (VDC) technologies (specifically 3D/4D modeling tools) for the coordination of the MEP systems on this project. This paper illustrates the challenges the team addressed and the specific benefits that the team accomplished using VDC tools for the MEP coordination process.

2 BACKGROUND

Previous research has focused on documenting and understanding the current MEP coordination process in the US construction industry (Tatum and Korman 1999, Tatum and Korman 2000). The research describes the state of the MEP coordination process in the US construction industry and specifically focuses on how project teams coordinate MEP systems. Korman calls this process the Sequential Composite Overlay Process (SCOP). In this process, the specialty subcontractors or the engineers develop the detailed drawings for their own scope of work and overlay the drawings on a ¼" scale and then using a light table try to identify potential conflicts that might occur in the routing of the MEP systems. The conflicts are then highlighted on the transparent drawing sheets and then addressed before the fabrication and installation process. An example of this process is shown in Figure 2 from a recent project that one of the authors was involved in.

Figure 2. MEP coordination session at the Palo Alto Medical Foundation Project in Fremont, CA, USA using the SCOP. Drawings representing different trades are overlaid on a light table to detect clashes between the MEP systems. Image courtesy DPR Construction, Inc., CA, USA.

Based on the authors' recent experience in the US construction industry we can say that this process is still followed on a majority of projects that are delivered using a variety of project delivery approaches ranging from Design-Bid-Build to Design-Build to Design-Assist.

Substantial research work has also been done to identify the design, construction, and maintenance knowledge that is needed for the MEP coordination process, the representation of this knowledge, and a proposed computer-aided methodology that could be used to improve the MEP coordination process (Korman et al 2003, Tabesh and Staub-French 2005). The proposed computer-aided methodology includes tools such as 3D/4D models of MEP systems along with the use of automated clash detection programs that allow project teams to superimpose the models and check for conflicts in three-dimensional space. The use of these automated clash detection programs has started to happen on commercial construction projects. Although there is a lot of research on benefits of using 3D/4D tools in commercial construction (Koo et al 2000) there is little literature and research on what the challenges and benefits of using such tools are specifically for the MEP coordination process. The Camino MOB is one of the few projects that has used the automated tools for MEP coordination and has collected metrics that can be shared.

3 CHALLENGES OF IMPLEMENTING VDC TOOLS FOR MEP COORDINATION ON THE CAMINO MOB

The Camino MOB team decided early on to use the VDC tools (specifically 3D/4D and automated clash detection tools) for the MEP coordination process (Khanzode et al 2005). The architect for this project is Hawley Peterson and Snyder Architecture, the general contractor is DPR Construction, Inc., the mechanical engineer is Capital Engineering. The owner, along with the architect, engineer and contractor pre-qualified the MEP subcontractors for their ability to coordinate and collaborate their work with the work of other subcontractors using 3D/4D tools. The MEP subcontractors selected for this project include Southland Industries (HVAC), JW McClenahan Company (plumbing), Cupertino Electric (electrical), and North Star Fire Protection (fire protection). The specific challenges the project team addressed are as follows:

1. How to set up a project organization to best utilizes the VDC tools?
2. What roles should each of the project team members play in the coordination process?
3. How to address issues such as technical setup and sharing of models and drawings?
4. How should the coordination process be structured and managed?

The project team iteratively developed guidelines to help address these questions. These guidelines evolved and became more refined as the project team started working together, including:

1. Role of the general contractor (GC) and specialty contractors in the coordination process
2. Levels of detail in the architectural, structural, and MEP models
3. The coordination process
   a. Setting up the technical logistics
   b. Kicking off the coordination process
   c. Establishing the sequence of coordination
   d. Managing handoffs between designers and detailers
   e. Working in the "Big Room"
   f. Using 3D clash detection tools to identify and resolve conflicts
   g. Managing the process using the Last Planner System
   h. The final sign-off
4. Coordination of the installation process

4 ROLE OF THE GC AND SPECIALTY CONTRACTORS IN THE COORDINATION PROCESS

Role of the general contractor

The general contractor (GC) enables the VDC-supported MEP coordination process by acting as the main facilitator rather than the author of the drawings and models. The GC enables and coordinates the hand-off of information from the architects and engineers (A/E's) to the subcontractors as well as the modeling and coordination work itself.

