Construction Management of **STEEL CONSTRUCTION**

Scheduling Estimating Module

PROJECT MANAGEMENT•SCHEDULING•ESTIMATING

AMERICAN INSTITUTE OF STEEL CONSTRUCTION INC.
AISC
FOUNDED 1921

INDEX

2 SCHEDULING AND ESTIMATING MODULE

SCHEDULING AND ESTIMATING

2.1 Overview

Construction of the structural frame for a building project is a significant and critical project phase, which represents a substantial portion of the project, in terms of time, money, equipment, and personnel. Structural steel, with proper planning, offers the potential for significant time and cost benefits over other structural systems. In order to take full advantage of these potential benefits, close coordination among the parties and proper planning is essential. An understanding of structural steel activities and their sequence, as well as their relationship to preceding and subsequent construction phases, is important in being able to take full advantage of the schedule reductions which can be generated by using steel. Module Two is intended to introduce students to scheduling and estimating issues which are important in planning for structural steel construction. Project management and contractual aspects of steel construction were presented in Module One of this manual; the reader should refer as needed to Module One for supporting information which is relevant to the scheduler and estimator.

The discussions in this section are based on a typical midsize (three to ten-story) building project similar to the case study discussed in section 1.2. (See case study project documents in Appendix A.) The case study project is based on a general contract form of project management. However, the issues presented in this educational module are also relevant to construction management and design-build project environments.

SCHEDULING

2.2 Introduction to Scheduling

The construction of structural steel is fast paced. On-site construction time is reduced relative to other systems by fabricating steel components prior to erection. Steel may also be erected in all seasons, which provides scheduling flexibility for the overall project. The reduction of on-site time along with scheduling flexibility can ultimately lead to significant savings in general conditions and financing costs.

The fabrication of steel components requires careful planning and close coordination among the various parties. Shop drawing approval, ordering of material, erection planing, fabrication, delivery, and erection activities need to be well orchestrated to ensure a streamlined, delay free process. The preparation of a proper schedule of structural steel activities and integration of this schedule into the overall project schedule are important activities in planning for structural steel construction.

The intent of this portion of the manual is to provide students with an understanding of scheduling structural steel construction by 1) defining the usual structural steel activities, 2) presenting information on sequencing and durations, and 3) discussing scheduling methods which are used in preparing the structural steel schedule. In addition, a discussion of methods for avoiding delays in structural steel is presented.

2.3 Project Delivery Participants and Coordination

A large number of professionals are involved in the construction of a structural steel frame. Industry participants and their roles were discussed in detail in Module One, Section 1-5. The need for proper communication and coordination among the participants is essential for the timely completion of the structural steel.

In order to make an effective and practical schedule for the execution of the overall project, the scheduler should understand how the roles and responsibilities of the participants impact the schedule. The steel contractor, together with the general contractor, will play primary roles in coordinating the various participants. The general contractor will facilitate communications between the designer, other subcontractors, and the steel contractor. The steel contractor will coordinate the suppliers and lower tier subcontractors for the steel contract.

2.4 Project Phases

All building construction projects consist of a series of broad construction phases. While there may be considerable overlap and concurrent activity between the phases, building construction projects may generally be characterized as consisting of the following:

1. Site work
2. Foundation
3. Structural frame (steel construction)
4. Enclosure
5. Electrical and mechanical installation
6. Finishes
7. Testing and operations

The structural steel phase has a significant impact on the overall project schedule; completion of the structural frame is generally considered a significant milestone in overall project completion. Completion of the frame allows the work of the architectural, mechanical, electrical, and finally the finishing trades, to proceed.

While the structural steel phase above is shown as a single phase that follows the foundation work, in actuality considerable pre-erection work consisting of shop drawings, material ordering, and fabrication is conducted simultaneously with the site work and foundation phases. A well integrated overall project schedule will have fabricated steel ready for erection by the time foundations are completed.

Careful coordination between the general contractor and the steel contractor is essential to ensure an efficient overall construction plan. The general contractor and steel contractor will need to decide on an erection sequence. Site layout for construction operations will need to be determined. The steel contractor will need to decide on equipment and methods to be used to erect the steel. Delivery and erection strategies for fabricated steel need to be considered. Early input and consultation with the steel contractor is essential and will allow the general contractor to prepare an effective overall project schedule.

2.5 Overview of Steel Construction Activities

The steel construction phase consists of a large number of detailed activities and sub-activities. However, the entire set of activities can be placed into two broad categories as shown below (AISC 1997, Koch 1997):

1. Fabrication related activities
2. Erection related activities

The two categories of activities are described in detail in the following section 2.6. Other details related to producing a schedule for steel construction are also provided.

Fabrication related activities consist of reviewing the project plans, preconstruction planning, ordering of material for the main steel members, preparing erection and shop drawings, obtaining approval of shop drawings, fabrication and delivery. These activities provide the preparatory work for on-site erection of the structural steel frame.

Erection activities consist of the on-site assembly of the frame, plus considerable pre-erection work. Erection planning and sequencing, equipment selection, safety planning, etc. are all important erection activities. Steel erection can often set the tone for the overall project, and a well coordinated erection plan and timely completion of the frame can greatly enhance the project's success.

Fabrication and erection activities are the responsibility of the steel contractor. This contractor may be a fabricator who subcontracts erection or could be the steel contractor who has the expertise to fabricate and also erect the work. For the case study project, both fabrication and erection were undertaken by the same company.

2.6 Fabrication Related Activities

Structural steel arrives at the job site as a fabricated, ready - to - assemble product. However, prior to delivering the steel to the project site, a considerable amount of activity is undertaken by the steel fabricator (steel contractor). The fabricator has the following primary responsibilities as identified below:

1. Order/purchase steel
2. Produce erection drawings
3. Produce fabrication shop drawings
4. Fabricate steel
5. Quality control
6. Deliver structural steel
7. Coordinate delivery of deck and steel joists
8. Coordinate delivery of miscellaneous steel

Order/purchase steel. Once the contract has been awarded, steel shapes are ordered for the project from the steel mill. Generally, the main beam and column shapes are ordered immediately after contract execution in order to have steel at the fabricator's plant as erection and shop drawings are approved by the design engineer. On expedited or smaller projects, steel may be ordered from a steel supply service center (warehouse) or come from the fabricator's own stock. Fabricators usually maintain an inventory of certain widely used shapes in stock (a sample listing obtained from one of the fabricator members of the Industry Technical Committee is provided in Appendix C). Depending on the project design, specifications, cost, and schedule, the steel fabricator will determine the most appropriate sources of material.

Mill orders often require from 4 to 10 weeks notice before delivery. With fast-track projects, where there may be frequent changes and additions, reordering from a mill can be expensive and impractical. In this case, the fabricator may use service centers or over-design members to accommodate changes. Service centers are usually more expensive sources of material compared to mills. Mills often require that steel members be purchased in 5-ton bundles with a minimum order of 20 tons. This can be a problem when only a small number of certain size members are needed, or if a member is a less common size. When preparing a schedule, the scheduler must consider the timing of steel delivery, based upon purchasing from different sources.

Produce Erection Drawings. The fabricator is responsible for preparing erection drawings (commonly called E Sheets), that show piece marks and where various steel members are to be installed on the job site. These drawings are produced before or simultaneously with the fabrication shop drawings. E-Sheets are also used during the shop drawing approval process in order to identify the exact location of a particular member. Proper identification of the pieces is important so that other detailers and designers know the location of members shown on the shop drawings. The production of E-Sheets for the case study project was spread over 10-12 weeks. See Appendix A for a sample erection drawing for the case study project.

Produce Fabrication Shop Drawings. Shop drawings with details, dimensions, and location of bolts and welds are necessary for fabrication. Shop drawings provide the instructions that the shop worker will follow to fabricate the steel. Shop drawings are sent to the architect and/or structural designer for approval. Shop drawing preparation and approval is an important stage. Defective or incomplete shop drawings create significant problems and time delays during fabrication and erection.

Issuance of contract drawings and specifications that do not conform to Section 3 of the AISC *Code of Standard Practice* is a primary cause of defective or incomplete shop drawings. For this reason, all entities involved in the process of reviewing the contract drawings and specifications on behalf of the steel contractor should exercise great care in dealing with these documents and should forward prompt RFI's up the project chain-of-command whenever ambiguities appear in these contract documents.

