

IMPACTS OF CAD ON THE SUBMITTAL PROCESS

A Thesis

by

JAMES ANDREW DE LAPP

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2003

Major Subject: Construction Management

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ABSTRACT

Impacts of CAD on the Submittal Process.

(December 2003)

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The efficiency and accuracy of design is critical for construction success. The realization of design is dependent on complete and coordinated design documents that are finalized through the submittal process. This process involves the transfer of design intent from the architect and engineer to the specialty trade contractor for the production of shop drawings. The use of information technology to increase the ability to meet this intent is not being fully utilized today.

A case study was selected on the campus of Texas A&M University to investigate the impacts of CAD on the submittal process. The project was selected because it utilized both hand and CAD methods to produce shop drawings. The data collected included all contract documents, submittals, submittal logs, and interviews with the project participants.

A comparative analysis was made between the shop drawings that were completed by hand and those that were done by CAD. An analysis quantified the number of notes and corrections made by the reviewers during the submittal process. A separate analysis was made of the number of errors in the interpretation and transferring of background information from the contract documents in the shop drawing production.

Finally, interviews were conducted with the project participants to determine the cost associated with utilizing CAD to produce shop drawings. Although based on a single case study, the data showed that CAD had important impacts on the submittal process. The data suggests that when CAD is used to produce shop drawings, there are significantly less notes or corrections by the reviewers. It also suggests that the electronic transfer of design data from the architect and engineer to the subcontractor can ensure better design accuracy and lower overall project cost.

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TABLE OF CONTENTS

| | Page |
|---|------|
| ABSTRACT..... | iii |
| ACKNOWLEDGEMENTS..... | v |
| TABLE OF CONTENTS..... | vi |
| LIST OF FIGURES..... | vii |
| LIST OF TABLES..... | viii |
| INTRODUCTION..... | 1 |
| PROBLEM..... | 2 |
| RESEARCH METHODOLOGY..... | 9 |
| RESULTS..... | 13 |
| CONCLUSIONS..... | 19 |
| Liability concerns with electronic data exchange..... | 20 |
| Use of electronic media and other technologies..... | 22 |
| REFERENCES..... | 24 |
| APPENDIX A..... | 26 |
| APPENDIX B..... | 27 |
| APPENDIX C..... | 32 |
| VITA..... | 36 |

LIST OF FIGURES

| FIGURE | Page |
|--|------|
| 1 Shop Drawing Submittal Flow Diagram Using Hand Drawings..... | 3 |
| 2 Shop Drawing Submittal Flow Diagram Using CAD Files..... | 8 |
| 3 All Project Submittals by Type..... | 13 |
| 4 Shop Drawing Submittal Review Status..... | 14 |
| 5 Number of 24"x36" Sheets by Subcontractor..... | 15 |

LIST OF TABLES

| TABLE | Page |
|--|------|
| 1 Comparison of hand and CAD drawings..... | 16 |
| 2 Estimated cost savings by using CAD..... | 18 |

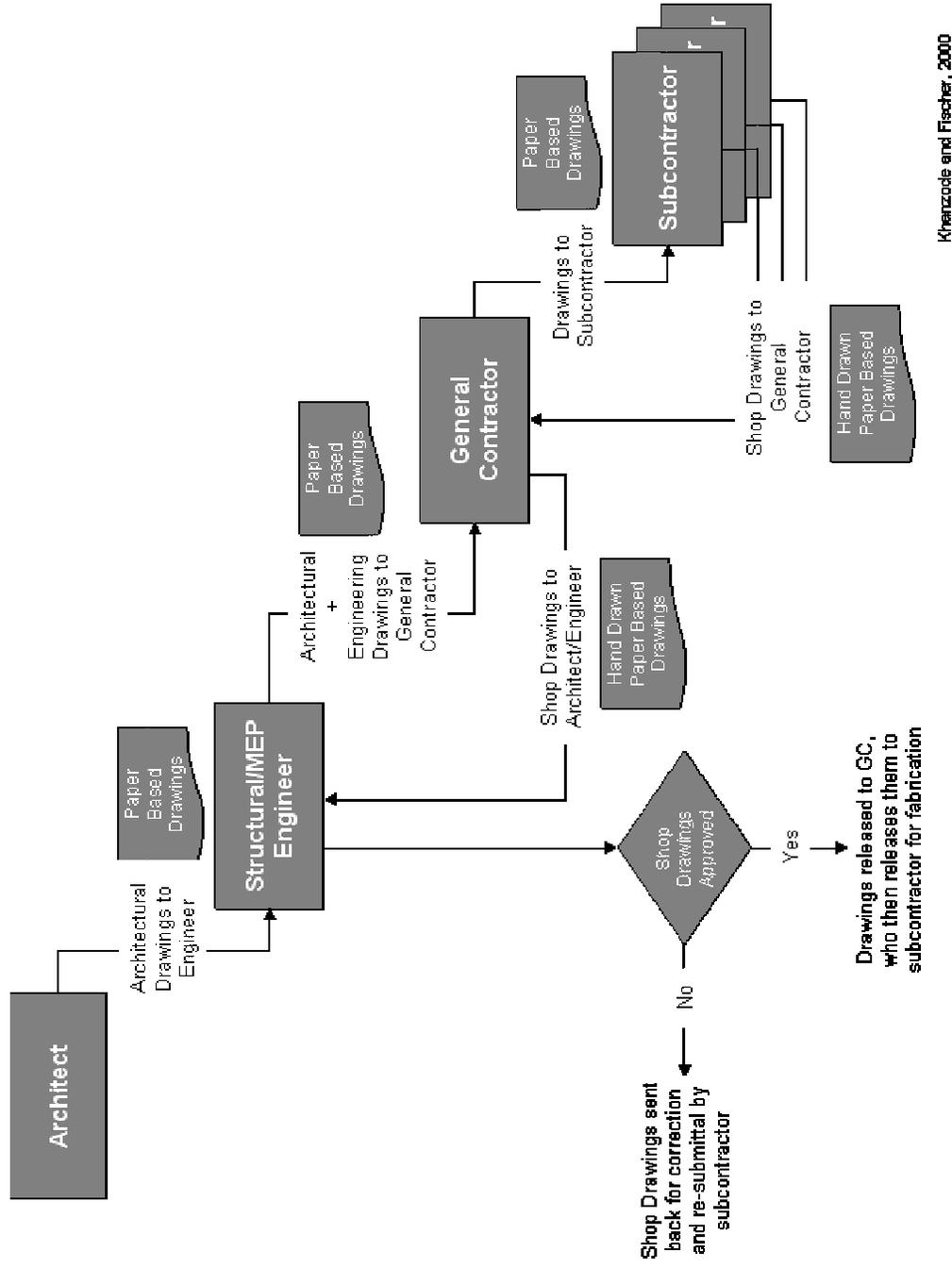
INTRODUCTION

The efficiency and accuracy of design is critical for construction success. The transition from the designer's intent, manifested through the contract documents (CD's), to the realization of a building involves the integration of additional design information to supplement the CD's. The integration of this information is done through an iterative process of submittals to the architect/engineer (A/E) from the general contractor (GC) and his subcontractors. The submittal process is a deliberate and necessary part of the building design and production process. Despite a solid effort to integrate as much information as possible into the CD's the contractor and subcontractors must provide additional information to facilitate the construction of a building. This additional information is manifested through the production of shop drawings by the subcontractors. Shop drawings have become the main interface between the end product described in the CD's, and the physical realization of the CD's (Pietroforte, 1997). It is important to produce shop drawings that accurately represent both the designer's intent and the method of construction. The ability to integrate both of these is essential but difficult. One method to increase the ability to efficiently and accurately produce shop drawings that are well coordinated is through the use of information technology. However, the use of information technology to assist in this process is not being fully utilized today.