The GC's role in initial modeling and coordination is much the same as on the project as a whole: developing a workable detailing schedule together with the A/Es and subcontractors to support the construction schedule. Once the schedule is established, the GC's Project Engineer assigned as the MEP coordinator works together with the detailers to achieve sign-off milestones using the Last Planner System™ (Ballard 1994).

Role of the specialty contractors

The specialty contractors are responsible to model their portion of work using 3D tools. In our experience on this project using the VDC tools for MEP coordination, the HVAC contractor takes a lead role in the coordination process. The HVAC equipment like VAV boxes, fire smoke dampers, duct shafts, and low and medium pressure ducts take up the most space in the above-ceiling space. It is our observation that detailers of other trades (plumbing/electrical/fire sprinklers) would much rather like to know how the HVAC equipment, duct shafts, and main ducts are routed since that has the most impact on how they will route their utilities. The HVAC contractor therefore models at least the main medium pressure and low pressure duct lines and shafts so that other trades can coordinate and route their utilities around these duct lines. The specialty contractors are also involved early in the process so that they can provide input into the constructability and operations issues to the design team. Some contracting methods that allow for early involvement of specialty contractors include the Design-Assist and Design-Build contracting methods. In both methods the specialty contractors are brought in early (somewhere between the conceptual and schematic design phases). In the Design-Build method the specialty contractor is also the engineer of record for the MEP systems while in the Design-Assist method this responsibility may rest with an independent or third party engineering and design firm. The Camino MOB project used the Design-Assist contracting method. This method worked well for the coordination process for the project.

5 LEVELS OF DETAIL IN THE ARCHITECTURAL, STRUCTURAL AND MEP MODELS

One of the questions that most teams have when starting the 3D modeling effort is: "What to model in 3D?" This question should be answered by the whole team involved in the 3D coordination effort. The goals set out by the team for the coordination effort will play a big role in determining what to model. On most projects MEP/FP coordination can be divided into two distinct coordination efforts:

- Coordination of underground utilities like plumbing and electrical
- Above-ceiling coordination of all the MEP/FP utilities

If the team decides to do both underground and above-ceiling coordination using 3D tools then elements like foundations and framing are required for the coordination effort.

Another important question is: "What level of detail should be included in the models?" There is clearly a tradeoff between the level of detail in the models and the uses they can provide to the coordination effort. For example, including casework details in the architectural model is necessary for determining the exact locations of the plumbing rough-ins in the walls but is not needed for coordination and conflict detection with other systems like HVAC. The project team should collectively decide the level of detail question.

The coordination of MEP/FP systems using VDC tools requires that project teams plan to create 3D models for:

- Architectural elements like interior walls, ceiling
- Structural elements like the main structural framing, slabs, and foundations
- Mechanical systems like duct work, etc.
- Plumbing systems like the gravity lines and hot and cold water piping
- Electrical systems like the major conduits and cable trays
- Fire protection systems with the mains and branches
- Other specialty systems like medical gases depending on the project

6 MANAGING THE COORDINATION PROCESS

Getting the technical logistics right

Technical Logistics plays an important part in the coordination process. It is likely that many 3D models will be used on the project, and each subcontractor will create their models. Team members should agree to some basic rules at the outset of the project so that the sharing of electronic 3D models is efficient and benefits the whole team. The project team should address the following issues:

- 3D models are accompanied by standard word documents describing revisions therein
- 3D models are posted to a project website, ftp site, or a document collaboration site determined by the team which includes the GC, subs, owner, and A/E team
- The collaboration site provides secure and remote access to all the model files
- A clear file path structure is set up on the server to organize the model files and other relevant documents
- Everyone works from and posts to the same server
- The server is backed up every night
- Borders and title blocks are not transmitted with the drawings
- The insertion point for all drawings is based on the 0,0,0 insertion point established in the architectural drawings