The scheduler needs to keep in mind the time required for production, submission, and receipt of approved shop drawings from the structural engineer. Production and approval of shop drawings should be included as independent activities in the schedule. Some contracts specify time limitations for shop drawings approval. Occasionally the need for resubmission of rejected shop drawings may affect the schedule of the entire project.

In cases where fabricators are required to perform design work of complex connections, it may be necessary for fabricators to have a Professional Engineer (PE) on staff or to contract work with an outside consultant. This entire operation can have an impact on shop drawing preparation for the project. The production of fabrication shop drawings for the case study project required approximately 10 to 12 weeks. This process overlaped with the shop drawing approval because shop drawings were submitted in several batches, with batches being sent for approval every other week. See Appendix A for two fabrication shop drawings (one for beams and one for columns) for the case study project.

Fabricate steel. Material ordered from the steel mill or service center, is delivered, unloaded, and stored at the fabricator's plant. Steel beams are ordered to length, while steel columns are generally ordered from the mill 2" longer than required in case the ends are not square. The mill cuts steel into lengths varying from the minimum length to plus 2". Because of this possible length variance, the steel pieces may have to be cut to their final lengths prior to fabrication. For an extra charge, warehouses can supply steel lengths cut to their exact size. After approved shop drawings are received by the fabricator, steel is brought into the shop and the fabrication process begins. This process typically consists of the following steps:

1. Cut to proper lengths
2. Create templates and /or mark steel
3. Punch and/or drill holes
4. Camber members (if required)
5. Prepare accessory steel pieces
6. Add shop-welded or bolted pieces to members and make special cuts
7. Clean members (can be done prior to cutting)
8. Tag steel members
9. Surfaces treatment (painting and galvanizing) steel members, if required.

Templates may be made or automated equipment may be used to transfer information on the shop drawings to steel pieces, so that the holes/slots can be made at the required location. Pieces are then welded or bolted together to form the required assemblies and create members with section properties which are different from than those of the standard shapes, e.g. clip angles and base plates. Specialty cuts, such as coping are performed. Some steel may also require straightening or cambering.

The time required by the various fabrication steps as noted above, depends on the fabricator's personnel skills, available shop facilities, location of the plant etc. Fabrication of a sequence may require several weeks to complete; therefore the fabricator will need to plan shop hours to accommodate the schedule of several simultaneous projects. It is important for the scheduler to give proper consideration to all of these factors when establishing the structural steel schedule.

Quality Control Inspections. In-house quality inspections are normally carried out at the assembly stage; piece lengths are measured, and the location of bolt holes, bolt diameters, added pieces, and weld quality and size are examined and checked for compliance with the shop drawings. Steel pieces which pass inspection are labeled and painted (if required) and stocked in the fabrication yard for shipment. For future identification, the steel is labeled with piece marks (a code specific to a piece of steel), plus a job number or code. If the project is large and divided into sequences, the sequence code is also indicated on the steel. The labeling technique will vary from one fabricator to another. Tags, paint, or crayon markings are common examples of labeling.

Deliver Structural Steel. One of the most important tasks of the fabricator is delivery of structural steel to the job site. Transportation options, such as truck and trailer, rail system, and water transport can be adopted depending upon the size and quantity of the steel members, location of job site, and the general economy. Shipping by trucks and trailers is the most common method of delivery. Many fabricators are equipped with their own trucking fleet. If this is not the case, or the amount of work exceeds the capacity of the fabricator's fleet, independent drivers are subcontracted to deliver the steel to the job site.

The maximum length and width of a fabricated member that may be transported in Michigan by trailer are 110 ft and 16 ft, respectively. These size restrictions can vary from state to state. The load carrying capacity of the common trailer ranges from 20 to 25 tons, taking approximately two hours to load a trailer.

Depending on the project's size and on-site storage conditions, the material is either shipped all at once or "as needed" based by sequence. The erection contractor and/or the fabricator break down large steel projects into sequences. A given sequence defines a section of the project and the pieces of steel included in that section. A typical sequence for a small to medium size project consists of 2 to 5 truckloads of steel; for large projects, from 6 to 12 truck loads. Close communication and cooperation between the fabricator and the erector is essential in coordinating the deliveries with the erection schedule. The fabricator will also need to consider deliveries for other projects that may be in the shop at the same time. Other important delivery considerations are site conditions, access for trucks, as well as storage space for material, if required.

Coordinate Delivery of Decks and Joists. The steel contractor arranges for shop drawings, delivery, and erection of metal decking and open web joists through lower tier subcontractors. The metal deck and open web joists are released for production when the shop drawings are approved. The steel subcontractor (or representative) coordinates delivery to the job site according to the erection schedule.

Coordinate Delivery of Miscellaneous Steel. The steel subcontractor may also subcontract miscellaneous steel fabrications such as railings, stairs, and floor gratings. Their delivery to the job site is coordinated by the steel subcontractor in conjunction with the general contractor and the overall project schedule.

2.7 Erection Related Activities

Steel erection is the process of field assembling structural pieces to create the frame, roof truss or other structural systems. Erection of steel members can commence after all the steel is fabricated or after certain portions are fabricated, depending upon the size of the project. Some steel subcontractors (fabricators) have in-house erection capabilities and others enter into a subcontract with an erector. In some instances, the erectors also serve as primary steel subcontractors. An erector has the following major responsibilities as listed below:

1. Design of temporary bracing system
2. Steel frame erection
3. Roof truss assembly and placement
4. Field corrections
5. Safety during the erection
6. Inspection and testing

Design of Temporary Bracing System. One of the erector's responsibilities is to design the temporary bracing system during construction. During the erection process, steel members are temporarily held in place with an adequate number of required bolts, to allow for leveling and plumbing (vertical and horizontal alignment) adjustments. Other sections of the structure expected to add lateral stability may not be installed until after the steel is in place. Because of these conditions, the structure may not be stable when subjected to high winds or other adverse weather conditions.

The steel erector is responsible for the design of the bracing system and may require the services of a structural engineer. AISC's publication on bracing systems, titled "Erection Bracing for Low-Rise Structural Steel Buildings," AISC (1997) also provides information on various types of bracing systems. The design of the bracing system is normally done by the erector, before the delivery of steel to the job site.

Steel Frame Erection. The construction of a steel frame is a repetitive process of placing columns, attaching beams, leveling and plumbing (vertical and horizontal alignment), and bolt tensioning. This practice produces the basic structural framework, while attachment of miscellaneous steel products completes the steel phase of the project. Steel frame erection consists of the following steps as listed below:

1. Attachment of the base columns and adjustments to appropriate elevation
2. Attachment of major horizontal structural components, i.e. beams and girders
3. Erection of temporary braces for unbraced frame sections
4. Plumbing (vertical and horizontal alignment) of the frame and completion of connections, i.e. fully tension connections and tighten anchor rods
5. Attachment of minor horizontal steel members, i.e. joists, purlins (roof support), and lintels (supports brick or block masonry)
6. Attachment of metal decking and other miscellaneous steel products

For a multi-story frame, the same process is repeated for the subsequent stories. Columns can be erected for more than two stories at a time. For the midsize case study project, steel erection was completed in 10-12 weeks, with a 230 ton crane.

Roof Truss Assembly and Placement. Roof trusses are used to support longer spans such as those found in sports facilities or convention centers. The method of placement depends upon the size of the truss, together with accessibility and capacity of the crane. The major components of a truss are produced in the fabricator's shop. However, if the truss is too large to transport as a single unit, it may be shipped in pieces to the site, where assembly will be completed by ironworkers in the field. After placement of the truss, lateral support systems consisting of beams or smaller truss assemblies are installed.

Field Corrections. Field correction of small errors (such as missing or non-matching bolt holes, incorrect location of an attached piece, etc,.) found in the fabricated steel components, are also the responsibility of the erector. Ironworkers in the field are equipped to perform minor cutting and welding alterations as required. However, If the problem is extensive, the component may need to be returned to the fabrication shop. Therefore, while scheduling the steel construction phase of a project, certain time allowances should be allotted for a moderate level of field corrections, as this impacts the productivity of the erection crew.

Inspection and Testing. A number of inspections and testing procedures are performed during and after erection. In addition to inspection and testing done by the erector, project specifications may require an independent testing agency to perform certain tests on the job site. These tests relate mainly to bolted and welded connections.