This thesis follows the style and format established by the *Journal of Construction Education*.

PROBLEM

Improving the submittal process requires an understanding of how it works today. The coordination effort between the architect's CD's and the installation of a particular trade's work is based on a process of redundant drawing, checking, redrawing, and rechecking that is 'systematically' organized to catch mistakes before they are installed on site (mb2010, 2003). A typical project would take the following path of the A/E creating a set of CD's and then passing them to a GC. The GC will review the CD's and pass those drawings to the subcontractors of his choice, where the shop drawings for their particular trade would be produced. The shop drawings are then passed back through the GC for review and then onto the architect or engineer for final review and approval. Once approved, the drawings are sent back to the GC who then releases them to the subcontractor for fabrication or installation. If the drawings are not approved, they are sent back to the GC and the passed onto the subcontractor for correction and re-submittal. Depending on the status of the shop drawings, the process may have to be repeated until approved (see figure 1). Of significant note is that the design information being passed from the A/E to the subcontractor is typically through paper-based drawings drawn by hand. Interpretation is done at each level to determine the intent of the individual and then redrawn by the subcontractor in the shop drawing production process. As interpretation is made at each level, the process is susceptible to human error in transferring design information and intent.



Kharzode and Fischer, 2000

Figure 1: Shop Drawing Submittal Flow Diagram Using Hand Drawings.

Several problems exist within the submittal process that contribute to making this process inefficient. Contract documents can have missing and uncoordinated information from the different design disciplines. This can be the result of assumptions that have not been made explicit, or just simple omissions and errors (Pollalis, 1997). It has also been attributed to fast-track construction that produces drawings out of sequence (Post, 2000). Incomplete or inaccurate information creates a situation where the subcontractor will generate several requests for information (RFI's) to answer questions about design intent. This can severely slow down the submittal process, which already requires passing information through so many parties.

There is also a problem of redundant (duplicate) information within the CD's. "It is the norm rather than the exception to duplicate information at the different stages of the design process, from programming all the way to producing the building" (Pollalis, 1997). Specifications repeat most of the information the designer wants to put in their drawings. Because the CD's are never perfect, changes are often generated. When a change is made to a drawing that has applicable notes in the specifications, the change must be made in both locations and vice versa. This is an example of redundant effort in rewriting the same information between the drawings and the specifications. This also creates an opening for miscoordination between the two major items that make up CD's. Conflicting information within the CD's only increases the possibility for conflict in the shop drawing production.

Construction documents also have numerous nonapplicable details and specifications that are later crossed out, creating additional drawings, which are unnecessary

(Patterson, 2002). This has been attributed to the desire to “fill” a drawing sheet and attempt to put as much information as possible into the CD’s. This unnecessary information included in drawings continues to confuse contractors and creates an added cost to the design documentation (Patterson, 2002).

Producing shop drawings in addition to the contract documents can even be seen as redundant. Some have suggested finding ways to combine the shop drawing process with the contract documents all together. Charles Thomsen from 3D/I recommends reducing “the silly wasted duplication” between the contract documents and shop drawings. “If we develop a process where the trades are selected either by bid or negotiation, during the development of construction document, we can integrate their knowledge and their drawings into the process” (Post, 2000).

All of these problems contribute to confusion among the project participants and inefficiencies in the submittal process. These inefficiencies require a longer time for design and production, and ultimately additional cost to the client. The challenge is efficiently creating a complete set of documents that integrates all required design information and accurately reflects how a building will be constructed.

Several possible solutions to making this process more efficient have been suggested, but each has their own advantages and risks. Alternative delivery methods, such as design-build, have become a popular method of construction. The delivery process was created as a way to improve the coordination and integrate the project participants

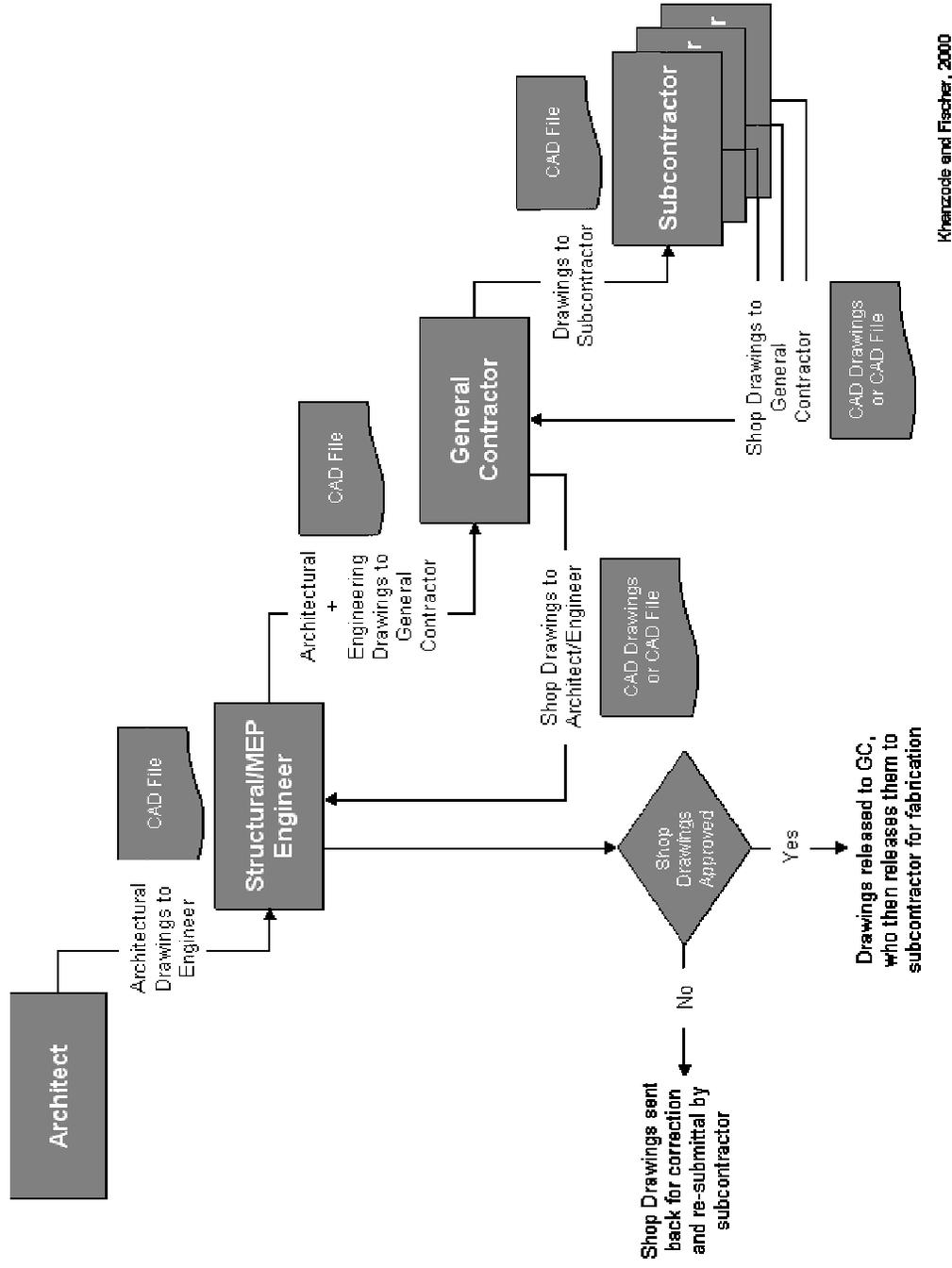
involved between design and construction (Peck, 2001). By having the architect and engineer work for the general contractor, the coordination between the design and construction process can be more effective, potentially saving time and money.

