

Construction Document Changes to Improve Constructability

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Synopsis

The look and layout of construction documents (CDs) has not changed in decades. Based on results from commissioning efforts, construction site visits, and through a series of interviews with contractors and design firms, Target Corporation Architecture/Engineering reviewed an alternate document layout. Easier to produce and read CDs will aid coordination for design teams and improve understanding of constructability for installing contractors. Improved coordination and understanding ultimately results in a finished project better meeting the owner's project intent; the ultimate goal of the commissioning process.

Results of research led to focus on the following:

1. Sheet numbering system that aided information flow
2. Drawing layout to help avoid multiple cross references to other sheets
3. Common sheet layout between disciplines to aid cross discipline coordination
4. Increased information on drawings versus specifications
5. Appropriate plan scale - using more blow-ups of complex areas
6. Review graphic layout, line weights, screening, etc to improve readability

Traditional CD sets contain the floor plan on one sheet, blow-ups on another sheet, risers on an independent sheet, with details and schedule in the back of the drawing set. Our revised sheet layout combines all common information on a particular area of the building on a single drawing. Now as the design team works on the plumbing floor plan in the food service area, they can make changes to the plumbing risers on the same sheet. Details related to plumbing are also on that sheet, allowing a plumbing contractor to have all information needed to finish an area of the building without referencing back and forth between plans. Many of the document changes will evolve into Building Information Modeling (BIM). BIM tools, such as clash detection between disciplines, provide a means for improved documentation.

About the Author

Scott Williams, PE, is Manager of Mechanical Engineering for Target. In addition to a Bachelor of Science in Mechanical Engineering from the University of Minnesota, he holds a Masters in Business Administration from the University of St. Thomas. Prior to joining Target in 1999, Scott spent 18 years with a Minneapolis consulting firm, most recently as Vice President. At Target, he manages the development of mechanical prototype documents, R&D efforts, and refrigeration engineering. As a consultant, Scott managed projects for health care facilities, college campuses, and corporate clients. He is a member of ASHRAE and past president of the Minnesota Chapter. Scott is also on the Advisory Council of the California Commissioning Collaborative.

Background

Target is rather unusual in the retail industry because it maintains a significant Property Development group responsible for the construction and operation of our stores. Real Estate, Construction, Building Services, Store Planning, Architecture, and Engineering all reside under Property Development. Architecture and Engineering consists of a staff of over 150. Target opens stores three times each year (March, July, and October). Approximately 110 new stores are constructed and another 80 receive significant remodels each year. Currently Target's store base is approximately 1500 in 47 states and Target also owns and operates corporate buildings and distribution centers across the United States. Overall, approximately 225,000,000 square feet of property is managed.

The construction documents for each store start from a prototypical set of documents based on one of two store types. Prototype (P) has approximately 110,000 ft² of sales area, and SuperTarget adds a full grocery with a total of 140,000 ft² of sales area. Prototypical documents presented to the design teams are completely laid out and coordinated between disciplines. These documents could be considered up to 80 percent complete for prototypical projects. Site specific code requirements and design modification such as heating and cooling requirements turn prototypical documents into site specific CD sets. The prototype process allows for continuous improvement of the construction documents and the construction process, so the quality of Target's buildings has traditionally been high. As stores are becoming increasingly unique design, (i.e. multi-level, unique footprint, developer's shell), more design and coordination issues occur that lead to costly field change orders, construction delays, or poor operation at turnover to store operations.

In 2006, Target added a full time Commissioning group to manage the commissioning efforts on new store and remodel projects, along with retro-commissioning the existing store base. The commissioning process at Target is viewed as a way to improve the design and construction of prototype and unique stores while ensuring building systems are operating as efficiently as possible. Process improvements based on learning from commissioning can be incorporated into typical processes to improve end results and reduce the project specific commissioning efforts.

Design, bid, build is the typical construction process for a Target project. General contracts are usually negotiated within a group of experienced General Contractors, while the sub contracts (mechanical, electrical, refrigeration, etc) are usually bid to local sub contractors. Target directly purchases many building components such as building automation system, rooftop air conditioning units, VAV boxes, lights, and refrigeration systems. Specialty contractors such as Testing, Adjusting, Balancing (TAB), and controls installation are also procured directly through Target using experienced vendors.