2.8 Work Breakdown Structure (WBS) for Scheduling

Production of a Work Breakdown Structure (WBS) is the starting point for the development of a detailed schedule for a project. The WBS is the breakdown of a project into its component parts to increasingly lower levels. This breakdown is continued until the project is fully defined in terms of activities. An activity is a single work step that has a recognizable beginning and end. Activities are time and resource consuming tasks (CQR 1992).

The WBS is a name for an end-item-oriented family tree type subdivision of a project. It graphically displays the work involved in a project. It provides a framework for organizing and ordering the activities that comprise a project, and is the basic cornerstone of effective project management.

The WBS for the structural steel phase of the case study project is illustrated in Figure 2-1. This WBS is based on the following six sub-phases within the structural steel construction phase. These sub-phases provide a logical method to divide the case study project into scheduling activities. Fabrication and erection related activities as described in earlier sections, can be easily represented as part of the six sub-phases listed below:

1. Material procurement
2. Shop drawing preparation
3. Shop drawing approval
4. Fabrication
5. Erection
6. Inspection and testing

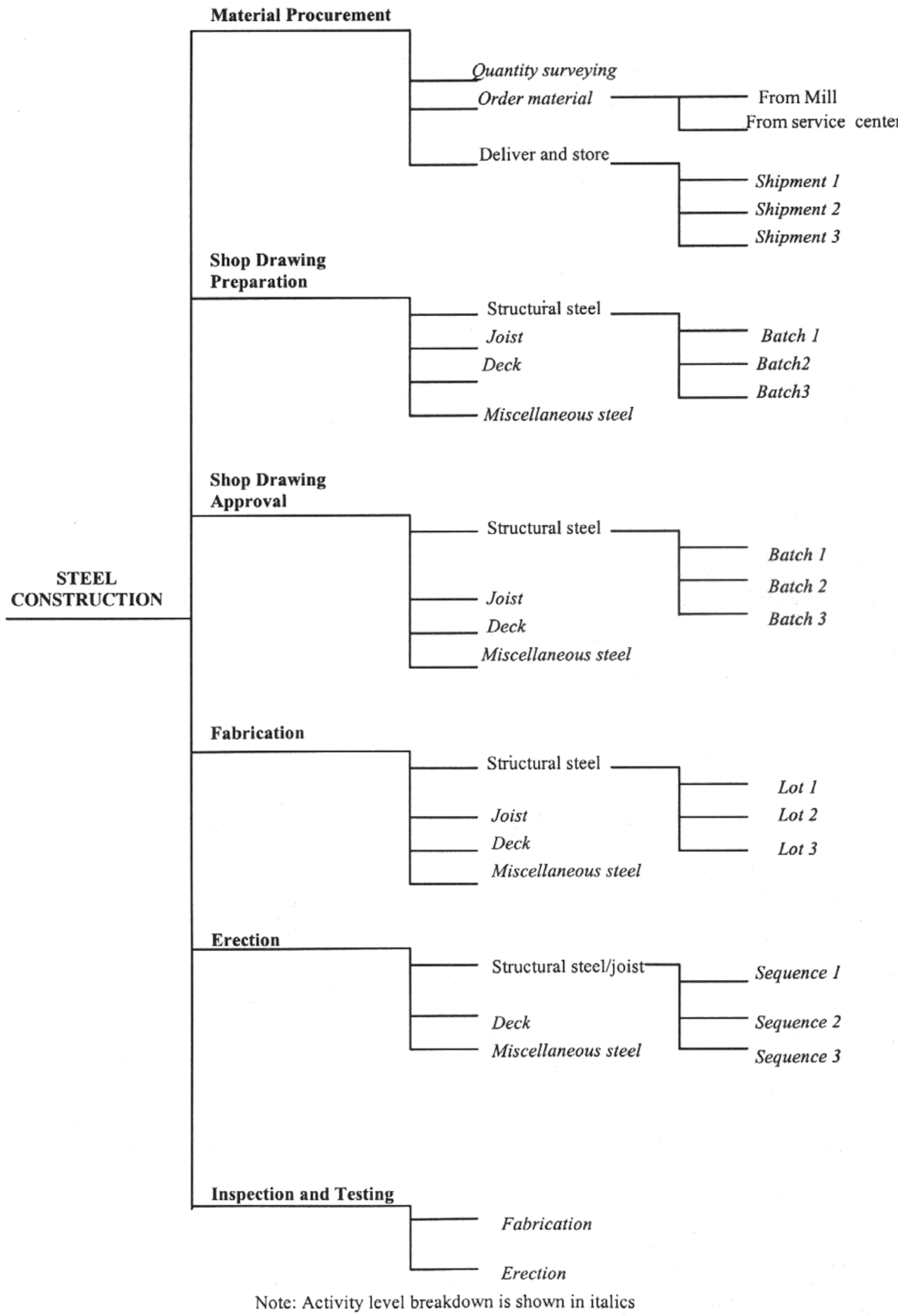


Figure 2.1 Work breakdown structure (WBS)

2.9 Activity Durations

Durations of the steel construction activities depend on a number of factors. These include: type of project and location, time of year, material availability, economic conditions, fabrication shop availability, crew skill, size of crew, number of crews used, etc. For the purpose of developing the schedule for the case study project, typical durations agreed upon by the Industry Technical Committee are used. These durations are summarized in Table 2.1. Based on the schedule developed for the case study project, the total project duration is 115 working days.

S. No	Activity Description	Duration (working days)	Comments
1	Quantity surveying	5	
2	Order material	5	
3	Delivery and storage of material	20	For each shipment
4	Shop drawing preparation structural steel	10	For each batch
5	Shop drawing preparation Joist	10	
6	Shop drawing preparation deck	10	
7	Shop drawing preparation miscellaneous steel	10	
8	Shop drawing approval structural steel	10	For each batch
9	Shop drawing approval joist	10	
10	Shop drawing approval deck	10	
11	Shop drawing approval miscellaneous steel	10	
12	Fabrication of structural steel	15	For each lot
13	Fabrication of joists	20	
14	Fabrication of deck	20	
15	Fabrication of miscellaneous steel	15	
16	Erection of structural steel/joist	20	For each sequence
17	Erection of deck	20	
18	Erection of miscellaneous steel	15	
19	Inspection and testing fabrication	15	
20	Inspection and testing erection	5	

Table 2-1 Activity durations for the case study project

2.10 Critical Path Method (CPM) Network Diagrams

During the development of the schedule for the case study project, the following assumptions were made:

1. The structural steel was delivered in three sequences (shipments)
2. The shop drawings for the fabrication of the structural steel were prepared and approved in three batches
3. The shop drawings for the joist, deck, and miscellaneous steel were prepared and approved in a single batch for each
4. The fabrication of the structural steel was carried out in three lots
5. The fabrication of the joist, deck, and miscellaneous steel was carried out in a single lot for each
6. Erection of structural steel and joists was carried out by the steel erector, and divided into three sequences (shipments)
7. Erection of deck and miscellaneous steel was carried out in a single phase

The alphanumeric codes shown in Table 2.2 were assigned to the activities to identify and sort them out efficiently and conveniently.

Codes	Description of Alpha portion	Comments
ST 001	Start of the project	001-series for all the activities in the start up phase
MP 100	Material procurement	100-series for all the activities in the material procurement phase
SP 200	Shop drawing preparation	200-series for all the activities in the shop drawing preparation phase
SA 300	Shop drawing approval	300-series for all the activities in the shop drawing approval phase
FB 400	Fabrication	400-series for all the activities in the fabrication phase
ER 500	Erection	500-series for all the activities in the erection phase
IT 600	Inspection and testing	600-series for all the activities in the inspection and testing phase
FI 700	Finish of the project	700-series for all the activities in the finish phase

Table 2.2 Alphanumeric codes assigned to activities

A CPM diagram provides a logic diagram that shows complex sequential relationships among various construction activities. For the case study project, the following layouts are provided:

1. Detailed CPM diagram (Figure 2.2), showing all activities according to execution framework
2. CPM diagram on the basis of the sub-phases (Figure 2.3), showing all activities by grouping them into various sub-phases
3. CPM diagram on the basis of responsibilities of the participants (Figure 2.4) presenting all activities by grouping them under execution responsibility

Primavera Project Planner ® (P3) version 2 (Primavera 1997) was used to develop various network diagrams. Based on the activity durations listed in Table 2.1 and the scheduling logic presented in Figure 2.2, the overall project duration for the case study project comes out to be 163 calendar days or 115 working days.