Early definition of the roles of project participants by integrating the general contractor, and even the major subcontractors during schematic or conceptual design, can facilitate more integrated design information (Post, 2000). Effective design is the product of effective teamwork among the owner, the designer, and the contractor (Construction Industry Institute, 1987). Early integration of specialist trade subcontractors in the design process can also help ensure that a building will stay within the client's budget. Redundant information can be avoided if the responsibilities of each team member can be defined precisely at the outset of the project. This definition of roles and coordination leads to basic control of the design process. Design control is the successful integration of all technical requirements to produce quality project design deliverables. This can be achieved by establishing a plan for how documents will be prepared (Hart, 1994). Finally, architects must be aware of their responsibility for coordinating and integrating all the information produced by various trades (Glavinich, 1995).

One of the most potentially promising solutions to integrating all necessary design information into the shop drawings, allowing total design realization and limiting the iterations of the submittal process, is the use of CAD. The use of CAD versus hand drawing does not change the overall submittal process. The only change in the process is the actual format used to create and transfer the drawings by substituting CAD files

for paper-based drawings when transferring information to the subcontractor (see figure 2). This assumes that the CD's were produced using CAD. During the production of shop drawings, it is common for a materials fabricator who uses CAD to ask the architect for the electronic drawing files so that they can prepare their shop drawings more economically (Middlebrook, 1991). An example of designing a sprinkler system for a building shows how money could be saved when sharing electronic files. Having the architect provide CAD files for the building shell to the various trades at no cost could substantially reduce redundant drawing. Redrawing a buildings' shell can increase the cost of the sprinkler system by \$3500, depending on the size of a building (Patterson, 2002). Using CAD allows the option of plotting drawings at any requested size for review by the general contractor or A/E. CAD drawings are also reusable; any future changes to the design documents can be made readily.

This research will investigate the impacts of CAD on the submittal process by conducting a comparative analysis of the hand produced and CAD produced shop drawings for a project. The results will attempt to draw conclusions about the impacts of information technology in the submittal process; and in particular the impacts CAD has on shop drawing production.



Kharzode and Fischer, 2000

Figure 2: Shop Drawing Submittal Flow Diagram Using CAD Files.

RESEARCH METHODOLOGY

To investigate this question a case study building was identified which utilized both traditional hand drawings and CAD. The project is located on the campus of Texas A&M University in College Station, TX. The project is comprised of several support buildings for a sports complex. The total complex is 27,347 sq. ft. with the main athletic training facility building containing 16,062 sq. ft. All buildings are steel frame with a masonry exterior. The project was started on 2 November, 2001 and was scheduled to be completed on 2 November, 2002. However, because of some delays for weather, and a few change orders, the project was completed on 23 December, 2002. The initial estimate for the building was \$4,317,133 which was \$212,869, or 5% less than the actual completion cost of \$4,630,002. The client (Texas A&M University) is very well informed about the construction process, and has substantial resources to manage and supervise the construction of the facility. The project was a traditional design, bid, build project, with a negotiated lump sum contract. The A/E firms and the GC have both done work for the Texas A&M University system before. All pertinent information was collected during the construction of the project. This information included; a complete set of the working drawings, a copy of the specifications with addendums, copies of all submittals, copy of the submittal log, and a copy of the change order log. The drawings produced by the A/E firms were very complete, and the specifications were extremely thorough. The submittals that were collected were broken down into several categories; color approval, customized vendor drawings, manufacturer data specification sheets, shop drawings, and others.

- Color approval - Submittal of a vendor's specific color or pattern by the contractor to the architect for approval per the specifications and design intent.
- Customized vendor drawings - Utilizing vendor specific software, the contractor can customize the detailed drawings with the heading and information specific to the project. An example includes the electronic control panels produced by SIEMENS®.
- Manufacturer data sheets - Submitting a photocopy of a manufacturer's actual data sheet that details a specific piece of equipment or method of installation.
- Shop Drawings - Separate drawings produced by a subcontractor detailing how their specific trade will fabricate and install their work. These drawings are based on the working drawings handed down by the A/E firms and the general contractor. Typically these drawings are produced from scratch and specific to this particular project.
- Other - Submittals that do not fall into one of the previous four categories, such as welder certifications.

The submittals with shop drawings were further analyzed to determine several factors; which drawings were drawn by hand or CAD, the numbers of drawings sheets produced in each submittal, and how many sheets were produced per subcontractor. The sizes of the drawing sheets were also measured, and the total number of square feet of drawing space was calculated per submittal. As stated earlier, during the shop drawing review process several project participants review the drawings. After the shop drawings are officially submitted, they are reviewed by the general contractor, then the engineer, and

finally by the architect. At any point in this review process any reviewer can make corrections, highlight errors, or make notes to the shop drawings. This process may occur more than once, and continues until the drawings meet the approval of all parties. During the researcher's review of the shop drawings submitted for this project, the shop drawings were analyzed to see how many notes were made by the reviewer on the drawings, how many corrections were made by the reviewer on the drawings, and how many errors were made during the transfer of background information.

- Note by reviewer - A reference to refer to the contract documents, verification of a request for information (RFI) by the subcontractor, or other general note.
- Correction by reviewer - Actual change to the shop drawings because of some type of error. Typically a wrong calculation in sizing, placement, or other correction.
- Error in background information - Errors in the translation of the CD's when redrawing the background information for the shop drawings, such as column grid or dimensions from the contract documents.