- Anything not intended to be seen in the 3D model is erased prior to file transfer

In addition, projects using products compatible with the .dwg format or the Autodesk CAD file format should use the following guidelines:

- Use only standard AutoCAD fonts in model space; do not use true type fonts or custom AutoCAD fonts
- For all AutoCAD based models each trade will use the EXTERNAL REFERENCE (Xref) command to bring any drawing needed into the "background"
- Xref's are not to be bound or inserted
- All Xref's are detached prior to transferring drawings to other trades
- Nothing is drawn in paper space
- No trades draw anything on layer zero (0) or Defpoints
- Drawings are purged (AutoCAD purge command) and audited (AutoCAD audit command) prior to file transfer to get rid of any errors or garbage in the drawing file
- Text is on different layers from the graphics so that the text can be turned off without turning off the graphics
- Any thick lines to designate wall fire ratings are on separate layers
- All layers are on and thawed
- All entities are delivered with colors, line types, and line weights set to bylayer

Kicking off the coordination process – the first steps

The first step in the coordination process is the kick-off meeting that involves all the team members (architect, engineer, GC, and subs). The items to discuss in this first meeting include the following:

- Get the technical logistics right
- Perform the initial space allocation of the above-ceiling space which involves identifying the zones that each of the trade contractors is going to occupy (Figure 3)
- Determine the breakup of floor plans so that they can be coordinated in smaller batches

Sequence of coordination

In our experience the MEP/FP coordination process using 3D/4D tools is most efficient if it follows the sequence below:

- Start with the 3D structural and architectural model
- Add miscellaneous steel details to the model
- Perform preliminary space allocation (as indicated in the previous section)
- Identify hard constraints (locations of access panels, lights, etc.)
- Draw the main medium pressure ducts from the shaft out
- Draw the main graded plumbing lines and vents
- Draw the sprinkler mains and branches
- Draw the cold and hot water mains and branches
- Draw the lighting fixtures and plumbing fixtures
- Route the smaller ducts and flex ducts around the utilities drawn before
- Route the smaller cold and hot water piping, flex ducts, etc. last

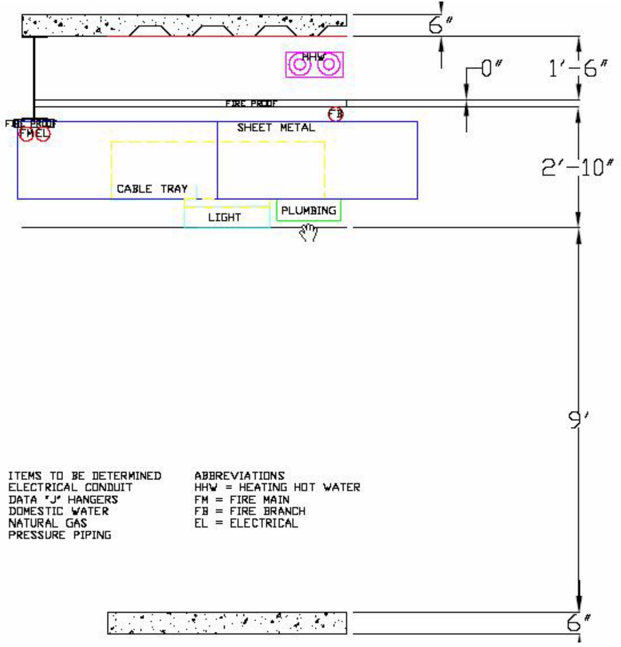


Figure 3. Screenshot of the initial space allocation of the above-space utilities for the MEP systems. This space allocation allows subcontractors to identify the general location of their systems as a starting point for their work. Image courtesy DPR Construction, Inc., CA, USA.

