CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

Potential Savings from Standardized Electronic Information Exchange: A Case Study for the Steel Structure of a Medical Office Building

By

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SUMMARY

CIFE TECHNICAL REPORT #121

Title: ***Potential Savings from Standardized Electronic Information Exchange: A Case Study for the Steel Structure of a Medical Office Building***

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1. Abstract:

• The objective of this research project was to document the current process of design, detailing, fabrication and erection of structural steel on an actual construction project. The goal was to identify the limitations of this process and identify specific problems created due to the lack of standards in sharing of information between project participants, and to demonstrate how CIMSteel Integration Standards will play a role in this process in the future.

2. Subject:

- What is the report about in laymen's terms?

This project documents the current structural steel delivery process on a medium sized commercial construction project to identify the limitations of the current process and identify how information exchange standards like CIMSteel can address these limitations.

- What are the key ideas or concepts investigated?

The key idea investigated is how the use of information exchange standards might lead to increased process efficiencies in the structural steel delivery process.

- What is the essential message?

The essential message is that, for faster, better structural steel project delivery process it is imperative that standards such as CIMSteel Integration Standards be adopted.

3. Objectives / Benefits:

- Why did CIFE fund this research?

CIFE did not fund this research.

- What benefits does the research have to CIFE members?

Benefits include: understanding of the current project delivery process, and a view into how the process might work in the future.

- What is the motivation for pursuing the research?

The motivation to pursue this research is two-fold: 1) The CIMSteel Standards were endorsed by the American Institute of Steel Construction recently and there was a need to identify what are some of the problem areas these standards addressed. 2) Identify a real world scenario of how the process might work in the future.

- What did the research attempt to prove/disprove or explore?

The research goal was to detail the chronology of a typical design change on a small construction project and show its effects on fabrication and construction to provide an illustration for possible improvements with better and faster information sharing between project parties and phases.

4. Methodology:

- How was the research conducted?

The research was conducted as a case study on a commercial construction project over a period of nine months. Research included collection of data generated during the life-cycle of a project and interviews with project participants and other stakeholders.

- Did the investigation involve case studies, computer models, or some other method?

The investigation included a case study on the steel design and erection for a medical office building in the SF Bay Area. It did not include computer models.

5. Results:

- What are the major findings of the investigation?

The major findings of the study are: there are inherent limitations in a paper-based structural steel delivery process and that these problems can only be addressed by adoption of standards such as CIMSteel for exchange of information between project participants.

- What outputs were generated (software, other reports, and video, other)

A case study report and a conference paper were generated from this research.

6. Research Status:

- What is the status of the research?

This research is now completed.

- What is the logical next step?

To identify a similar project and evaluate the structural steel delivery process that uses the CIMSteel Standards and then compare the two projects to identify and contrast the process improvements.

- Are the results ready to be applied or do they need further development?

The results are specific for a particular problem on a very specific type of project and would need further validation for various types of project and various problems.

- What additional efforts are required before this research could be applied?

A comprehensive study of the problems associated with the process across a wide range of project and comparison with a project that uses the exchange standards to identify process improvements.

POTENTIAL SAVINGS FROM STANDARDIZED ELECTRONIC INFORMATION EXCHANGE: A CASE STUDY FOR THE STEEL STRUCTURE OF A MEDICAL OFFICE BUILDING

by

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1. Executive Summary

Based on a typical design change on a typical project this study shows how inefficiencies in the current paper-based information exchange between designers, detailers, fabricators and builders lengthened project duration by about 11% and increased cost by about 7% due to field modifications, overtime and lost revenue. The study analyzes the causes for these inefficiencies and shows how adoption of the CIMSteel Integration Standards (CIS/2) would help eliminate the inefficiencies and their effects. The consistency and speed of electronic information exchange based on CIS/2 will enable the structural steel industry to respond faster, better, and more cost-effectively to the needs of today's construction clients.

2. Introduction

The current structural steel delivery process for a construction project is characterized by paper based exchange of information between the project participants. This paper based process leads to redundancies, errors and omissions, duplication of information and effort, and difficulties in communicating changes in design in a timely manner. These inefficiencies often lead to cost overruns and project delays. The objective of this study is to illustrate the information sharing between different project participants during the structural steel delivery process on a recently completed construction project. Specifically the objectives are to understand the limitations of the current process and to explore how the CIMSteel Integration Standards, recently adopted by the American Institute of Steel Construction (1,2,3), would help address some of these limitations in the current process.