The number of notes, corrections, and errors in background information were broken down by the different drawing formats. These formats included CAD produced shop drawings and hand-drawn shop drawings. To gain a better understanding of how the iterative process of shop drawing production and review was executed, additional information was desired to supplement the contract documents. This information could only be gained by conducting personal interviews with the project participants. During the interviews several questions were asked of the participants (see Appendix A), which

opened a dialogue about their preferences for using CAD to complete shop drawings and aided in obtaining the costs associated with this process. Information was collected from the architect, engineer, and four subcontractors (see Appendix B). The four subcontractors included; structural steel, concrete reinforcing, mechanical, and electrical. Shop drawings were produced by other subcontractors, but were not used in the collection of cost data because the manufacturer and not the subcontractor produced the shop drawings as a part of their service or product. Shop drawings that were produced but not included in this study were; metal roofing, toilet partitions, walkway covers, and lockers.

RESULTS

For this project 182 submittals were submitted for review. The submittals were sorted into the categories of: color approval, customized vendor drawings, manufacturer data sheet, shop drawings, and others (see figure 3). More than 50% of the submittals were copies of the manufacturer's data specification sheets. However, shop drawings represented more than 25% or 46 of the total submittals.

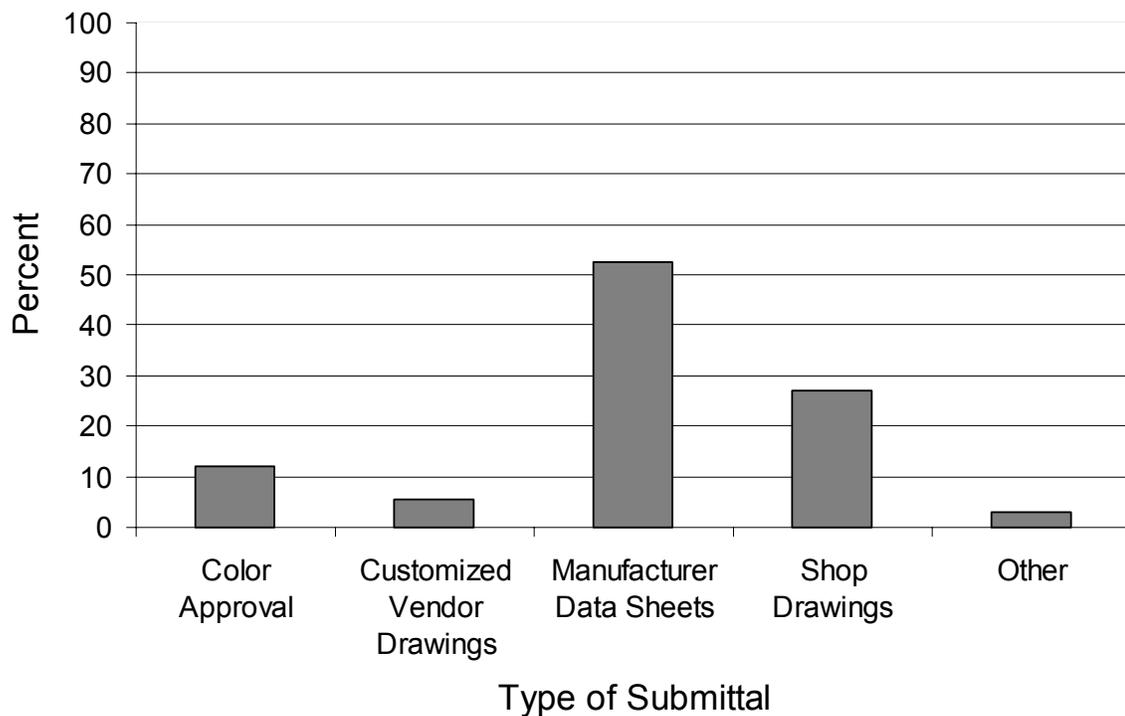


Figure 3: All Project Submittals by Type.

Of the 46 submittals that contained shop drawings 34 were analyzed. As stated earlier, shop drawings that were produced by the manufacturer were not utilized in this study. The 34 shop drawings that were reviewed included those from the structural steel,

concrete reinforcing, mechanical, and electrical subcontractors. Comparing these 34, it was determined that 15 or 45% were approved the first time they were reviewed without any marking, 14 or 42% were approved with some type of note, 3 or 8% were to be revised and resubmitted, and 2 or 5% were rejected. Only the revise and resubmit, and the rejected submittal had to go through the review process a second time (see figure 4). These numbers represent the first time the submittals were submitted, ultimately all submittals were approved.

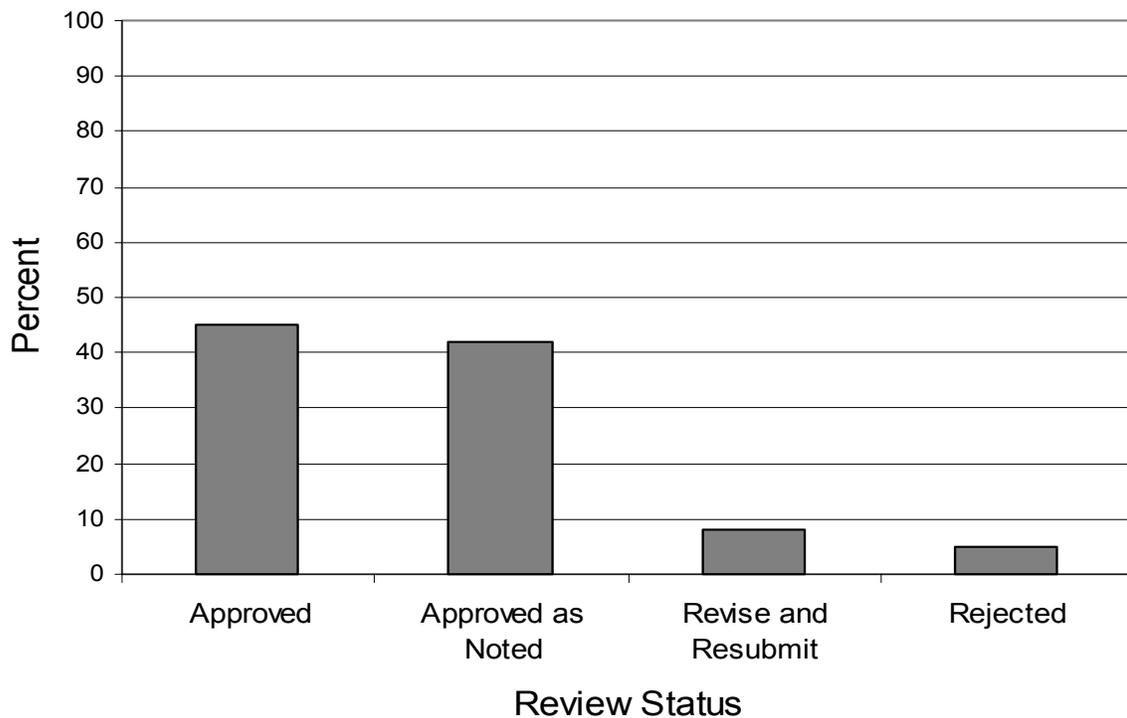


Figure 4: Shop Drawing Submittal Review Status.