Managing the handoffs between the designers and subcontractor's detailers

In the US construction industry, the traditional building process involves a host of specialty firms focused on specialized, small portions of work. This is true for both the design and the construction phases of the project. During the design phase architects work with a host of design consultants like structural engineers, acoustical consultants, and mechanical engineers, etc. to complete the design of the facilities. During the construction process the general contractor typically coordinates the work of many specialty subcontractors. There is no single master builder. In this environment managing the hand-off of information from designers (who are typically the engineers of record) to the subcontractors' detailers becomes extremely important. In a fast track project where design and construction overlaps managing the handoffs between designers and subcontractors is doubly important.

The project team should collaboratively determine how the design will be broken down into small enough batch sizes that allow detailers to coordinate and complete an area so that fabrication can begin. This is an iterative process between the design and construction teams. For example the Camino MOB project developed a process chart and document (shown in figures 4 and 5) to determine the handoff between the design and the construction teams.

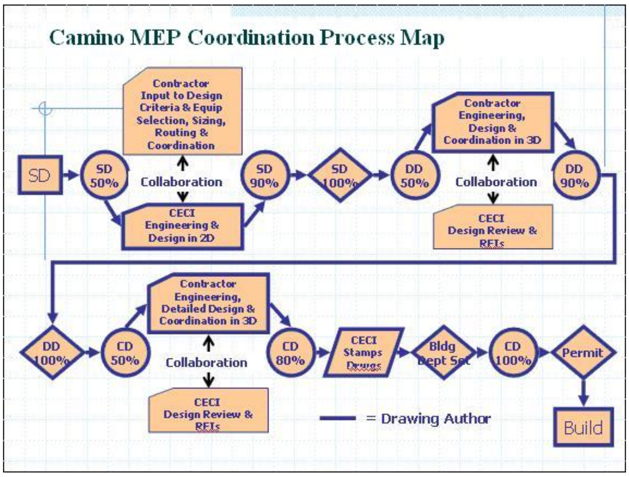
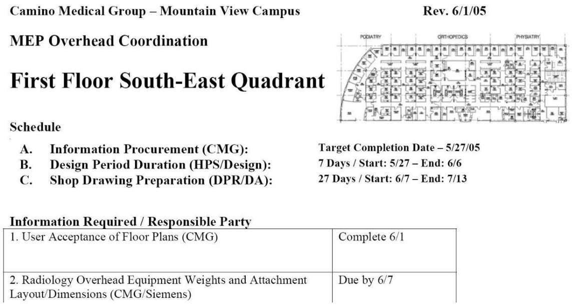


Figure 4. The handoff process that was developed collaboratively by the Camino MOB design and construction teams. It indicates that the design and detailing teams will collaboratively work together at the beginning of the schematic design stage (50% SD), and the detailing team for the subcontractors will start creating the 3D models at the detailed design stage and complete the modeling effort with a fully coordinated design in 3D at the end of the construction documents phase. Image courtesy DPR Construction, Inc., CA, USA.


Camino Medical Group – Mountain View Campus **Rev. 6/1/05**

MEP Overhead Coordination

First Floor South-East Quadrant

Schedule

A.	**Information Procurement (CMG):**	**Target Completion Date – 5/27/05**
B.	**Design Period Duration (HPS/Design):**	**7 Days / Start: 5/27 – End: 6/6**
C.	**Shop Drawing Preparation (DPR/DA):**	**27 Days / Start: 6/7 – End: 7/13**

Information Required / Responsible Party

1. User Acceptance of Floor Plans (CMG)	Complete 6/1
2. Radiology Overhead Equipment Weights and Attachment Layout/Dimensions (CMG/Siemens)	Due by 6/7

Figure 5. The MEP coordination handoff document prepared by the Camino MOB design and construction team to manage the handoffs between the design and construction team. The figure shows the handoff schedule for the first floor south east quadrant. The Camino MOB team used smaller than normal areas to hand off the design information to the subcontractors' detailing team. Image courtesy HPS Architects, Mountain View, CA, USA.