Introduction

Target updates prototypical construction documents continuously. Every four years or so, Target goes through a major review of store layout, exterior design, construction materials, and

processes to produce a new prototype. For the most recent major review a team was formed to review typical building updates and costs. Another team (CD Production) was directed to review the constructability of the construction documents. Designing and constructing a fairly repetitive building allows for significant refinement over time, so documents are considered to be in pretty good shape. When discussion began on how the documents could be improved, the team first stepped back and used a clean sheet approach when presenting information. As the existing document set was reviewed, it became obvious that CDs are typically laid out for the benefit of design teams rather than construction teams. Years of changes to the prototypical CD set resulted in drawing numbering that provided no information other than a placeholder and partial plans placed on sheets because of available space rather than an actual tie to the other plans on that sheet. The multi-discipline review team concluded there were real opportunities to make improvements to the document layout.

As further justification to providing more constructible documents, consider that A/E design services may cost \$2000 per sheet in a construction document set while the cost to construct the information contained on each CD sheet could be \$40,000. (Design and construction cost varies significantly between building types). From this perspective, it is easy to see that adding design time to improve construction processes is likely to result in a net lower cost for the owner with even small percentage savings in construction costs. When potential savings in reduced commissioning efforts and improved performance are factored in, time spent improving CD presentation shows immediate returns, along with long-term benefits.

Initial Work Plan

Discussion of opportunities with construction documents opened up potential improvements with not only constructability but also opportunities during design and throughout the life of the building. To help focus efforts, a work plan was developed to address the following issues:

- Does current prototype document process work for increasingly complex unique stores?
- How can we use CAD as building modeling tool rather than just a drawing tool?
- Is there a more efficient way for the field (Construction) to receive and use construction documents? Bigger size, smaller size, color plots, electronic?
- How can CD documents be used for additional electronic equipment and material take-off?
- How could construction documents be better developed to be utilized by Building Services for the life of the building?
- What CAD and design tools would cut the time required for site specific CD production?
- How do we enhance ability of construction teams to understand design intent?

A questionnaire focused on CD production and constructability was sent to three General Contractors, a Target Site Construction Representative, an Architectural Consultant, an M/E Engineering Consultant, and a Structural Consultant for feedback and suggestions. The consultants chosen were either not involved with Target's design or had minimal experience with the program in an attempt to gain outside perspectives. Internal teams also provided feedback. The questionnaire included the following questions:

1. Are there variations to traditional drawings and specifications that would aid constructability? (Consider drawing size, scale, color, shading, etc.). Are there areas where more detailing or drawing would help field interpretation?
2. What are the trades-offs of providing information on drawings versus in the specifications?
3. What specific information could be included in the CDs to aid the permitting process?
4. Is there a preference of plan key notes versus notes directly on the plans?
5. Could plan details be presented in a way to improve understanding? Would photos be valuable? Would a separate detail book be easier to work with in the field? Would details on the plan sheet where referenced be preferred to a separate detail sheet?
6. What processes could be provided to design teams to reduce the time required to create site specific plans from prototypical plans?
7. What impact will Building Information Modeling (BIM) have on the design and construction teams? (BIM uses modeling tools and standards to create a 3-D model with attributes on components rather than 2-D line drawing.)
8. Will construction firms use and benefit from BIM for items such as electronic material take-off? Will construction firms trust the information they receive from CD material take-off?
9. Will design firms accept responsibilities for CD accuracy if electronic material and equipment take-offs are used?
10. What is the best process to feedback as-built field conditions to allow accurate record documents turned over to operations teams?
11. Are there any additional ideas or comments?

Initial response was positive noting existing documents were doing a good job, but there were some good suggestions on areas to change. More than 200 individual comments and suggestions were received from the groups.

In addition to the questionnaire, the CD Production research team began investigation in several areas:

- Construction documents from multiple building types were reviewed and analyzed for layout and any differences in transfer of information.
- An independent study group was set up to review Building Information Modeling (BIM) and how it could be used at Target.
- The team met with a Six Sigma Black Belt to determine if Six Sigma processes could help in CD Production and Constructability Research. Suggestions included:
 - Determine problem and what you want to fix. Find sub-problems.
 - Focus on reduced time to complete a process typically has greatest return.
 - Use caution in using outside review feedback to separate opinion from fact.
 - Use data to make decisions.
- Electronic certification of documents was reviewed as a method to help improve document flow and limit risks to Certifiers.
- Document layout and presentation was reviewed to help expedite code review.