The number of drawings produced by each subcontractor varied significantly. The structural steel subcontractor produced 80 sheets that were 24"x36" and 4 sheets that

were 30"x42" with a total of 515 sq. ft. of drawing space all drawn by hand. The concrete reinforcing subcontractor produced 16 sheets that were 24"x36" with a total of 96 square feet of drawing space drawn by hand, and 6 sheets 24"x36" with a total of 36 sq. ft. of drawing space drawn by CAD. The six sheets drawn by CAD were from a single submittal that was rejected because the concrete reinforcing subcontractor submitted a copy of the A/E firm contract documents for his shop drawings. The mechanical subcontractor produced 16 sheets that were 30"x42" and one sheet 11"x17" with a total of 141.5 sq. ft. of drawing space all drawn by CAD. The electrical subcontractor produced 9 sheets that were 24"x36" with a total 54 sq. ft. of drawing space drawn by CAD. Because the sheet sizes varied significantly between the various subcontractors and the fact that CAD drawings can be plotted at any size, the drawings were averaged to the modal size of 24"x36". The total number of 24"x36" shop drawing sheets produced by each of the four subcontractors is represented (see figure 5).

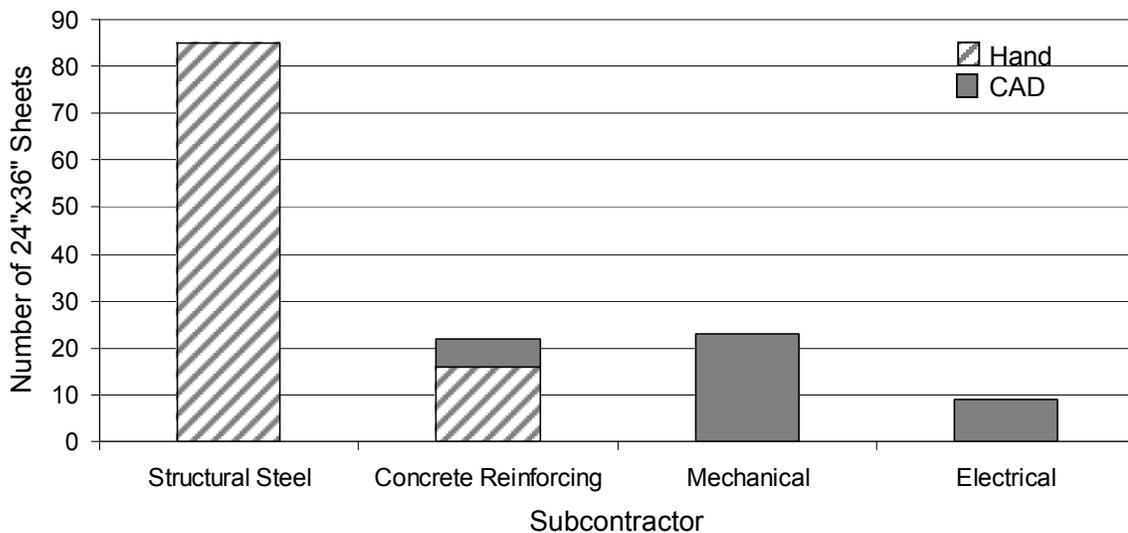


Figure 5: Number of 24"x36" Sheets by Subcontractor.

Quantifying the number of notes or corrections by the reviewer and errors in the transfer of background information was then completed. The results were that hand produced shop drawings had a total of 155 or 86% more notes by the reviewer than CAD produced shop drawings, which had just 8. The number of corrections by the reviewers included 115 from the hand produced shop drawings or 114% more than the CAD produced shop drawings, which had 0. Finally, the number of errors in the transfer of background information included 6 in the hand produced shop drawings or 50% more than the CAD drawings which had only 1 (see table 1). By dividing the number of occurrences of a note, correction, or error by the number of 24"x36" drawing sheets, gives the number of occurrences per 24"x36" sheet (see table 1). The results established that hand produced drawings had 2.73 occurrences per sheet, while CAD had just 0.24 occurrences per sheet, or roughly one occurrence per every four 24"x36" sheets.

Table 1

Comparison of hand and CAD drawings

| | Number of Occurrences (N) | Number of 24"x36" Sheets (S) | Occurrence per sheet (O=N/S) | % Greater than CAD |
|---------------------------------|---------------------------|------------------------------|------------------------------|--------------------|
| Hand | | | | |
| Note by Reviewer | 155 | 101 | 1.53 | 86% |
| Correction by Reviewer | 115 | | 1.14 | 114% |
| Error in Background Information | 6 | | 0.06 | 50% |
| TOTAL | 276 | | 2.73 | 91% |
| CAD | | | | |
| Note by Reviewer | 8 | 38 | 0.21 | N/A |
| Correction by Reviewer | 0 | | 0.00 | N/A |
| Error in Background Information | 1 | | 0.03 | N/A |
| TOTAL | 9 | | 0.24 | N/A |

A second part of this research was to determine the cost associated with redundant drawing had CAD files been transferred to share background design information. As the collection of information and interviews with the project participants progressed, it became clear that much of this data could not precisely be obtained. The reason for this is that the shop drawings are produced by draftsmen that get paid by the hour. These draftsmen did not maintain exact hours they worked on specific parts of the project, or in redrawing background information. Therefore, to obtain the cost data that was associated with producing the drawings, the subcontractors gave their “best estimate” for the cost they spent in redrawing the background information (see table 2). When asked in the interview (see Appendix A), three of the subcontractors stated that the savings would have been “around a couple of thousand dollars.” The fourth stated that he would spend approximately \$200 per drawing sheet to transfer the background information (see Appendix B). By looking at the cost for the subcontractor and the estimated savings, you get a 0.5% savings or \$9,200 by sharing the CAD backgrounds from four subcontractors for this project. Although in this project the cost savings does not seem significant, when total profits from projects are typically 3-5%, this can reflect a much greater savings on a project of higher cost.

Table 2

Estimated cost savings by using CAD

| Project Participant | Drawing Method | Original Contract Cost | Actual Contract Cost | Estimated savings by using CAD Backgrounds | Percent Savings |
|------------------------------------|-----------------------|-------------------------------|-----------------------------|---|------------------------|
| Structural Steel Subcontractor | Hand | \$183,680 | \$191,908 | ± \$2,000 | 1.04% |
| Concrete Reinforcing Subcontractor | Hand/CAD | \$68,300 | \$68,420 | ± \$2,000 | 2.92% |
| Mechanical Subcontractor | CAD | \$950,562 | \$950,546 | \$200/Page or ± \$3,200 | 0.34% |
| Electrical Subcontractor | CAD | \$409,805 | \$469,076 | ± \$2,000 | 0.43% |
| | TOTAL | \$1,612,347 | \$1,679,950 | ± \$9,200 | 0.55% |

In the interviews with the subcontractors (see Appendix B), all expressed that having the background CAD files would have saved them time in producing their shop drawings and ultimately saved the client money. All subcontractors also expressed that whenever the backgrounds were available, they would be used. The only instance in which the background information would not be used is when the original A/E drawings are of poor quality. The Architecture and Engineering firm gave no explanation as to why the backgrounds were not passed to the GC and onto the subcontractors for this project, but the conclusion can be made from the interviews, that it was because the GC never requested them. Based on the interviews of the project participants, it was also clear that no industry wide system is established to standardize transferring the CAD file backgrounds from the A/E firms to the GC or subcontractors.