Working in the big room

Coordination of detailed design is an intensive process due to the many reciprocal dependencies between the routing of the MEP systems. It involves designers and specialty contractors. The detailing work for each trade is dependent on information from the designers and other trade contractors. For example the plumbing detailer is interested in finding out the location of waste and vent shafts from the design team and the location of the main duct runs from the mechanical subcontractor. At the same time the mechanical subcontractor is interested in finding information about the gravity lines from the plumbing subcontractor so that he can correctly locate the duct lines. The coordination effort involves a fair amount of reciprocal dependencies that need to be resolved quickly. Latency in decision making and information access can seriously impact the fast track project schedule. These challenges are addressed by co-locating the design and detailing teams (Thompson 2003), (Levitt and Kunz 2002). The goal is to create a collaborative work environment where the decision making latency can be reduced.

It is our experience that detailers must work side-by-side in one "Big Room" to model and coordinate their designs to meet the coordination schedule. Although we cannot precisely say by how much, this shortens the overall time for modeling and coordination and is more economical in the end for all concerned parties because the detailers won't need to wait for postings to see what others are doing which greatly reduces wasted detailing efforts. Figure 6 shows the Big Room that was set up by the Camino MOB project team. Detailers for the various specialty subcontractors sat in a single room, shared resources like servers, internet connection, printers and plotters, and coordinated the detailed design with each other and the design team in this room.

Figure 6. The "Big Room" on the Camino MOB project with all the detailers from the specialty trades working together in a single room. All the coordination of the MEP systems was done in this room. All the construction documents were also generated from this one Big Room. Image courtesy DPR Construction, Inc., CA, USA.

Using 3D clash detection tools to identify and resolve conflicts

There are commercial tools available that allow project teams to combine 3D models from multiple CAD systems into a single model and determine if two or more systems conflict with each other. One such tool is NavisWorks JetStream which has a module called "Clash Detective" that allows teams to automatically analyze the 3D models of the different disciplines for conflicts between systems. This tool was used on the Camino MOB project.

Conflict identification and resolution is an iterative process. The models are first combined into a single model and then the clash detection program is run to identify clashes between systems. The clashes are then resolved in their native programs and the iteration is performed until all clashes are resolved (Figure 7).

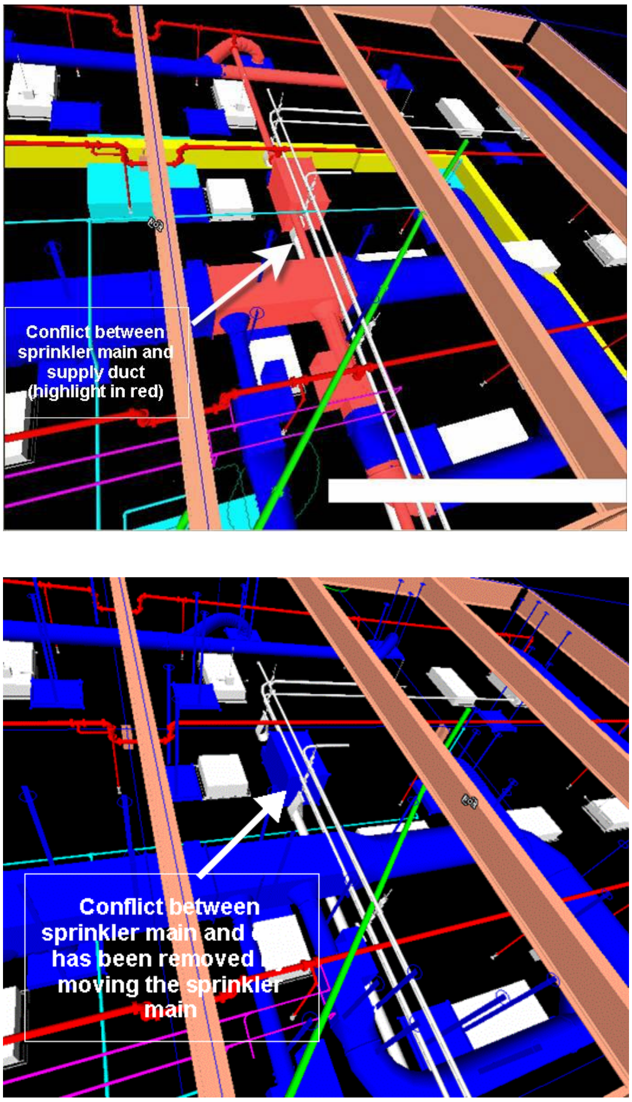
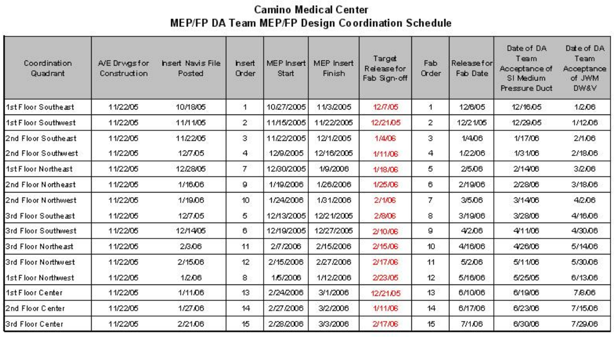