Research Results

Results from the initial research were consolidated into areas that required further refinement. There were many immediate wins from the research that were quickly incorporated into the current prototype design documents. Summary results from all sources were consolidated into a “**Top 11**” list for additional CD Constructability research including:

1. **Plan Layout:** Two (2) options were considered.
 - A. Follow National CAD Standards (NCS) for consistency of presentation. This provides distinct specific sheets for plans, blowups, details, etc.
 - B. Consolidate information on specific areas (such as food service, pharmacy, guest services, garden center.) on one or two sheets including blow-ups, details, elevations etc. to minimize “page turning” in field.
2. **Drawing Numbering:** Review NCS for numbering. Goal is to provide easier reference for common areas between disciplines.
3. **Key Notes:** Review use of key notes versus plan notes. Make use of CAD tools for standard key notes.
4. **Appropriate Plan Scale:** Utilize more blow ups of complex areas. Attempt to use consistent blow ups between disciplines.
5. **Alternate Drawing Size:** Larger plots will allow more information on sheets. Half size plots may be more manageable in field. Impact on field plotting must be reviewed.
6. **Color Plots:** Use color plots for store elevations. Consider color plots for engineering systems to enhance interpretation.
7. **Graphic Layout:** Review line weight, screening, fonts, cells, cross discipline drawing consistency, drawing accuracy, etc. to aid drawing modification by store design teams and enhance readability.
8. **Plotting Process:** Review process to ensure plotting by field contractors is of consistent quality and installing contractors see documents as the design team intended. Plotting process and responsibilities needs to be reviewed and documented. Pen tables are currently being reviewed to improve universal consistency.
9. **BIM:** Independent review process underway.
 - A. Review will determine if BIM will be available for prototype development. Some BIM strategies are already included in current CDs, including automatic material take-off of display racks and automatic calculations of refrigeration system volume during design layout.
 - B. BIM also allows automated material take-off to aid design verification and material procurement. Equipment schedules could include quantities, in addition to model numbers. Full electronic take-offs may require contractors to use a version of the CAD program used in design. Procurement processes will need to be changed to incorporate use of electronic take-offs. Construction and Procurement are very interested in taking advantage of this technology.

10. **Move appropriate information from Spec to Drawings:** Drawings are more available to the field and more likely to be reviewed. Show appropriate information on the drawings so the field will not have to refer to the specifications to know what to build. Update specification to CSI standards will also be incorporated.
11. **Electronic Certification:** Process to speed up certification while providing safeguards for Engineer/Architect of record. Would also allow direct CAD to TIF conversion posting of documents. Automated drawing history tracking was also investigated. Fifteen States currently allow use of electronic certification and the trend is for more to follow.

Progress to Date

Plan Layout

Document layout was modified to consolidate information on a single sheet when possible and to provide some consistency between disciplines. For example, some of the more complex areas of the building such as food service, pharmacy, front offices, and grocery/deli were highlighted for enlargements. Many of these areas were enlarged on the plan in the past, but the new layout emphasized consistency between the disciplines on which scale to use and where to break the enlargement plans. The consistency of the plans along with the new numbering system described below assists coordination efforts for the design and construction teams.

The other significant change in plan layout is the consolidation of information regarding a specific area of the building on one plan sheet. The mechanical plumbing plans in particular were modified to bring together enlarged plans, riser diagrams, details, and schedule information. Now the design team can complete all work in a given area and modify risers as piping layout is changed. Above and below floor piping in a given area is easier to coordinate with both plan views on a single sheet. For the construction teams, the revised layout requires less referencing between sheets to find appropriate details or schedules. Drawing sets are often broken up in the field, and it is likely the construction team working on a specific area does not have all detail sheets or schedules. With required details on the sheet where they are referenced, it is more likely the construction teams will review and follow detail intent. (See Figure A)