CONCLUSIONS

This research conducted a comparative analysis of a case study that utilized both hand drawn and CAD drawn shop drawings in the submittal process. The problems associated with the integration of all necessary information into shop drawings and the iterative nature of the submittal process was described. A method of sorting the submittals, and quantifying the number of shop drawings was developed. By analyzing the number of notes, corrections, and errors in transferring background information between the hand drawn and CAD shop drawings, it was determined that the hand-produced drawings had a much higher occurrences of a note, correction, or error in transferring background information. This suggests that utilizing CAD to produce shop drawings reduces the occurrence of a note, correction, or error in base information. The cost associated with utilizing CAD was also analyzed to determine that using CAD to transfer design information during the submittal process could increase cost savings by 0.5%. This work supports the use of CAD to produce shop drawings, and share electronic copies of drawings between the A/E and the contractors in the production of their shop drawings. Explanations for why CAD drawn shop drawings had fewer errors than hand drawn were not confirmed, but one possible reason may be that the reviewers assume because the drawings are done using CAD, they must be more accurate and therefore spend less time reviewing them. Another reason could be that mechanical and electrical subcontractors, which used CAD for this project, do so because they are seen as more “professional” trades. In some instances, mechanical subcontractors may even use their CAD drawings in the actual production of items such as ductwork.

Strength of this research includes the findings which were consistent in each category that was investigated. Every result demonstrated that CAD could only help to increase the accuracy and the efficiency in which shop drawings could be produced. Weakness in the research includes the cost data that was obtained from interviews with the subcontractors was only a “best estimate” on their cost savings by having CAD files. Obtaining more accurate and definitive information on actual cost savings would have been beneficial. It is also possible that had the subcontractors which produced drawings by hand, used CAD to produce their drawings; they could have had the same number of occurrences of a note, correction, or error. Finally, although the results suggested that CAD was better than hand drawn shop drawings, they only represent data from a single case study. Conducting an analysis on multiple projects which use hand and CAD in shop drawing production and the submittal process; and use CAD files to transfer design information, would produce findings that could be more valuable.

Liability concerns with electronic data exchange

Much of the concern over sharing electronic files with contractors is the increase in liability (Singer, 2003). The issue of liability is not new to the construction industry, but the increasing ease in which the electronic CAD files can be shared has rejuvenated the concern over liability resulting from sharing these documents. “Contractors consistently ask for electronic backgrounds they can use for the preparation of shop drawings. In that situation, we cooperate and facilitate the process and confirm that we have the contractor’s signed concurrence that we retain our copyright and are held harmless, to the full extent of the professional standard, from the contractor’s use of our documents”

(Dougherty, 2002). The issue of liability is of most concern to the architect and engineer who produce the CD's. The American Institute of Architects (AIA), in Documents *A201 General Conditions of the Contract for Construction* and *B141 Standard Form of Agreement Between Owner and Architect*, address the issue of liability by defining where the liability should be placed in shop drawing production and review. It states that shop drawings are not a part of the Contract Documents, and that the contractor shall not be relieved of responsibility for deviation from requirements of the contract documents by the architect's approval of the shop drawings. (American Institute of Architects, 1997). Two documents were written for the AIA by a large insurer of design professionals (Victor O. Schinnerer & Company, Inc.) to address the issues related to the sharing of electronic data. The documents highlight several aspects of sharing electronic data, other than the technological requirements. Victor O. Schinnerer & Company, Inc. suggests when the "Instruments of Service" are transferred; the design professional should reserve the right to remove the professional seal and title block from documents turned over to the client, thus limiting concerns over future claims. If a transfer of electronic data does take place, firms often demand a separate agreement requiring indemnity for the time and costs to a firm involved in a dispute over CAD information (see Appendix C). They also go on to say that the transfer agreement should specifically state that if any conflict exists between the hard copy drawings from the A/E and the CAD information, that the hard copy always governs.

Use of electronic media and other technologies

The use of CAD, the Internet, and other mobile technologies have increased the ability to expedite the process of taking a design idea and constructing it. This increased dependence on technology has changed the way designers and constructors operate. By utilizing Internet based websites for hosting projects, the flow of design documents can be streamlined, and communications can be improved. This could reduce much of the duplication that now exists between the architect and the trades, and reflect a lower cost to the owner (Post, 2000). The first application of an integrated computer software system in the construction industry has been CIMsteel (Computer Integrated Manufacture of Steelwork). The American Institute of Steel Construction endorsed CIMsteel in 2000, as a means to eliminate paper design and coordination for structural steel design and fabrication. CIMsteel is a complete software system that has demonstrated the integration of the design process from outline design through manufacturing details via the seamless transfer of data from one computer system to another. There is no loss of data from one system to another and the results of calculations in one system can be used by another system and vice versa. The intent is to go from design to specific details in less than two hours with the confidence that all of the data is compatible and there is not data corruption when transferring from one system to another (Khanzode and Fischer, 2000). Although this system has its advantages, the advances in the ability to share files online via the Internet provide additional benefits. Utilizing Internet based technologies allows communication between remote users with the ability to share files, comment on changes, and post

requests for information (RFI's). A system developed at the Construction Engineering Research Laboratory (CERL) in Champaign, Illinois by the United States Army Corps of Engineers (USACE) has become USACE's common access database for design information on a project. The system is called the Design Review and Checking System (DrChecks). It is now used throughout the Corps of Engineers, Department of State's Office of Foreign Building Operations, General Services Administration, Naval Facilities Engineer Command, Federal Aviation Administration, and numerous civilian A/E firms.

Based on this work, topics for future research that should be considered include; expanding the study and research beyond one case to make the research results more generalizable, and collection of cost data during the design process from both the A/E and the subcontractor. This could be accomplished by having the draftsmen track the hours they spend on redrawing background information for the project. This data would give more accurate cost savings information when CAD is used as compared to hand produced shop drawings. Finally, tracking the time spent on review of drawings produced by hand and CAD would also be valuable. This information could be used to determine if both CAD and hand produced shop drawings received the same amount of review time. Continuing to improve the integration of design information and the use of information technology is vital to increasing the efficiency and accuracy shop drawings and the submittal process.

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APPENDIX A

Interview questions with Project Participants

Questions asked of the A/E firms included:

- Did the A/E firms provide CAD files to the General or Sub Contractors?
- If yes, did you charge for transferring this data?
- If yes, how much did you charge for the data?
- If you provided CAD files to the General or Sub Contractor, did you make them sign a waiver?
- Have you found that providing the CAD files makes the production of the shop drawings and the review process more efficient?
- What type of CAD program does your firm use?
- Does your firm use web-based drawing rooms to share drawing files?