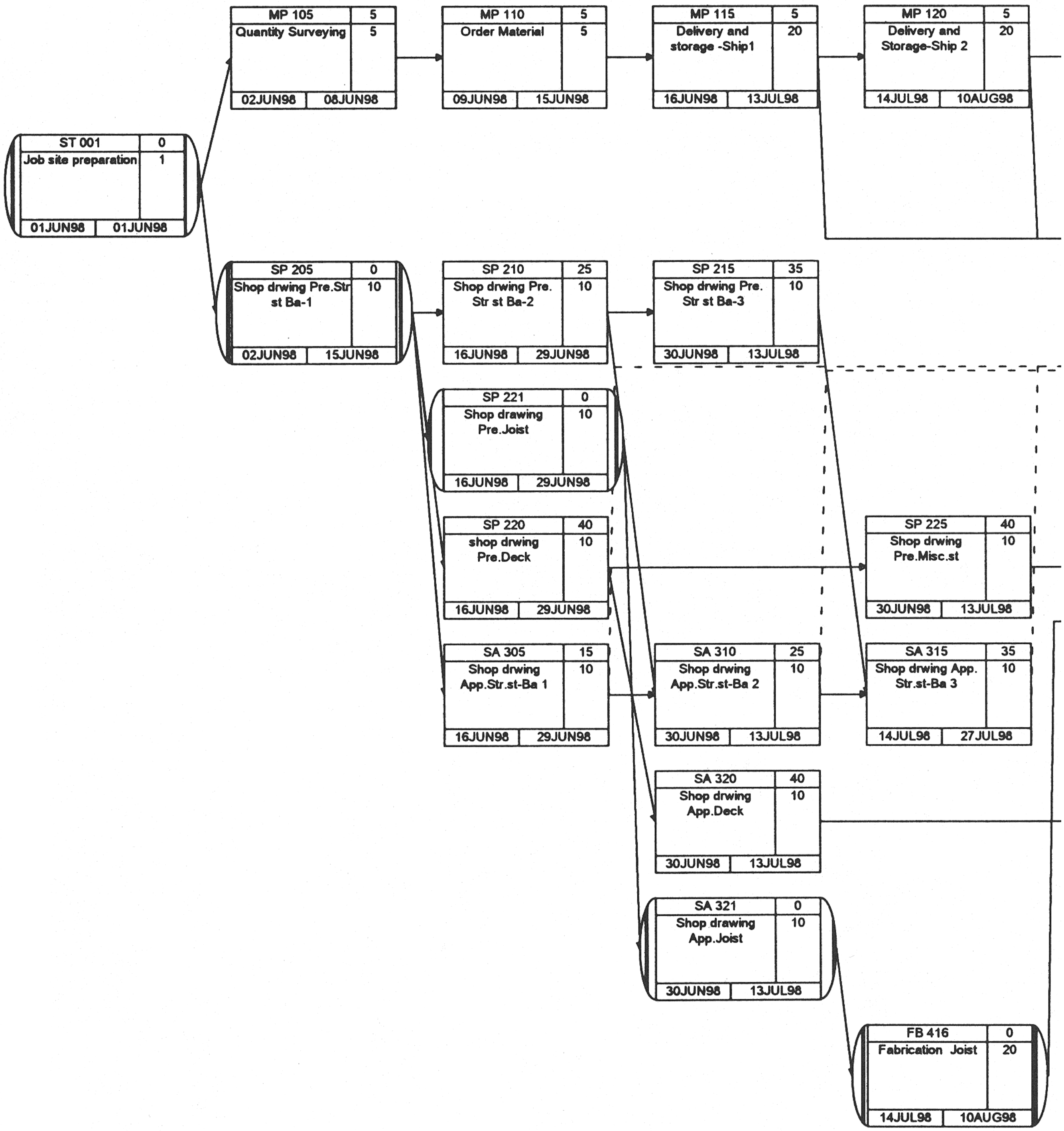
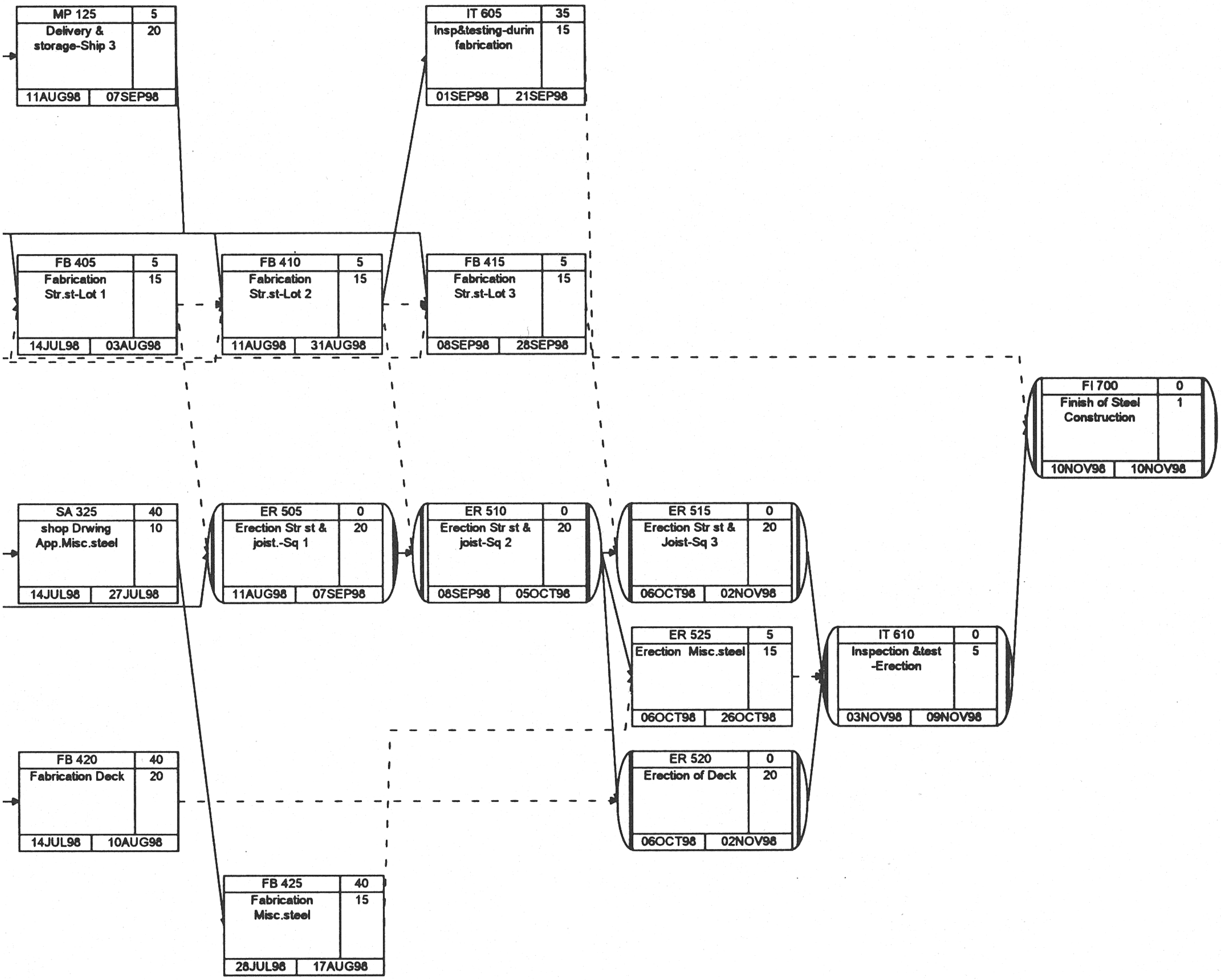