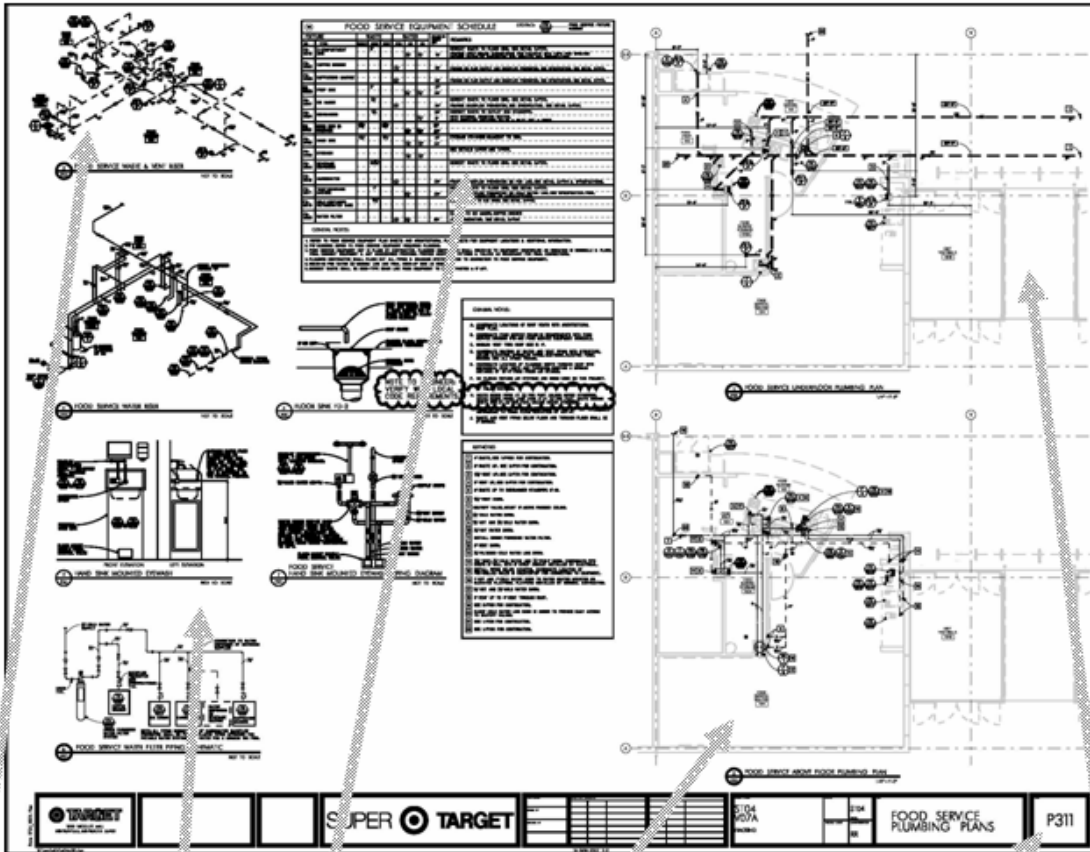
The new sheet layout with details provided on the sheets on which they are referenced means the same detail is on several sheets within the set. This concept took a little discussion since there is concern that having the same detail on multiple sheets could lead to confusion if a detail is changed on one sheet but not the others. CAD allows details to be referenced from one location onto multiple sheets, so there should be minimal risk, provided CAD protocol is followed.

Appropriate Plan Scale

The emphasis on constructability highlighted some plans where a larger scale would allow clearer presentation of the information. As noted previously, appropriate scale was also seen as a consistent scale between disciplines. The revised plan layout, along with increased scale on some plans, resulted in some additional sheets within the CD set. In the mechanical set, the one

additional drawing from a set of 21, and added cost of printing distribution sets is minimal compared to the benefits of more constructible documents.

Figure A: Example of Revised Sheet Layout



Risers moved from sheet M9

Above floor plumbing moved from sheet M5

Equipment schedule moved from sheet M12

Underfloor plumbing moved from sheet M2A

Details moved from sheet M10

Revised numbering coordinated between disciplines

Graphic Layout

Throughout the document, revisions, line weights, hidden lines, screening, fonts, etc. were reviewed and updated. In addition to looking at the CAD plots for appropriate graphic layout, the actual plans the construction teams will see in the field were reviewed. Often graphics that look great when directly plotted on a high quality plotter will look significantly different if the original plots are scanned, sent out electronically to the field, and then plotted on a lower quality plotter. Light lines on the original plots can disappear on the final sets, or heavy lines can blend together with text and symbols.