Questions asked of the General and Subcontractors included:

- What was the cost to produce the shop drawings for this project?
- What percent of the shop drawing fee was for redrawing of background information?
- Did you receive CAD files that supplied background information for this project?
- Do you usually receive CAD files with background information for projects, and have they been beneficial?
- Does your company use some type of CAD program?

APPENDIX B

Results of interviews with project participants

Architect

The answers to the interview questions were extremely varied. As stated earlier, the CD's produced by the A/E firm were very complete. The drawings were all done using AutoCAD® as their primary software system. The architecture firms stated that as a practice they will provide copies of the CAD files to the GC only, and this is done only when requested. The architecture firm discussed how they view the shop drawing process and stated that the main reason they do not like contractors to use their drawings is that "the architect is not perfect" in everything that they do, and that the shop drawing process allows for a second set of eyes to look at the work and possibly catch mistakes. The architect also stated that when they provide a set of CD's to a GC, they will be a complete set and will not release an incomplete set. Any CAD files that the architect provides to the GC are "sterilized" copies of the original files, removing all approval stamps, dimensions, and other notes. The architecture firm does charge to provide the CAD files because of the work that is involved to sterilize the CAD files. The cost for the CAD files is based on the square footage of the facility. The architecture firm requires the GC to sign a waiver when providing the CAD files, absolving the A/E firm of any discrepancies in the files, that the files are being provided as a convenience to the GC, and that the CAD files are for use on that project only.

Engineer

The engineers for this project stated that they almost always provide the CAD files to Contractors. They stated that providing this information definitely saves time and money. The engineer firm usually provides the structural, mechanical, electrical, plumbing, and architectural drawings to the contractors. They take off the certifying seal and title block, make the drawings a read-only file, and have the contractor sign an indemnity waiver and agreement for transfer of the CAD files (Appendix B). By providing these files, the engineering firm said it also helps to produce better “as-built” drawings. The engineer firm usually charges \$50.00 per CAD file. This charge is to cover the service of copying the files, and removing any identification information.

General Contractor

The General Contractor for this project did not request copies of the CAD background information for their subcontractors. They stated that the subcontractors may have requested these files from the A/E firms directly, but that they do not ask for these files as a part of their service. The most obvious example of redundant drawing the GC sees is in the mechanical ductwork. According to the GC, the subcontractor can almost always use the engineers’ drawings to install the ductwork for a project, yet the A/E firms insist on having the mechanical subcontractor produce shop drawings. The GC understands the reasoning behind having the shop drawings done, but sees a lot of wasted effort in the process. The GC does use some Internet based plan rooms, such as the American General Contractors (AGC) plan room, to view information about possible future jobs.

Concrete Reinforcement Subcontractor

The concrete reinforcing subcontractor estimated spending approximately \$1,000-\$2,000 to redraw background information that could have been provided by A/E firm. They said that providing the CAD files would definitely save time in delivering their product. Their experience is that many A/E firms will charge approximately \$300 dollars per sheet, and they almost always have to sign a waiver to release drawings. AutoCAD® is the primary means of producing their drawings, but much work can be drawn by hand on CAD backgrounds. Approximately 5% of the concrete reinforcing contract is for drawings/design. The concrete reinforcing subcontractor has seen a decline in the quality of design documents, which they attribute to the fast growth in the construction industry with new A/E firms that have little experience. The concrete reinforcing subcontractor said the submittal process is very slow and often changes are made by the A/E without ever getting information to the subcontractor in a timely manner, creating additional work and cost to the project.

Mechanical Subcontractor

The mechanical subcontractor rarely uses the prints or CAD drawings provided by A/E firms because of the inaccuracies and poor quality that they see 95% of the time. They have seen a serious lack of coordination between the different subcontractors and the A/E. The mechanical subcontractor has seen that the A/E typically works with each subcontractor individually, and does not coordinate the total effort. Because of this, the mechanical subcontractor prefers the delivery process of design-build over design, bid, build. This mechanical subcontractor has one full time draftsman that gets paid approx

\$20.00/hr. When they do need the CAD background files, they will try to work a trade for the files such as a discount off a change order. However, when the project is of significant size and complexity, the mechanical subcontractor will pay the \$1,000-\$2,000 to get the CAD files to save time. According to the mechanical subcontractor, their draftsman usually spends 1 day per page to redraw the background information.

Electrical Subcontractor

The electrical subcontractor did not receive the CAD backgrounds for this project.

However, if these backgrounds had been available, the electrical subcontractor said that it could have saved them approximately \$2,000. They use AutoCAD[®] as their primary CAD software. The electrical subcontractor normally requests the backgrounds for a project. In the past few years, they said obtaining these backgrounds has not been a problem. Usually they have to sign a waiver for the CAD files, and it is common for the A/E firm to remove their seal prior to providing these files. The electrical subcontractor said that the use of Internet based technologies to share files is being used more in their office on large-scale projects. Finally, the electrical subcontractor identified their largest problem is the coordination with specialty consultants on the project. These coordination problems include knowing where power outlets will be required and where a specialty contractor will need them prior to the electrical drawings being done. To reduce the occurrences of this happening, the electrical subcontractor will often hold coordination meetings prior to and during the design phase to incorporate as many of the consultants input as possible into their shop drawings.

Steel Subcontractor

The steel designer that did the shop drawings for the steel subcontractor confirmed that having CAD background files would speed up the shop drawing production process, but the designer does all of his work by hand. Allowing the steel designer to photocopy the drawings would be more beneficial to their production process. If the steel designer uses the A/E drawings, they are asked to sign a waiver. Some A/E firms the steel designer works with on a regular basis prefer them to use their drawings because they know their information is correct. Either way, the steel designer still ends up tracing the drawings and just checking the dimensions as he goes along, so they do not have to scale everything from scratch. The cost for designing and detailing the steel on this particular project was \$27,000 plus \$4,000 in later changes. According to the steel designer, being able to copy the A/E drawings would have saved approx \$2,000 on the cost of the drawing/detailing work.

APPENDIX C

WAIVER, RELEASE AND INDEMNITY AGREEMENT

Whereas, _____ hereinafter "Engineer" has utilized certain electronic CADD files in preparation of drawings for the Project:
on behalf of: _____, the "Owner", and:

Whereas: _____ a Subcontractor for:
Or: _____ a sub-tier contractor to:
hereafter "Subcontractors" desires to obtain copies on magnetic disk of certain of the Engineer computer aided drafting (CADD) files consisting of construction drawings for the Project, hereinafter, "Electronic Media," and

Whereas, Engineer is willing to provide copies for the convenience of Subcontractors only under certain express conditions of understanding, acknowledgment and covenant as hereinafter provided without qualification.