The focus of this study is a typical medium-sized office building that was recently completed by a leading construction company in the San Francisco Bay Area. This $8 Million project involved a two-story structural steel framed building. The specific goals of the study are:

1. To illustrate and analyze today's process of sharing of information between project participants involved in the structural steel delivery process[1] on this project.
2. To identify the limitations of the current paper-based process during each phase of the structural steel delivery process.
3. To identify the bottlenecks and redundant tasks in the information sharing process.
4. To exemplify and quantify time delays and cost impacts that could be attributed to inefficiencies in information sharing in the structural steel delivery process for this project using a very specific example of a small design change.
5. To explore opportunities for application of the CIMSteel Integration Standards that could potentially increase the efficiency of the structural steel delivery process through design – procurement integration.

This study deliberately looks at one small problem on a typical building project in great detail. The point is to illustrate fully where problems often occur and to examine how the CIMSteel Integration Standards would eliminate or alleviate such problems. By itself, the problem presented would, of course, not warrant the development, adoption, and implementation of CIS/2. However, the problem illustrated in detail is, in our experience, symptomatic of problems in the industry, and the potential impact of CIS/2 is far greater than the particular savings in the isolated case.

3. Project Overview

The project is located in Northern California. The building is a two-story 56,000-sq. ft. building, with tilt-up panel construction, and interior steel framing consisting of tube steel columns, and steel joists. Rolled shapes are used for framing the floor openings. The floor system consists of metal decking with lightweight concrete. The project was put to bid on September 5, 1997 and was completed on September 1, 1998. The total cost of the project at completion was $7,936,200. This was about $600,000 more than the first published estimate. There was a significant delay during the building of the shell, due to delays in the structural steel delivery process, which eventually led to a delay of about 40 calendar days and $55,000 in additional construction costs. This delay could also be blamed for a loss of about 30 days worth of revenue from this facility for the client, which is estimated to be about $500,000.

4. Structural Steel Delivery Process on the Project

The project was a negotiated Guaranteed Maximum Price (GMP) contract between the Owner and the General Contractor (GC). The Owner independently hired an Architect who in turn contracted with a Structural Engineering firm. The General Contractor was

1 The process of design, detailing, fabrication and erection of structural steel.

responsible for putting the project to bid and contracting with a subcontractor to execute the structural steel delivery process. The General Contractor also coordinated the Mechanical / Electrical / Plumbing and Fire Protection design-build subcontractors. The Structural Steel Subcontractor used independent fabricator and erector firms to execute the project. The organization chart for the project is shown in Figure 1.

The structural steel delivery process, or sharing of information between the project participants, from design to fabrication to erection, is shown in Figure 2.

A survey of the project participants showed that every project participant used some kind of a software tool within their own functional areas. Table 1 lists the software tools used by the project participants.