Figure 2.2 Detailed CPM diagram



MP 125
5
Delivery & storage-Ship 3
20
11AUG98
07SEP98
IT 605
35
Insp&testing-durin fabrication
15
01SEP98
21SEP98
FB 405
5
Fabrication Str.st-Lot 1
15
14JUL98
03AUG98
FB 410
5
Fabrication Str.st-Lot 2
15
11AUG98
31AUG98
FB 415
5
Fabrication Str.st-Lot 3
15
08SEP98
28SEP98
FI 700
0
Finish of Steel Construction
1
10NOV98
10NOV98
SA 325
40
shop Drwing App.Misc.steel
10
14JUL98
27JUL98
ER 505
0
Erection Str st & joist.-Sq 1
20
11AUG98
07SEP98
ER 510
0
Erection Str st & joist-Sq 2
20
08SEP98
05OCT98
ER 515
0
Erection Str st & Joist-Sq 3
20
06OCT98
02NOV98
ER 525
5
Erection Misc.steel
15
06OCT98
26OCT98
IT 610
0
Inspection &test -Erection
5
03NOV98
09NOV98
FB 420
40
Fabrication Deck
20
14JUL98
10AUG98
ER 520
0
Erection of Deck
20
06OCT98
02NOV98
FB 425
40
Fabrication Misc.steel
15
28JUL98
17AUG98

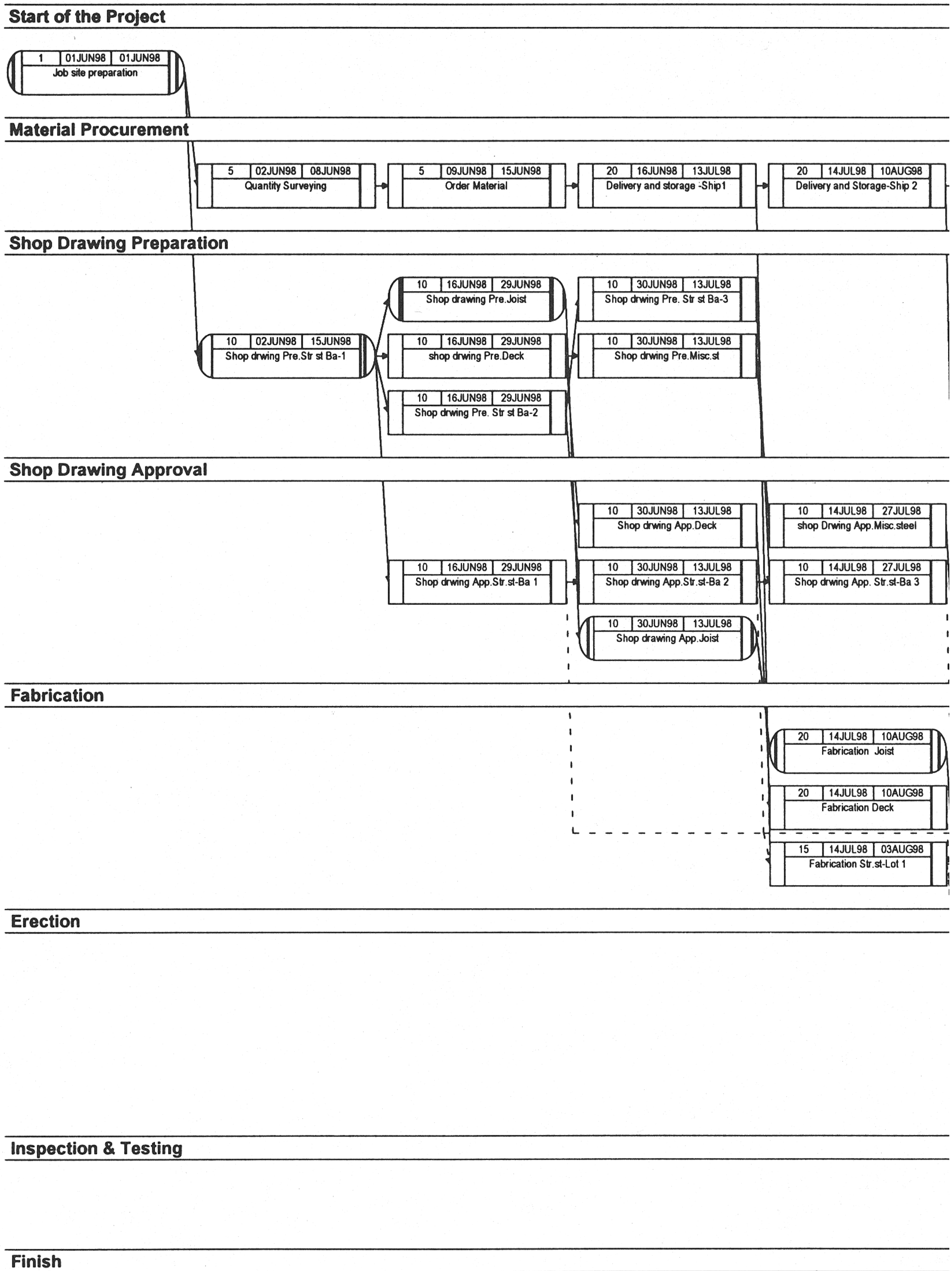
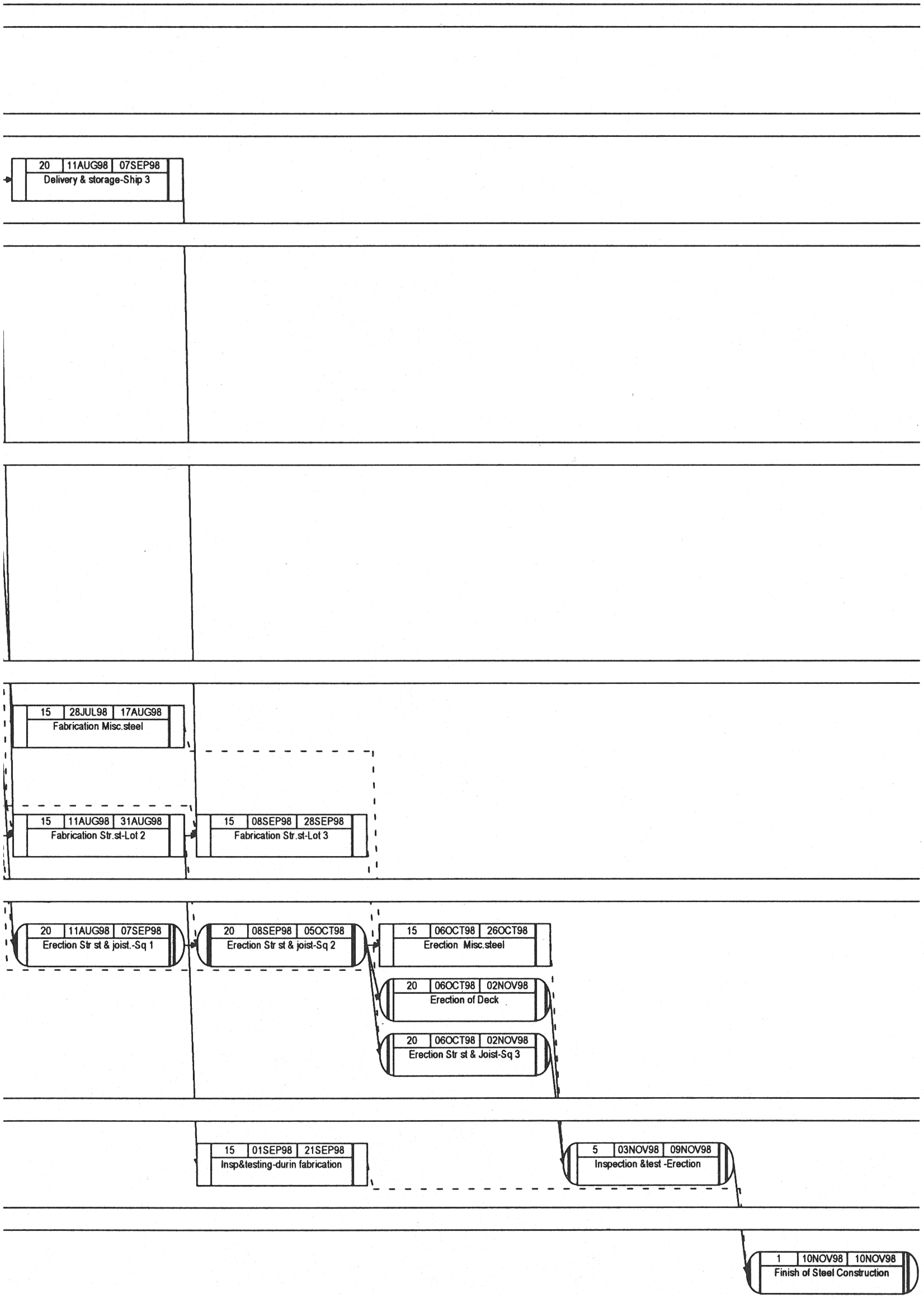