Figure 7. The picture at the top shows a clash or conflict between a supply duct and a sprinkler main pipe, highlighted in red. The picture at the bottom shows that the clash was resolved by moving the sprinkler main to the right of the duct. These clashes were first identified by using the NavisWorks' clash detection program and resolved in a subsequent clash resolution session. Image courtesy, DPR Construction, Inc., CA, USA.

Creating the design coordination schedule

The GC works with the MEP subcontractors to establish the coordination schedule. This schedule is the work plan to ensure that clash-free drawings are in the hands of installation crews in time for penetrations and hangers to be installed prior to the placement of reinforcement and concrete on the elevated decks. The coordination schedule also sets dates for a final all-hands clash detection workshop for each area in time for pre-fabrication of assemblies to meet the master construction schedule. For example, figure 8 shows a Microsoft Excel table that represents the coordination schedule developed on the Camino MOB project. The coordination schedule was developed with the help of designers and subcontractors. The schedule was pulled from the milestone of the MEP Insert start date (5th column from the left in the spreadsheet). This means that the team worked backwards from the MEP Insert milestone date to determine the preceding activities and durations to meet this milestone date. This helped in scheduling tasks as late as possible to minimize the potential for rework as much as possible and to maximize information availability for all the team members.



Camino Medical Center
MEP/FP DA Team MEP/FP Design Coordination Schedule

Coordination Quadrant	A/E Drwgs for Construction	Insert Navis File Posted	Insert Order	MEP Insert Start	MEP Insert Finish	Target Release for Fab Sign-off	Fab Order	Release for Fab Date	Date of DA Team Acceptance of SI Medium Pressure Duct	Date of DA Team Acceptance of JWM DW&V
1st Floor Southeast	11/22/05	10/18/05	1	10/27/2005	11/3/2005	12/7/05	1	12/6/05	12/16/05	1/2/06
1st Floor Southwest	11/22/05	11/11/05	2	11/15/2005	11/22/2005	12/21/05	2	12/21/05	12/29/05	1/12/06
2nd Floor Southeast	11/22/05	11/22/05	3	11/22/2005	12/1/2005	1/4/06	3	1/4/06	1/17/06	2/1/06
2nd Floor Southwest	11/22/05	12/7/05	4	12/9/2005	12/16/2005	1/11/06	4	1/22/06	1/31/06	2/18/06
1st Floor Northeast	11/22/05	12/28/05	7	12/30/2005	1/9/2006	1/18/06	5	2/5/06	2/14/06	3/2/06
2nd Floor Northeast	11/22/05	1/16/06	9	1/19/2006	1/26/2006	1/25/06	6	2/19/06	2/28/06	3/18/06
2nd Floor Northwest	11/22/05	1/19/06	10	1/24/2006	1/31/2006	2/1/06	7	3/5/06	3/14/06	4/2/06
3rd Floor Southeast	11/22/05	12/7/05	5	12/13/2005	12/21/2005	2/8/06	8	3/19/06	3/28/06	4/16/06
3rd Floor Southwest	11/22/05	12/14/05	6	12/19/2005	12/27/2005	2/10/06	9	4/2/06	4/11/06	4/30/06
3rd Floor Northeast	11/22/05	2/3/06	11	2/7/2006	2/15/2006	2/15/06	10	4/16/06	4/26/06	5/14/06
3rd Floor Northwest	11/22/05	2/15/06	12	2/15/2006	2/27/2006	2/17/06	11	5/2/06	5/11/06	5/30/06
1st Floor Northwest	11/22/05	1/2/06	8	1/5/2006	1/12/2006	2/23/05	12	5/16/06	5/25/05	6/13/06
1st Floor Center	11/22/05	1/11/06	13	2/24/2006	3/1/2006	12/21/05	13	6/10/06	6/19/06	7/8/06
2nd Floor Center	11/22/05	1/27/06	14	2/27/2006	3/2/2006	1/11/06	14	6/17/06	6/23/06	7/15/06
3rd Floor Center	11/22/05	2/21/06	15	2/28/2006	3/3/2006	2/17/06	15	7/1/06	6/30/06	7/29/06