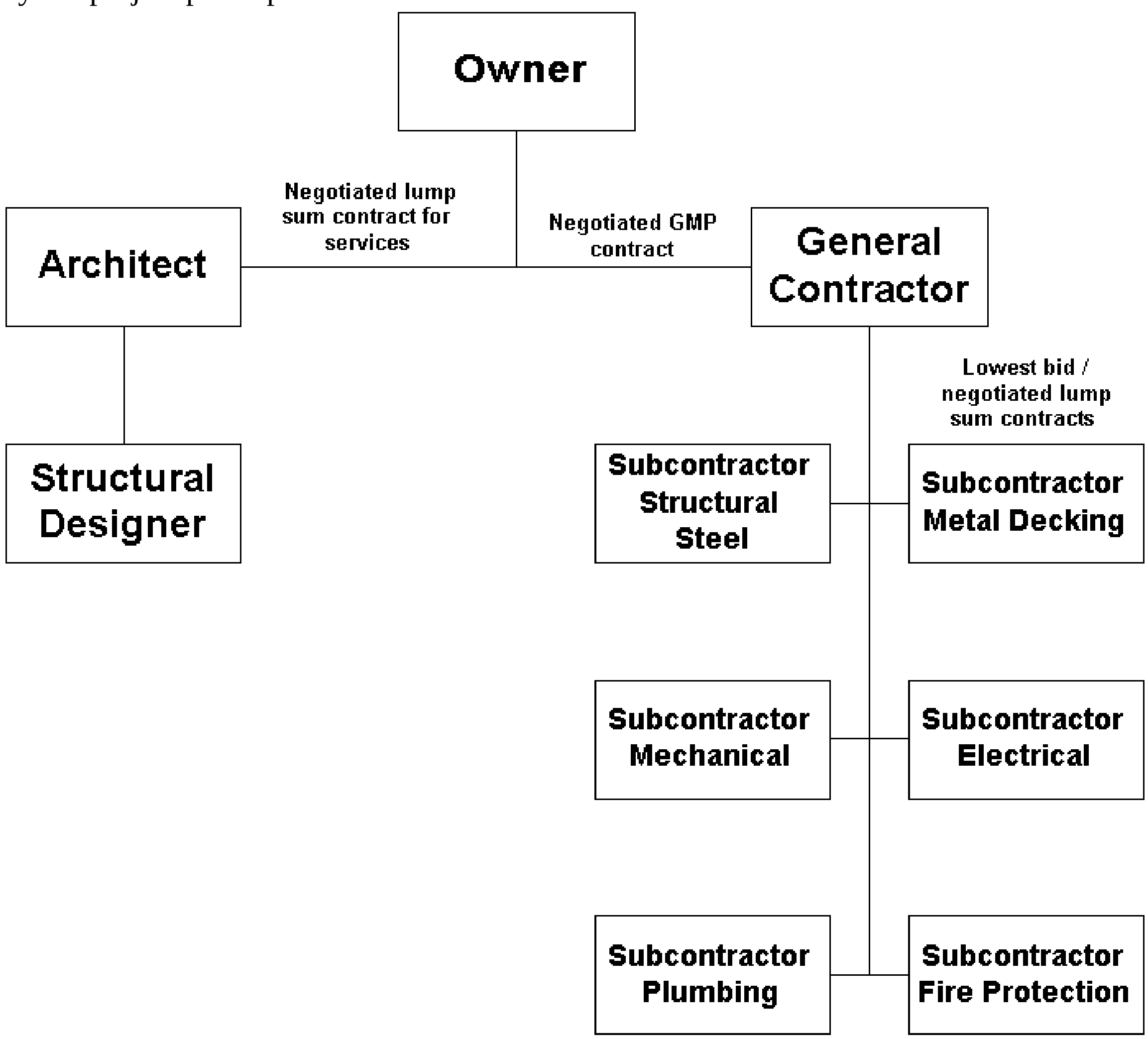

Figure 1. Organization chart of the project.

Figure 2 and Table 1 show that:

- Paper-based drawings were used to exchange engineering information between the project participants. This led to situations where team members were working with inconsistent sets of information until because the paper-based process was slow in communicating design changes to all affected project participants.

- The structural steel subcontractor used the paper-based architectural and structural drawings to create the shop drawings. This involved interpretation and re-creation of information on the design drawings issued by the structural engineer. There were a few instances where the design intent was not interpreted accurately and led to errors down the road.
- The structural engineer checked the shop drawings against the design drawings for accuracy. This also involved re-interpretation of the information.
- At every step the input to the software tools was keyed in by interpreting the paper-based drawings.

Thus, even though the project participants used various software tools within their disciplines, the sharing of information was through paper-based documents. Due to this paper-based sharing of information at every interface between project participants the engineering information had to be interpreted or re-created based on sometimes outdated paper-based documents.