Figure 2.3 CPM diagram on the basis of sub-phases


20 11AUG98 07SEP98
Delivery & storage-Ship 3
15 28JUL98 17AUG98
Fabrication Misc.steel
15 11AUG98 31AUG98
Fabrication Str.st-Lot 2
15 08SEP98 28SEP98
Fabrication Str.st-Lot 3
20 11AUG98 07SEP98
Erection Str st & joist.-Sq 1
20 08SEP98 05OCT98
Erection Str st & joist-Sq 2
15 06OCT98 26OCT98
Erection Misc.steel
20 06OCT98 02NOV98
Erection of Deck
20 06OCT98 02NOV98
Erection Str st & Joist-Sq 3
15 01SEP98 21SEP98
Insp&testing-durin fabrication
5 03NOV98 09NOV98
Inspection &test -Erection
1 10NOV98 10NOV98
Finish of Steel Construction

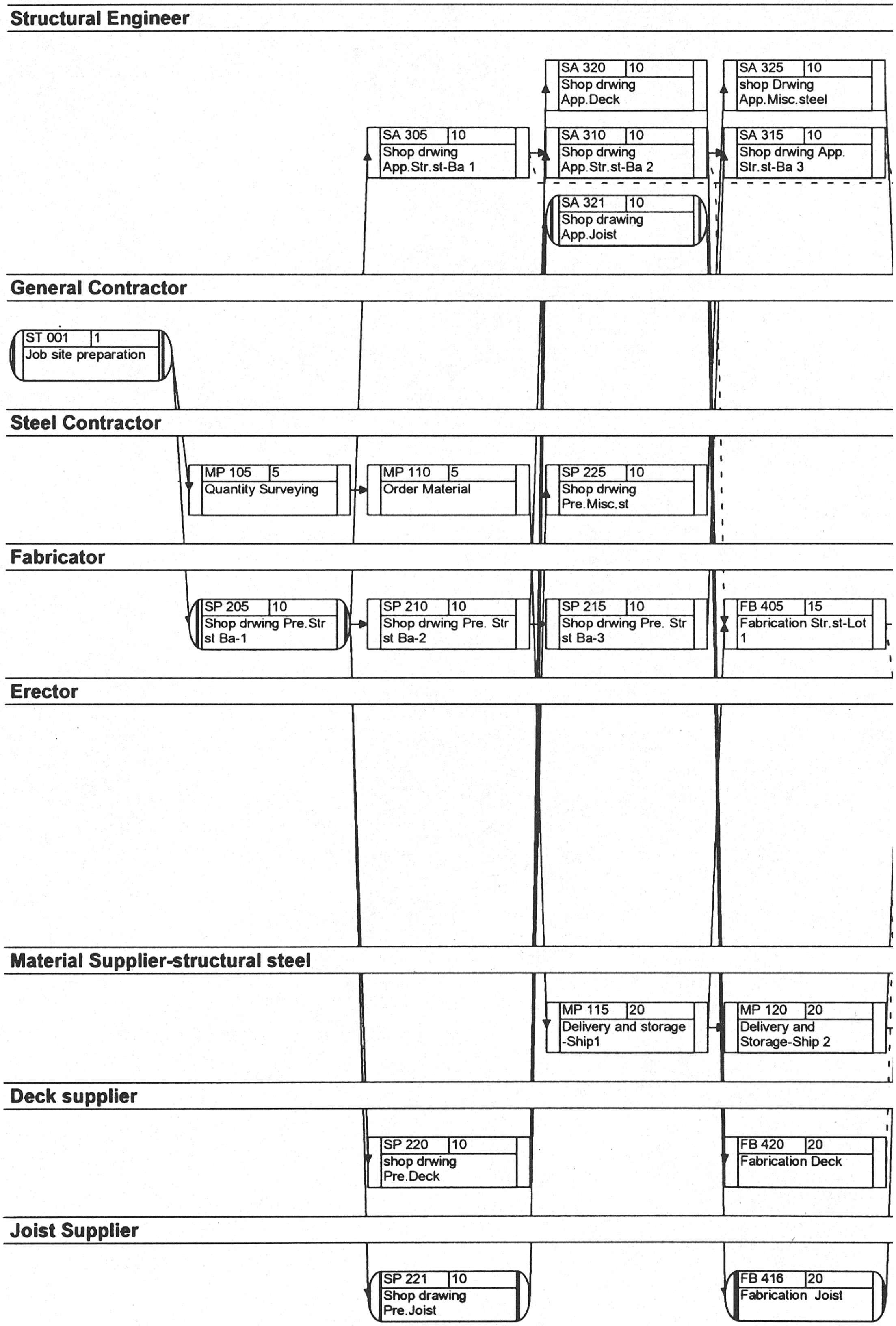
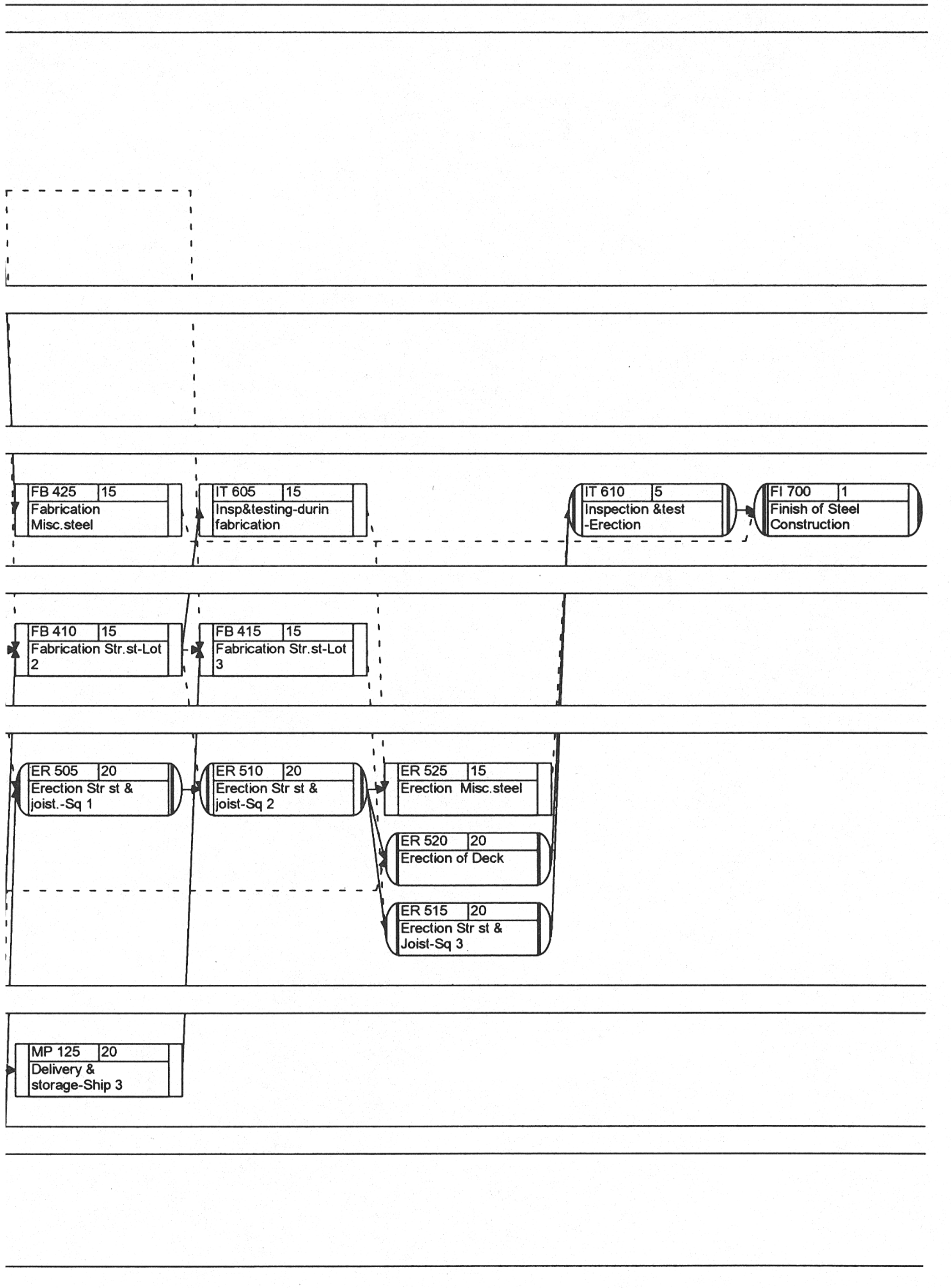