Now Therefore, Engineer and Subcontractor agree as follows:

1. **ACKNOWLEDGMENT AND LIMITATIONS:** It is acknowledged that (1) Engineer's instruments of professional services are the hard copy drawings and specifications issued by Engineer hereinafter "Instrument", (2) the Electronic Media are not substitutions for said Instruments, (3) differences may exist between said Instruments and the Electronic Media which Engineer is under no obligation to discover or disclose if known, (4) the Electronic Media may be incompatible with Subcontractor's software and hardware configurations. In all ways, including those enumerated, Subcontractors accept the Electronic Media "as is" and Engineer is under no obligation to correct, update for changes, enhance or maintain the Electronic Media for Subcontractors. Engineer does not represent or warrant that the Electronic Media are complete, free from defects, or accurate now or in the future. It is acknowledged, finally, that no client relationship is created by or through this instrument between Engineer and Subcontractors.
2. **WAIVER AND RELEASE:** Subcontractors agree all risk of incomplete, inaccurate, defective and variant information contained in the Electronic Media, and waives, quits, and forever discharges and releases the Owner, the Engineer and their officers, directors, employees and successors from every claim arising out of or related to any error, discrepancy, inaccuracy, variation or other defect in the Electronic Media, whether or not resulting in whole or in part from an act, error or omission of the Engineer and whether or not such claim is known or unknown as of the date of this waiver and release.
3. **REUSE:** The Electronic Media is not reusable for any other project or for additions or extensions of the project identified in the Electronic Media. Engineer does not authorize release of the Electronic Media to any person or party other than the Subcontractors, and the Subcontractors agree and covenant not to release the Electronic Media to any other party.
4. **INDEMNIFICATION:** Use of the Electronic Media shall be at the sole risk of the Subcontractors and without liability or legal expense to the Owner or the Engineer; further, Subcontractors shall, to the fullest extent permitted by law, defend, indemnify and hold the Owner, the Engineer and its officers, directors, employees and successors harmless from all claims, damages, including bodily injury or death, losses and expenses, including attorney fees, arising out of or resulting in whole or in part from the use of the Electronic Media.

5. DISPUTES: Due to the risk of damage, anomalies in transcription or copying and modification during use by Subcontractors where intended or otherwise, it is agreed the Engineer's archived copy of the Electronic Media, if Engineer chooses to maintain same, shall be conclusive, un rebuttable proof in all disputes over the content of the Electronic Media furnished to Subcontractors by this Agreement.

Wherefore, the parties have signed this Release, Waiver and Indemnify Agreement on the _____ Day of _____, 2003.

ENGINEER:

BY: _____

Title: _____

Date: _____

SUBCONTRACTOR:

By: _____

Title: _____

Date: _____

SUBCONTRACTOR:

By: _____

Title: _____

Date: _____

**AN AGREEMENT BETWEEN ENGINEER OF RECORD AND CONTRACTOR
FOR TRANSFER OF COMPUTER AIDED DRAFTING (CAD) FILES
ON ELECTRONIC MEDIA**

Engineer of Record _____ Contractor / Sub Contractor / Proposer _____

Project # _____ Date: _____

Project Name: _____

Location: _____

_____ will provide the following CAD files, dated _____ for the convenience of the Contractor in preparing shop fabrication drawings:

Drawings were prepared on the following:

Computer: _____ Hardware: IBM Compatible: Operating System: Windows Operating System
Software: Autocad 2000 / 2000-I

Contractor shall pay a service fee of Fifty Dollars per Sheet / Drawing File (\$50.00).

TERMS AND CONDITIONS:

1. _____ makes no representation as to the compatibility of the CAD files with any hardware or software.
2. Since the information set forth on the CAD files can be modified unintentionally or otherwise, reserves the right to remove all indicia of its ownership and/or involvement from each electronic display.
3. All information on the CAD files is considered instruments of service of and shall not be used for other projects, for additions to this project, or completion of this project by others. CAD files shall remain the property of and in no case shall the transfer of these files be considered a sale.
4. _____ makes no representation regarding the accuracy, completeness or permanence of CAD files, nor for their merchantability or fitness for a particular purpose.

Addenda information or revisions made after the date indicated on the CAD files may not have been incorporated. In the event of a conflict between sealed contract drawings and CAD files, the sealed contract drawings shall govern. It is the contractor's responsibility to determine if any conflicts exist. The CAD files shall not be considered to be Contract Documents as defined by the General Conditions of the Contract for Construction.

- 5. The use of CAD files prepared by shall not in any way obviate the Contractor's responsibility for the proper checking and coordination of dimensions, details, and quantities of materials as required to facilitate complete and accurate fabrication and erection.
- 6. The contractor shall, to the fullest extent permitted by law, indemnify, defend and hold harmless, and its consultants from all claims, damages, losses, expenses, penalties and liabilities of any kind, including attorney's fees, arising out of or resulting from the use of the CAD files by the Contractor, or by third party recipients of the CAD files from the Contractor.
- 7. believes that no licensing or copyright fees are due to others on account of the transfer of the CAD files, but to the extent any are, the Contractor will pay the appropriate fees and hold harmless from such claims.
- 8. Payment of the service fee is due upon receipt of the CAD files.

AUTHORIZED ACCEPTANCE

| | |
|----------------------|----------------------|
| By | by Contractor |
| Signature | Signature |
| Print Name and Title | Print Name and Title |
| Date | Date |

VITA

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CIVILIAN EDUCATION

Texas A&M University - College Station, TX 2003
Master of Science in Construction Management

Kansas State University - Manhattan, KS 1994
Bachelor of Architecture

MILITARY EDUCATION

US Army Command & General Staff College - Fort Leavenworth, KS 1999
Combined Arms Services Staff School

US Army Engineer School - Fort Leonard Wood, MO 1998
Engineer Officer Advanced Course

US Army Engineer School - Fort Leonard Wood, MO 1995
Engineer Officer Basic Course

EXPERIENCE

Company Commander
Company B 37th Engineer Battalion - Fort Bragg, NC 2000-2002

Operations Officer
XVIII Airborne Corps Staff Engineer Section - Fort Bragg, NC 1999-2000

Executive Officer
642nd Combat Support Equipment Company - Fort Drum, NY 1997-1998
Aide-de-Camp

10th Mountain Division - Fort Drum, NY 1996-1997

Platoon Leader
41st Engineer Battalion - Fort Drum, NY 1995-1996

AWARDS, QUALIFICATIONS

- U.S. Army Senior Parachutist Badge, Ranger Tab, Air Assault Badge
- Defense Meritorious Service Medal, Meritorious Service Medal, Army Commendation Medal (3 awards), Army Achievement Medal (3 awards), National Defense Service Medal (2 awards), Armed Forces Expeditionary Medal, Armed Forces Service Medal, Humanitarian Service Medal, NATO Medal (2 awards), Kosovo Campaign Medal, and the Army Superior Unit Award
- Associated Schools of Construction Graduate Competition First Place Award

PROFESSIONAL AFFILIATIONS

Association of United States Army, Army Engineer Association, Society of American Military Engineers, and the Association of Licensed Architects