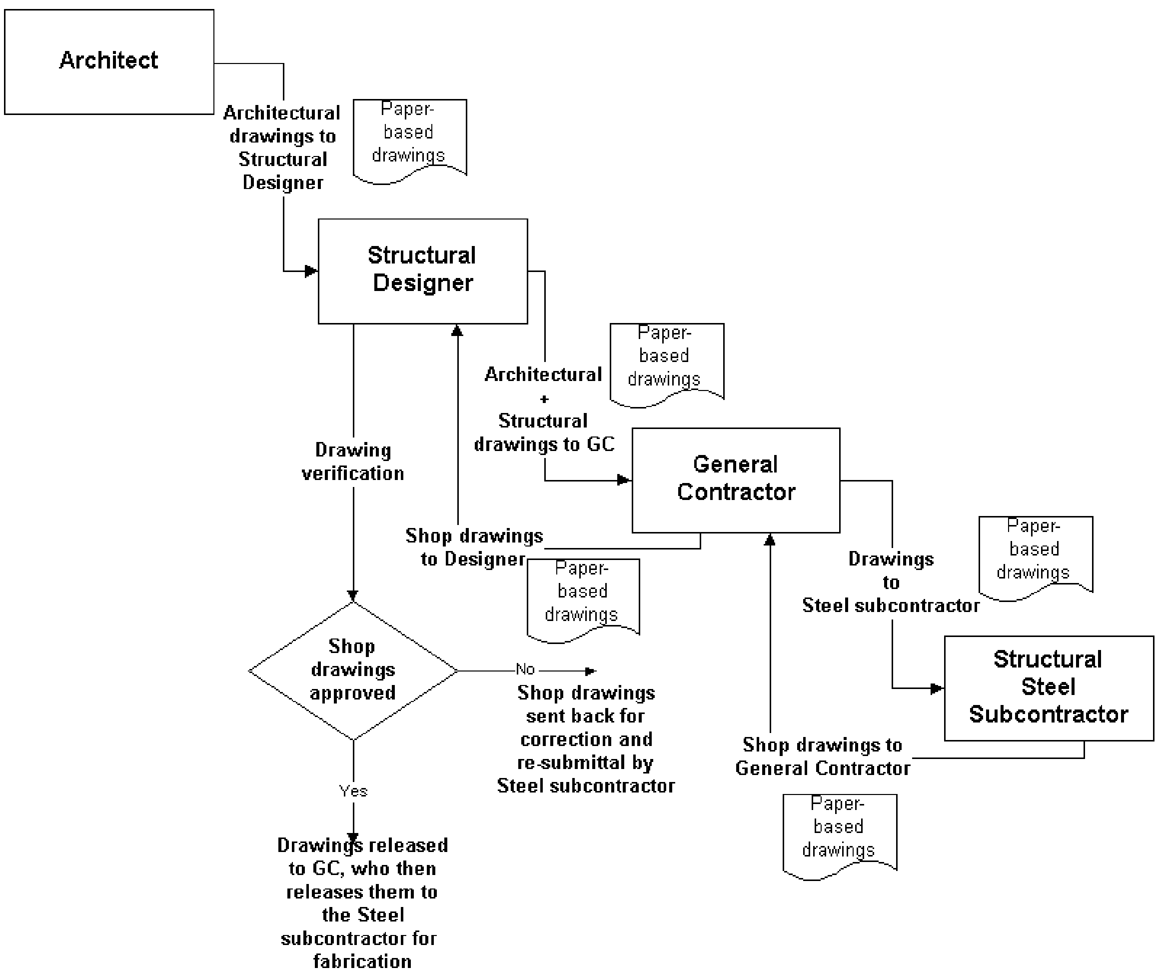

Figure 2. Structural steel delivery process. Sharing of information between different project participants.

5. Impact of Design Change on the Structural Steel Delivery Process

To determine, analyze and illustrate the impact of a design change on the structural steel delivery process we identified a small part of the structure that changed during the course of the project. This part of the structure is shown in Figure 3. As mentioned above, we would like to illustrate precisely, in the context of day to day work of engineering and construction professionals, where today's paper-based process leads to problems and what the impact of such problems on the project cost and duration is.

Project Participant	**Function**	**Software Tools Used**
Architect	Design	AutoCAD 13
Designer	Analysis and Structural Design	STAAD II
General Contractor	Estimating, Scheduling	Timberline Precision, Microsoft Project
Structural Steel Subcontractor	Shop Drawing Preparation Fabrication Job Costing	AutoCAD CNC Machines Spreadsheet Software

Table 1. The software tools used by the project participants.

The figure shows the change in opening size for a supply air duct opening on the second floor. The revisions to the supply air duct resulted in the following changes.

- Change in the opening size from 3'0'' x 2'0'' to 3'6'' x 2'6''
- Change in the beam that frames the opening from W8 x 10 to W12 x 14
- Change in the beam to joist connection due to change in beam size
- Change in column from C1 to C2

These changes are highlighted in Figure 3.