Figure 8: The pull schedule for the coordination of the MEP systems of the Camino MOB. It shows the target sign-off dates for each of the areas. The schedule was developed through a collaborative effort between the GC, the subcontractors, and the design team and was driven by the start date for MEP Inserts (5th column from the left). Image courtesy, DPR Construction, Inc., CA, USA.

Summary of guidelines

As described above the coordination of MEP systems using VDC tools is a multi-disciplinary effort that involves addressing important issues related to the organization of the team, the process used to coordinate the effort of various team members, and development of a plan on what to model and how to use the models to resolve conflicts.

We now discuss the benefits that the Camino MOB project team accomplished using the VDC-based coordination process described above.

7 BENEFITS

On the Camino project, the use of 3D/4D tools for MEP/FP coordination resulted in significant benefits for the project team:

- Superintendents were able to spend more time planning the job rather than reacting to field conflict issues on the project. The superintendents spent less than 5 hours in the last six months of the project dealing with field issues. On comparable projects they estimate that they would typically need to spend 2-3 hours each day dealing with issues related to field conflicts.
- Subcontractors are more knowledgeable about the project as they have been involved sooner and are resolving issues in the design and detailing stage that would typically come up in the field. We notice that a lot of reciprocal work that typically happens during construction has happened during design on the Camino project, resulting in more efficient construction.
- Only 2 of 233 RFIs on the Camino MOB were related to field conflict and construction related issues, and these two RFIs were for systems that were not modeled using VDC tools. We asked the project participants how this compares to similar projects they have worked on and found that this number is really small. Most participants put RFIs dealing with field conflicts

on comparable projects somewhere in the 200-300 range. We have not yet compared this performance to similar projects but believe that this is a remarkable performance.

- There are zero change orders related to field conflicts on this project. The project is now complete with 100% of MEP systems installed to date. There has not been a single change order due to a field related conflict.
- All the trades have finished their work ahead of or on schedule. The mechanical contractor estimates that their field productivity has improved between 5 to 25% (Figure 9). This improvement is based on comparing the estimated field productivity to the actual field productivity they were able to achieve and relates to the field labor only. They attribute this increased productivity to more off-site prefabrication and more bolt-in-place assembly on site that required less labor than estimated at the beginning of the project. This project is a Guaranteed Maximum Price (GMP) project and the mechanical contractor alone is giving back about $500K over his approximately $9.4M contract due to savings on field labor.