Drawing Notes

Improvements in drawing key notes were considered. Options reviewed included use of key notes exclusively or a combination of key notes and notes directly within the drawing. When key notes are used, the goal is to use similar key notes between plans. For example, if key note 2 is “3 inch vent through roof,” that same key note 2 should be used on other appropriate plans as well. In many cases, if documents are not too cluttered, placing the note directly on the plan view will save the construction team time referencing back and forth to key note descriptions. Cutting and pasting in CAD allows full descriptions to be placed in the documents nearly as easy as a key note symbol. CAD tools available, particularly with future Building Information Modeling, include programs to assist organization and placement of plan notes.

Drawing/ Specification Numbering

After completing preliminary sheet layout changes, a cross discipline team looked at numbering options. The National CAD Standard numbering system was very well organized, but did not fit the concept of providing a variety of information related to an area on one sheet. Using some of the concepts of the National CAD Standard, a numbering system was developed that helps coordinate multiple discipline sheets. For example, the primary floor plan is A111, E111, S111, M111, P111, and R111 (See Figure B). Specific enlarged plans of key areas also use coordinated sheet numbering. For example, the food service area enlarged plans are designated with (A), (M), (P) 301 for each discipline. This allows design teams and contractors to more easily find other discipline’s drawings, which will hopefully result in more cross discipline review and coordination. An attempt was also made to use the same enlargement scale and grid cutoff between disciplines as an aid to coordination. This coordinated numbering system also provides flexibility for use in unique projects, such as multilevel stores, and remodel projects.

Master specifications were completely revised to conform to the new CSI Master Format standards. This format should provide more consistent compliance with specification as contractors become familiar with the standard numbering sequences. Again there were modifications specific to Target required where the standards did not fully address the full scope of our projects. Refrigeration systems are an example.

Figure B: Example of Drawing Numbering System

ARCH		MECH		PLUMBING		FIRE PROTECT		REFRIG		ELECTRICAL		STRUCTURAL	
General Project Info	G001												
Site Plan	G002												
General Arch Info	A001	Plumbing & Mechanical Index	PM01							Electrical symbol list and Site Plan	E001	General Structural Notes	S001
										Electrical Site Plan	E002		
Supplemental Architectural Information	A011												
Architectural Demolition Plans & Details	AD11												
Exit Diagram	A021												
				Underfloor Plumbing	P100								
Parking (1st Lvl)	A101									Parking Ramp Lighting - 1st Floor	E101		
Subgrade, or 1st Flr Plan for Elevated	A110											Ground/Lower Lvl Plan	S110
Floor Plan	A111	Building HVAC	M111	Building Plumbing	P111	Fire Protection	F111	Refrig System Plan, Sched	R111	Lighting Plan - 1st floor	E111	Foundation Plan	S111
Ground Lvl Floor Finish, Blocking	A120												
Floor Finish, Blocking, Insulation	A121									Specialty Lighting Plan - 1st floor	E121		
Ground Lvl Floor Reflected Ceiling ...	A130												
Reflected Ceiling Plan	A131									Food & Guest Services Ltg Plan	E131		
Roof Plan	A141	Roof HVAC	M141	Roof Plumbing	P141					Office & Pharmacy Lighting Plans	E141	Roof Framing Plan	S141

BIM

Building Information Modeling (BIM) appears to be a likely change for the prototypical update in the future. Significant time and effort has been put into reviewing all aspects of BIM and better understanding how it would impact the design and construction process. Due to the significant changes that would be required with BIM, the cost to convert processes must be justified by potential savings. At this time, the product performance, cost, and payback are still under review. Initial findings conclude the architectural and structural packages from two major developers are fairly well developed. Mechanical and electrical packages are less developed but show promise.

Next Steps

Alternate Drawing Size

Larger drawing size is still under consideration. Larger drawings allow more area of the building to be shown without referencing between sheets. There is concern that larger documents will be difficult to handle in the field, and plotting larger sizes may present a challenge for some construction teams.

Design Intent Information

A design intent document for mechanical systems has been completed and will be included in master specifications. The design intent will be edited by project teams for each project and included in the issued construction documents. Information included in the design intent will be valuable for construction teams, building service personnel, commissioning agents, and future remodeling teams.