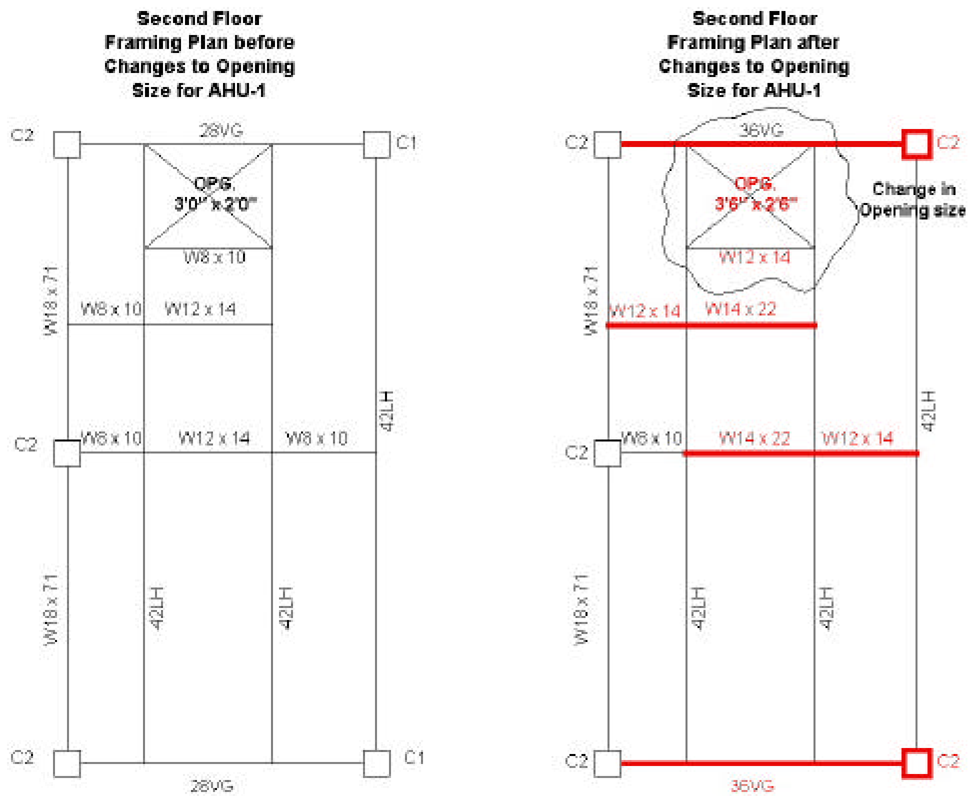

Figure 3. Partial second floor framing plan of the project illustrating changes in the structure due to change in the opening size for a supply air duct.

Let us now consider the impact of this design change on the structural steel delivery process and try to identify the bottlenecks in the process. The objective is to study how the design change information was communicated between project participants and whether this led to inefficiencies in the process and to any cost impacts or time delays. We first developed the timeline for when and how this design change was communicated to different participants in the structural steel delivery process. This is illustrated in Figure 4. Figure 5 shows the milestone events during the project and lists the activities the different project participants performed for these milestone events.

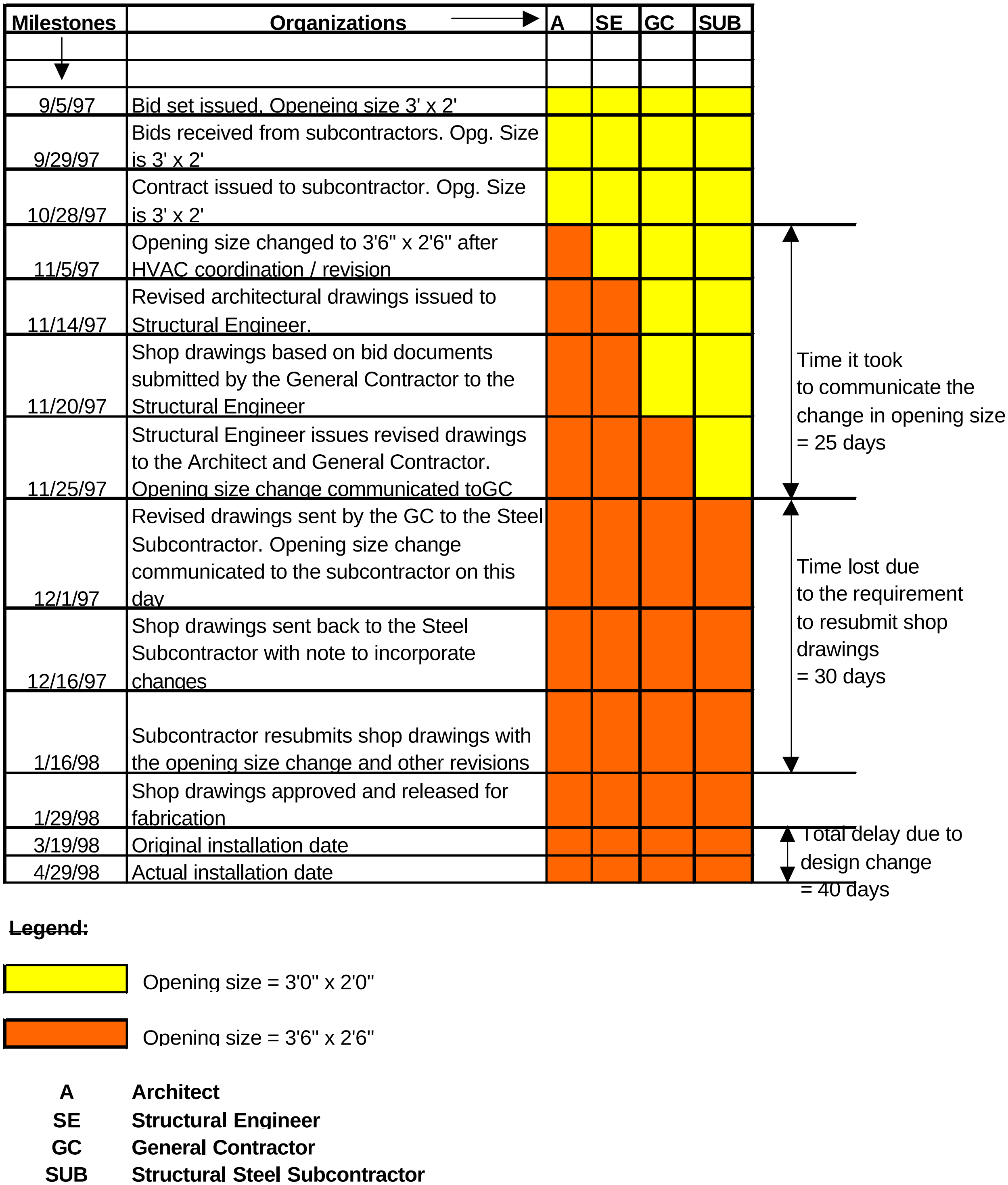

Figure 4. Sharing of Design Change Information between Project Participants.