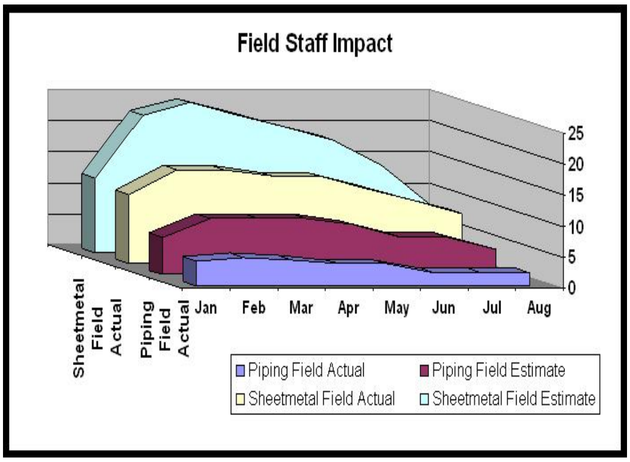


Figure 9. Estimated versus the actual hours spent by Southland Industries, the mechanical contractor for the piping and sheetmetal work at the Camino MOB. The picture shows a 5 to 25% improvement in the use of field labor. Image courtesy Southland Industries, San Jose, CA, USA.

- On the Camino MOB project a total of work-hours 203,448 have been spent to date, and there has been only one recordable injury (versus a national average of about 8 recordable injuries for these many hours). The superintendent attributes this to the improved workflow due to the use of 3D/4D models on the project which has resulted in more off site prefabrication, just in time material deliveries, and efficient field coordination and installation.
- All the plumbing and medium and low pressure ductwork is being pre-fabricated. The subcontractors attribute this to the use of 3D models for coordination. On comparable projects none of the plumbing and at most 50% of the ducts would typically be prefabricated.
- The subs could use lower-skilled labor for the field work compared to other projects where higher-skilled field labor is necessary for installation as the labor force typically needs to interpret 2D drawings, etc.
- The mechanical contractor had to carry out less than 0.2% (only 40 out of 25,000 hours of field work) of rework in the field. They attribute this to the accurate and coordinated 3D models that led to accurate fabrication and installation of almost all work the first time.
- The project team compared this fast track project delivery to a traditional Design-Bid-Build project delivery to compare how much savings accrued due to the use of VDC tools and a fast track project approach that hedged the effects of inflation. This study (Figure 10) indicates a savings of $9M and 6 months to the owner due to the use of the VDC tools and a collaborative virtual building project delivery approach.

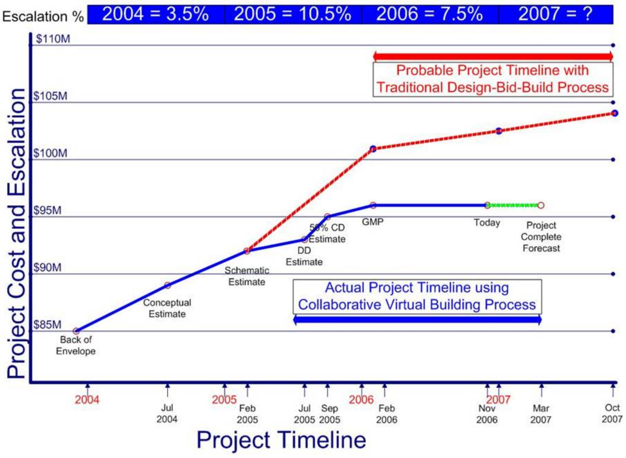


Figure 10. Comparison of the collaborative virtual building project delivery approach adopted by the Camino MOB team using VDC tools and the traditional Design-Bid-Build method of project delivery. The graph shows that due to the use of VDC tools and a fast track approach the team was able to save $9M and 6 months as compared to the traditional process. Image courtesy DPR Construction, Inc., CA, USA.

8 CONCLUSION

The Camino MOB experience demonstrates the significant value that application of VDC tools coupled with lean construction techniques/procedures can bring to the complex process of MEP coordination for technically challenging projects. The paper illustrates the challenges that project teams need to address when using VDC tools for the MEP coordination process. These challenges include determining how to organize the project team and structure the coordination process to best utilize the VDC tools, how to set up the technical logistics, and how to perform the coordination in a Big Room. The Camino MOB team has been able to reap remarkable benefits by utilizing VDC tools for MEP coordination. Prior research has proposed use of computer-aided tools for the coordination process, but this is one of the first project studies that have measured the real benefits of using VDC tools for MEP coordination.

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