Color Plots

Visit good installing contractors in the field, and you often see backline plans diligently highlighted in color by hand to differentiate systems. Why not provide the field color plots directly from the design team? Designers are able to use colors to keep track of various systems as they produce documents, so why not give installing contractors same advantage of differentiating systems by colors. There are process changes required for color plotting and distribution since plotting pen tables are not consistently set up to print what you see. Color plotting will also add cost to projects, so the benefit will have to be quantified prior to roll out. Color plots distributed to the field will be tested on an upcoming project.

Plotting Process

In the days of mylar and blueprints, documents in the field were of fairly consistent quality since they were typically distributed directly from the design team. Now with electronic transfer of documents, the field receives plans that may have gone through a scanning and conversion process and may be printed at a size other than the original scale.

Move appropriate information from Specification to Drawings

There are still opportunities to review moving information from specification to drawings. As a design team, it is often easier to place information in master specifications to avoid project-by-project placement of the information on drawings. But how often is the construction team seen with specifications out on the job site? There is certainly a need for specifications for material information and general installation methods, but information that relates to specific installation procedures, such as spacing of pipe hangers, would likely be better adhered to if placed on the drawings. This may take a little more time in the design phase, but the end result of a system installed according to design intent will provide a better long term benefit to the owner.

Electronic Certification

Electronic certification not only provides benefits to the certifier of avoiding wet signing multiple sets of CDs but also provides a more secure certification process. CAD tools are

available that will allow the certifier to lock down the drawing once electronic certification is applied, and any change to the document would remove the electronic seal. From a constructability standpoint, the benefit is the electronic certification allows direct transfer of the CAD file to TIF, PDF or other document viewing packages. As noted previously, wet signing documents often results in scanning of the signed hard copy, and the scanning process often reduces graphic quality. State registration requirements currently limit the application of electronic certification.

BIM

Building Information Modeling provides the biggest opportunity for improvement in construction documents since CAD. The intent of using BIM as a modeling versus drafting tool forces designers to think more about how the building will be constructed. Automated coordination tools within BIM can continuously provide clash and interference detection between disciplines. Other BIM tools assist in organization of details, key notes, and equipment schedules. Placing pipes and ductwork within a building model versus drawing lines on a background puts more responsibility on the design team to make sure the design is constructible. In the construction phase, BIM can provide material and equipment take-offs. The benefits to the owner should be more accurate construction bidding, reduced change orders due to design errors and field coordination, and ultimately a building that better meets the owner project requirements

Conclusion

An overall review of the constructability of construction documents was a valuable exercise for Target. As owner, designer, and operator of our buildings, it may be easier to incorporate changes in processes that may require more time during the design phase in order to improve the overall project. We can also push the new concepts to our consultants rather than a consultant attempting to sell a new concept to an owner. Some of the document revision concepts may be more applicable to the prototypical store design process, but many will apply to any building design. From a commissioning perspective, pushing the idea that construction documents should be produced to aid construction teams versus the convenience of the design team will help provide buildings constructed according to documents and better meeting the owner's project requirements.

The first sets of construction documents containing constructability improvements are just starting construction phase. Initial reaction from construction teams has been positive. We will be tracking stores through construction and commissioning to determine if there is a trend for lower requests for information, change order cost, and reduced deficiencies that could be tied to document improvements.

Recommendations

Owners

As building owners, ask your design teams how their documents are produced to aid constructability in the field. Be willing to spend more for design fees up front to provide more information in the construction documents. The investment will pay back with improved construction, reduced change orders, and likely construction cost savings.

Designers

Review your typical construction document set as if you are an installing contractor. Spend time in the field talking to contractors about how they interpret your documents and ask for suggestions on how to improve the documents. Use constructability of documents as a way to differentiate your services and inform owners where a little additional fee can lead to savings in construction.

Contractors

Let design teams and owners know where construction documents can be improved to aid constructability. Challenge design teams that do not provide good documentation with questions and let owners know about constructability of documents from their design teams.

Commissioning Teams

Work with owners and designers early in projects and suggest improvements to construction documents that make it easier to understand design intent. This will make completed project more likely to meet the owner's project requirements.