Figures 4 and 5 clearly show that the design change was not communicated to the fabricator for about 25 days after it was generated. This suggests one of two things:

1. The process itself contributed to this delay because it literally took this much time to convey the design information in the paper-based process to all project participants.

2. One of the project participants failed to communicate this change effectively.

Based on interviews with the participants we found that the project participants acted expeditiously to communicate this information. In this particular case it took about 25 days for the information to be communicated from the designer to the structural steel sub-contractor. We correlated this duration to other projects currently underway in the San Francisco Bay area. From discussions with superintendents and project engineers we concluded that three weeks is about the shortest time for design information to be communicated to fabricators using a paper-based process. In short, there is an unavoidable delay of three weeks in communicating design change information if the current sequential' linear and paper-based process is followed. Typically, this time is built into the project schedule. Most of the people interviewed expressed the sentiment that if we get the drawings right the first time and get them approved on time the project schedule would not be affected. For this to happen most of the design would have to be completed and accurate so that it can be correctly incorporated into the shop drawings. But given the competitive climate for most construction clients and the resulting fast track projects these days, the design details are not usually worked out at contract award, and the paper-based process does not give any flexibility of incorporating and revising design changes in time, without affecting the project schedule.

ID	Task Name	Milestone
1	Drawings issued to bid	9/5
2	Bids submitted by subcontractors	9/29
3	Subcontracts issued: Shop Drawings started	10/28
4	Opening size increased by Architect	11/5
5	Arch. drawings with changed opg. size given to Structural Designer	11/14
6	Shop Drawings submitted to Structural Engineer	11/20
7	Revised Arch/Struct. Drawings issued to the Gen. Contractor	11/25
8	Revised Arch/Struct. Drawings issued to steel subcontractor	12/1
9	Reviewed shop drawings sent back to the steel subcontractor	12/16
10	Shop Drawings resubmitted to the Structural Engineer	1/16
11	Drawings released for fabrication	1/28

Figure 5. Actual Project Schedule based on the Project Milestones.

The question now is whether this unavoidable delay in communication contributed to time delays and cost impacts to the project. From the project timeline shown in Figures 4 and 5 we can infer the following:

1. The design change took place on 11/5/97, and the shop drawings based on the original opening size were not completed and submitted until 11/20/97. This suggests that there was an opportunity to incorporate this information into the shop drawings before they were submitted for review and approval.
2. The structural steel subcontractor was working with old information even though it was no longer valid for about 25 days. The design change took place on 11/5/97 and the subcontractor came to know about it only on 12/1/97. It should be noted that the general contractor received the revised drawings on 11/25/97 but due to a holiday weekend and their review process this information was not communicated to the structural steel subcontractor until 12/1/97.
3. The change in design was not incorporated into the shop drawings that were submitted for review on 11/20/97. The structural steel designer requested another submittal with the changed opening size information. This added one more iteration to the shop drawing approval process. For the project to be on schedule the shop

drawings should have been released for fabrication on 12/16/97. But the shop drawings were released for fabrication only on 1/16/98. Thus, the design change added a month to the approval process and delayed fabrication by 30 days.

4. To try to keep the project on schedule the joists were manufactured with incorrect information and field modifications had to be done to the joist-beam connections.
5. Our analysis shows that a total of about $5,000 was spent in field modifications of the joists. The beams that framed the opening were manufactured based on the revised information and arrived correctly on the job site.
6. The design change led to delays in fabrication and erection. According to the original schedule the structural steel erection should have been completed by 3/19/98. The structural steel erection actually finished on 4/28/98. Thus the design change led to a delay of about 40 calendar days.
7. To keep the project on schedule as much as possible the contractor started to work overtime. The total amount of money spent on overtime during the tenant improvement phase was about $60,000 to make up for a total of 48 days that were lost in earlier phases. This suggests that about $50,000 was spent to make up for the 40 day delay due to the structural steel design change during later stages of the project. Thus, a total of $55,000 was spent on making up the schedule delay of 40 days and modifying the beam joist connections in the field.
8. The overall delay to the project resulted in lost revenue for the client. According to the owner's Director of Facilities Management, this loss in revenue is estimated to be about $500,000 above and beyond the cost of the project.