Figure 2.4 CPM diagram on the basis of the responsibility of the participants


FB 425 15
Fabrication Misc.steel
IT 605 15
Insp&testing-durin fabrication
IT 610 5
Inspection &test -Erection
FI 700 1
Finish of Steel Construction
FB 410 15
Fabrication Str.st-Lot 2
FB 415 15
Fabrication Str.st-Lot 3
ER 505 20
Erection Str st & joist.-Sq 1
ER 510 20
Erection Str st & joist-Sq 2
ER 525 15
Erection Misc.steel
ER 520 20
Erection of Deck
ER 515 20
Erection Str st & Joist-Sq 3
MP 125 20
Delivery & storage-Ship 3

2.11 Bar Charts

The primary advantage of the bar chart is its overall simplicity. It is easy to read and interpret, and therefore, can be an effective communication tool. The primary disadvantage is that it does not show the interrelationships among the project activities. For the case study project, the following layouts of the bar charts are provided. Primavera Project Planner ® (P 3) version 2 (Primavera 1997) was used to develop the various bar charts.

1. Summary bar chart (Figure 2.5), showing each sub-phase as a milestone activity
2. Bar chart on the basis of sub-phases (Figure 2.6); all activities by grouping them into various sub-phases
3. Bar chart on the basis of the responsibility of the participants (Figure 2.7), presenting all activities by grouping them under execution responsibility

To demonstrate the role of the schedule as a project management tool, each activity is assigned two sets of activity codes. One represents the sub-phase to which it belongs, and the other represents the party responsible for its execution. These activity codes can be used to sort out various activities in different scheduling layouts. Refer to Figures 2.3 and 2.6 for scheduling layouts based on sub-phases and Figures 2.4 and 2.7 for scheduling layouts based on responsibilities of the participants.