6. Bottlenecks in the process

The above analysis shows that the shop drawing creation, submittal and approval process takes about 60 days and it must go right the first time for the project to be on schedule. The process does not provide flexibility for any late changes in design once the shop drawing process gets underway. This suggests that the current shop drawing creation and approval process is a huge bottleneck in the overall structural steel delivery process.

7. Redundancies in the process

To determine the redundancies in effort and sharing of information, we studied how the information is created during the structural steel delivery process. Specifically we tried to identify the information needed and created by the different participants in the project delivery process. Table 2 illustrates important information required or generated during the structural steel delivery process. Obviously, information created by a project participant is needed by other participants. For example, the dimensions for various members in a steel structure are created by the architect and are needed by the general contractor, and the steel subcontractor. Because the current process is paper-based, if project participants need any information created by others, they have to interpret this information from the paper-based documents and then incorporate them into their project information systems.

Typically different project participants use different software tools for automating their processes (see Table 1). Even though different software tools are used by the different disciplines, there is no standard way in current practice to automate the exchange of information between these software tools. Note that the project participants from different disciplines will always need to use discipline-specific software. Hence it is impractical or even impossible to solve the data exchange problem by suggesting or mandating the use of the same software by all participants on a project. One could also imagine a purely managerial, organizational or contractual approach to improve information sharing on a project. For example, project participants could all be brought on board early in a collaborative setting. While this would reduce the time to inform all participants of a design change it would still not address the problems associated with reinterpreting and re-entering the project information.

Organizations → / Information ↓		O	A	SE	GC	SUB
Design Loads	Needs		x	x		x
	Produces	x	x			
Dimensions	Needs		x	x		
	Produces			x	x	x
Member Sizes	Needs		x	x	x	x
	Produces		x	x		
Connection Details	Needs		x		x	
	Produces			x		x
Installation Schedule	Needs	x	x	x		x
	Produces				x	
Fabrication Schedule	Needs			x	x	
	Produces					x
Erection Schedule	Needs			x	x	
	Produces				x	x

Legend:

O - Owner
A - Architect
SE - Structural Engineer
GC - General Contractor
SUB - Steel Subcontractor

Table 2: Information required and generated by different project participants during the structural steel delivery process.

8. How would CIMSteel Integration Standards help?

CIMSteel Integration Standards specify how structural steel information is represented and shared electronically between the various software applications used by the different project participants (1,3,5). A product model defined using the CIMSteel Integration Standards acts as a common data model that helps represent the engineering information required from design to fabrication and erection.

The CIMSteel Integration Standards were developed as a part of the CIMSteel project in Europe. The CIMSteel Project, carried out under the auspices of EUREKA concept, was a massive pan-European research effort, with collaboration between industry and academia in almost 12 European countries for 10 years at the expense of US $50 Million (2). The main objective of the CIMSteel project was to increase the efficiency and effectiveness of the European Structural Steelwork industry through the harmonization of Design codes and implementation of Computer Integrated Manufacturing techniques to the Constructional Steelwork Industry. CIMSteel Integration Standards are standards for exchange of Structural Steel information between different parties involved in the delivery of a project from design to fabrication and erection. The American Institute of Steel Construction (4) has also recently adopted the CIMSteel Standards.

A study of the CIMSteel Integration Standards shows that most of the software vendors who produce software for the structural steel industry are in the process of making their software products compliant with CIMSteel Integration Standards. We interviewed three software vendors in this area:

1. AceCAD Software, UK: Manufacturers of the StruCAD Detailing system (6)
2. FabTrol (7)
3. Intergraph (8)

These companies are developing translators that help in generating output in a standard format, in the form of a Data Exchange File. This Data Exchange File contains engineering information structured in such a way that it complies with the CIMSteel Integration Standards. This file can then be imported and the engineering information extracted to another CIMSteel Integration Standards compliant software application. Figure 6 illustrates this process.

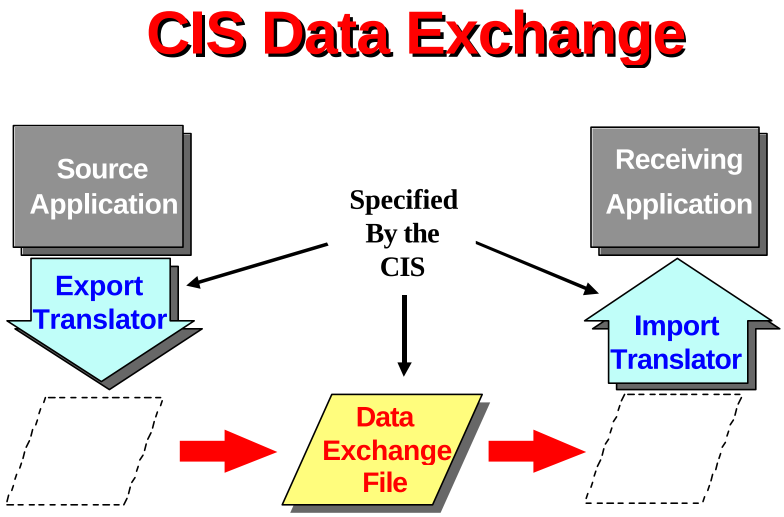

Figure 6. Information Exchange using CIMSteel Integration Standards. (Source: CIMSteel Integration Standards CD-ROM, Beta Release, Overview and Introduction)

If CIMSteel Integration Standards had been used for exchanging the engineering information electronically between different participants in the project delivery process the delay in communicating the design change information could have been avoided. We have included a schedule with modified milestone dates. This schedule is based on the assumption that the data is exchanged electronically and complies with the CIMSteel Integration Standards. For the case study project the schedule based on using the electronic data transfer based on CIS/2 is shown in Figure 7. We can see the following improvements in the overall delivery process:

- Reduced time in the bidding process. Because an electronic data model will be available for the subs, they can perform automated quantity take-off and turn around the bids more quickly than with a manual paper based process.
- Reduced time in the shop drawing approval process. The shop drawing creation and approval process can potentially be completely eliminated because the detailing applications can directly extract data from the design file and send a file that the design applications can verify for accuracy with respect to the original design. This process will evolve into a "shop model" approval process, therefore eliminating the development of shop drawings. Project team members will be able to extract the 2D drawings from the 3D-shop model at their discretion.
- Design changes can be communicated instantaneously. This is because only a single model will be used which can be transferred electronically or even made available over the Internet to all the project participants instantaneously.
- It may be possible to accommodate the design changes into the process without causing delays in the completion date of the project.

ID	Task Name	Sep	Oct (4th Quarter)	Nov (4th Quarter)	Dec (4th Quarter)	Jan (1st Quarter)	Feb (1st Quarter)
1	Drawings issued to bid	9/5					
2	Bids submitted by subcontractors	9/29					
3	Contracts Issued to subs: released for Shop Drawings		10/28				
4	Opening size increased by Architect			11/5			
5	Arch. Drawings with changed opening size to Structural Engineer			11/6			
6	Shop Drawings submitted to the Structural Engineer		10/28				
7	Revised Arch/Struct. Drawings issued to the General Contractor			11/7			
8	Revised Arch/Struc Drgs issued to the steel subcontractor			11/10			
9	Reviewed shop drawings sent back to the steel subcontractor			11/12			
10	Shop Drawings resubmitted to the Structural Designer			11/12			

Figure 7. Schedule based on the assumption that CIMSteel Integration Standards are used for representation and exchange of information between different participants involved in the structural steel delivery process.

9. Conclusions

In summary, our findings for this case study are as follows:

1. Sharing of information from the designer to the general contractor to the subcontractor is via paper based documents (drawings / specifications / spreadsheets / schedules). Hence different players often work with different design information at a given time. Delays in communicating changes in design often lead to time delays and cost impacts.
2. Currently the main process bottleneck is in the shop drawing creation and approval process, which takes a long time, involves re-production of almost all of the design information and provides little flexibility for design changes after the process gets underway.
3. Changes in design are not communicated in a timely manner across the disciplines involved in the process. In the case, a simple change in opening size resulted in changing the size of beams framing the opening. This design change was not communicated to the fabricator in time, and additional work had to be done on site which delayed the project by about 40 days.

4. Based on the data available, we estimated that about $55,000 were spent in the later stages of the project to make up for the delays caused during the structural steel delivery process and perform field modifications to the joists.
5. This delay cost the owner about $500,000 in lost revenue above and beyond the project cost.
6. Based on a preliminary review of the Logical Product Model Schema in the CIS/2 Beta release documentation, we conclude that the design information could have been represented using CIS/2 and shared instantaneously among the project participants in the form of a common data model.
7. The ability to share project information in an electronic and consistent format would not only speed up the information exchange; it would also reduce the processing time by each participant because the data re-interpretation and re-entry steps would be eliminated. It would also reduce the amount of wasted effort when design information changes because everyone would be working with current information. Finally errors due to misinterpretation of data and drawings would be eliminated.

It should be noted that the case study analyzed only a small example on a medium sized construction project. The structural steel component of the project was also not very intensive. Even then the example clearly shows the limitations of the current information exchange mechanisms in the structural steel delivery process. On larger projects, with more extensive structural steel work, and where the design is completed in phases the limitations of the current process are only magnified. Adoption of standards, such as CIS/2, that bring about the design-construction integration is therefore critical for the ability of the structural steel industry to respond to increasing pressure for faster, cheaper, and better projects from the clients.

10. References used in the case study:

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