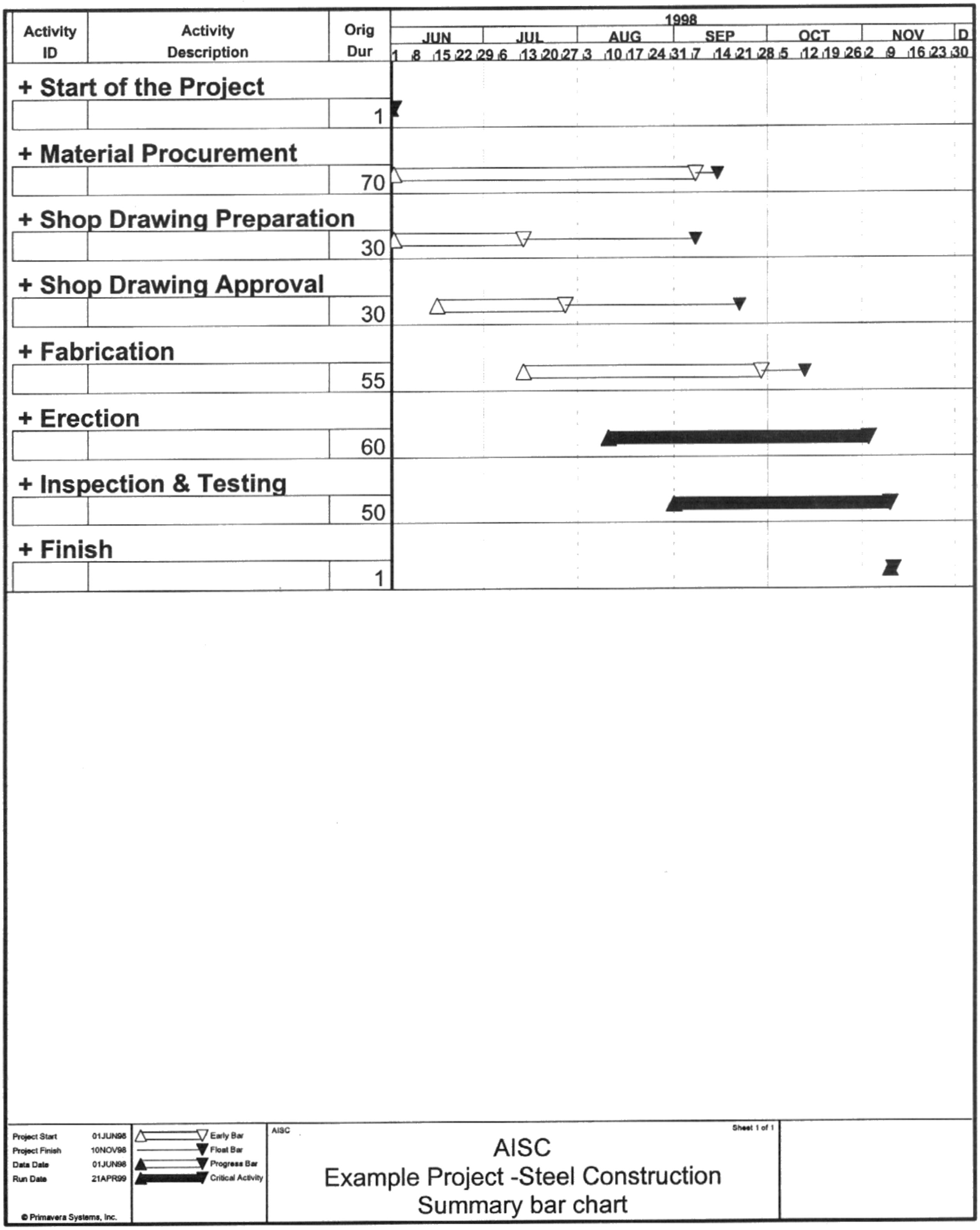


Figure 2.5 Summary bar chart

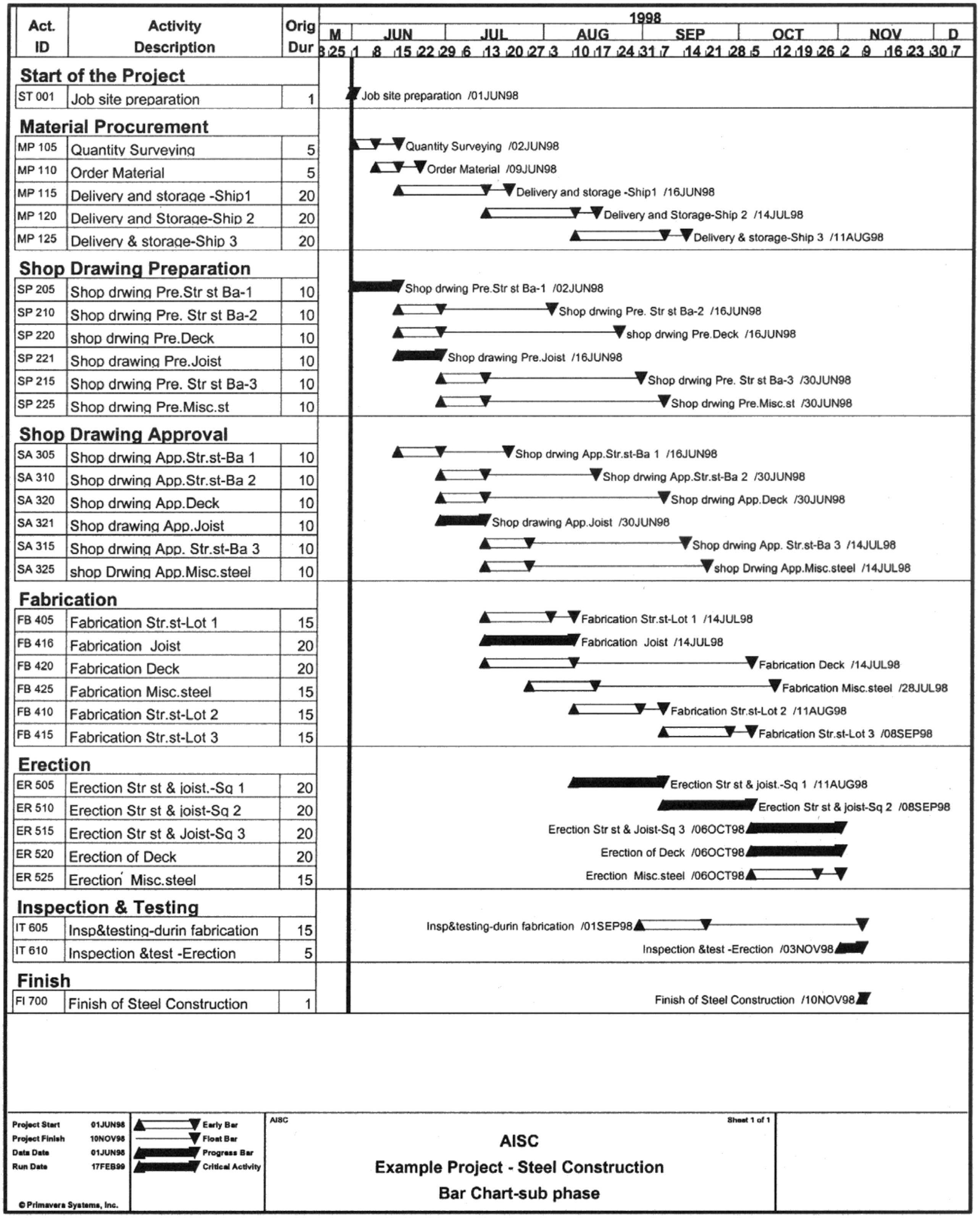


Figure 2.6 Bar chart on the basis of sub-phases

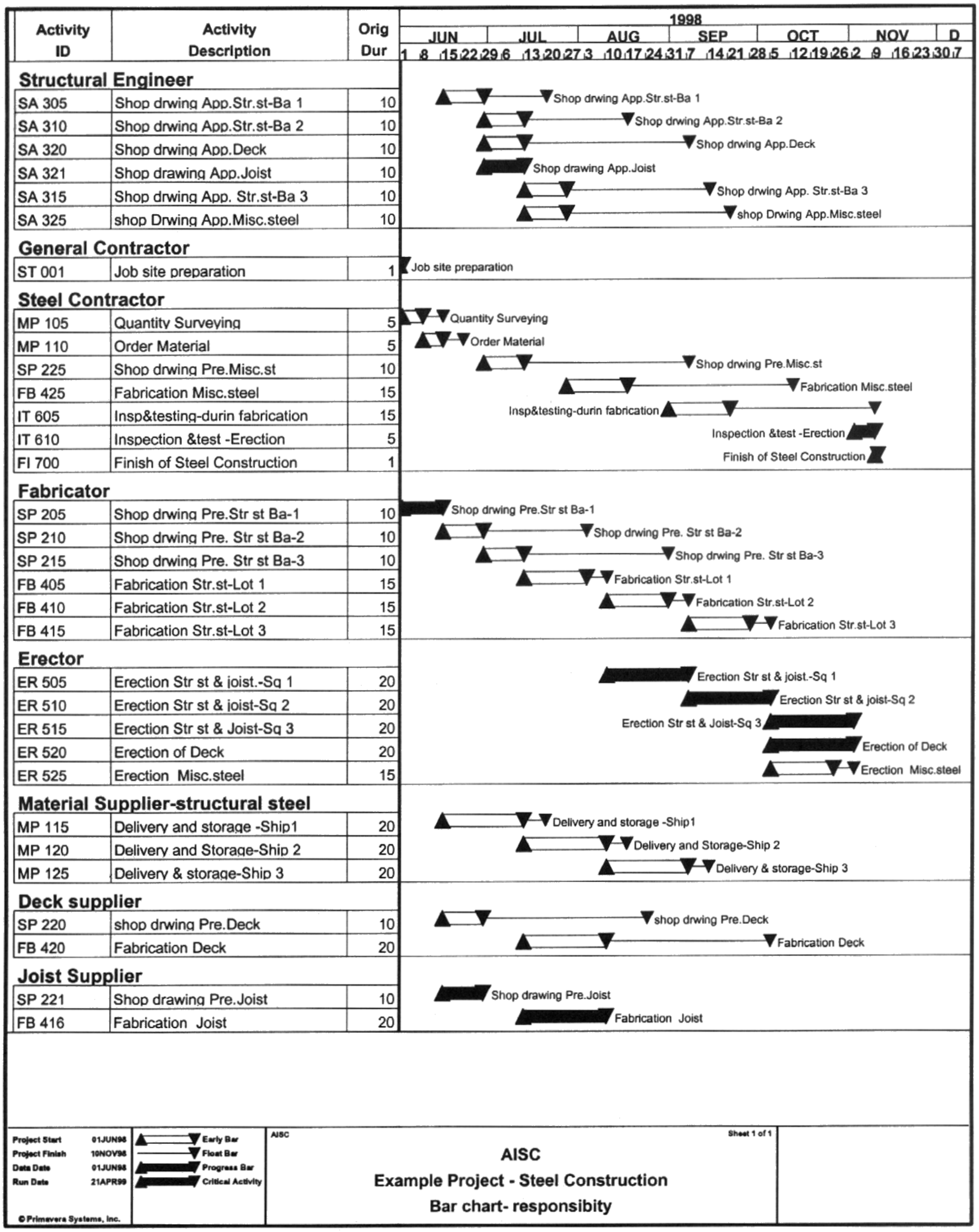


Figure 2.7 Bar chart on the basis of the responsibility of the participants

2.12 Steel Schedule Vs. Overall Project Schedule

One of the major benefits of steel construction is its reduced construction time compared to other competing materials, such as concrete or timber. This advantage can be achieved if the participants involved in the steel construction phase are well coordinated and follow a realistic time schedule. Previous sections broadly explained the different stages of steel construction, starting with material procurement to erection of the components. The purpose behind explaining the entire process was to provide information to the potential scheduler about 1) activities and their sequence which influence the steel construction schedule, 2) how to estimate the duration of the various activities in different situations, and 3) scheduling methods.

Steel construction is highly schedule driven with every activity in the steel construction phase dependent on other activities. Good communication and cooperation among various steel subcontractors and lower tier subcontractors is mandatory for completion of the project within planned time and cost. A realistic and complete schedule can provide the basis for communication and coordination. The schedule provides an excellent information and communication tool, with each participant knowing well in advance when their services are required at various stages of steel construction, and when each resource needs to be available on the site.

2.13 Items Impacting the Schedule

Major items that can affect the progress of the steel construction phase and consequently the overall completion time of the project are discussed in the following section.

Material Procurement. Material is commonly procured from the steel mill. Material purchased from a service center (warehouse) can cost 30 to 50% more. Lead time in the case of mill procurement is 4 to 6 five weeks for the first batch to be received and 6-10 weeks for final delivery. To save time, the ordering of material is initiated as quickly as possible after contracting and receipt of the "notice to proceed," without waiting for the preparation of shop drawings.

Shop Drawing Approval. Approval of shop drawings is another item that may greatly impact the completion of the project. Excellent coordination is needed during the shop drawing approval process. The AISC recommends two weeks for the approval of one batch of shop drawings (AISC 1997A). Some contracts specify a definite approval time for the architect/structural engineer. These time limitations must be adhered to while estimating the duration of activities. In fast track projects, shop drawings may sometimes be submitted directly to the structural steel engineer, or to both the engineer and the construction manager.(Refer to Figure 2.8)

Coordination Among the Various Sub Contractors. Coordination among various trade subcontractors and the steel contractor is important for timely completion of the project. Delays caused by one subcontractor can affect the time schedule of another subcontractor and subsequently adversely affect the overall progress of the project. In the conventional project delivery contract, the GC coordinates the trade contractors, while in CM projects, the construction manager coordinates the work. In any case, a realistic schedule will keep all participants informed of the progress of the work and of any changes made during the process.

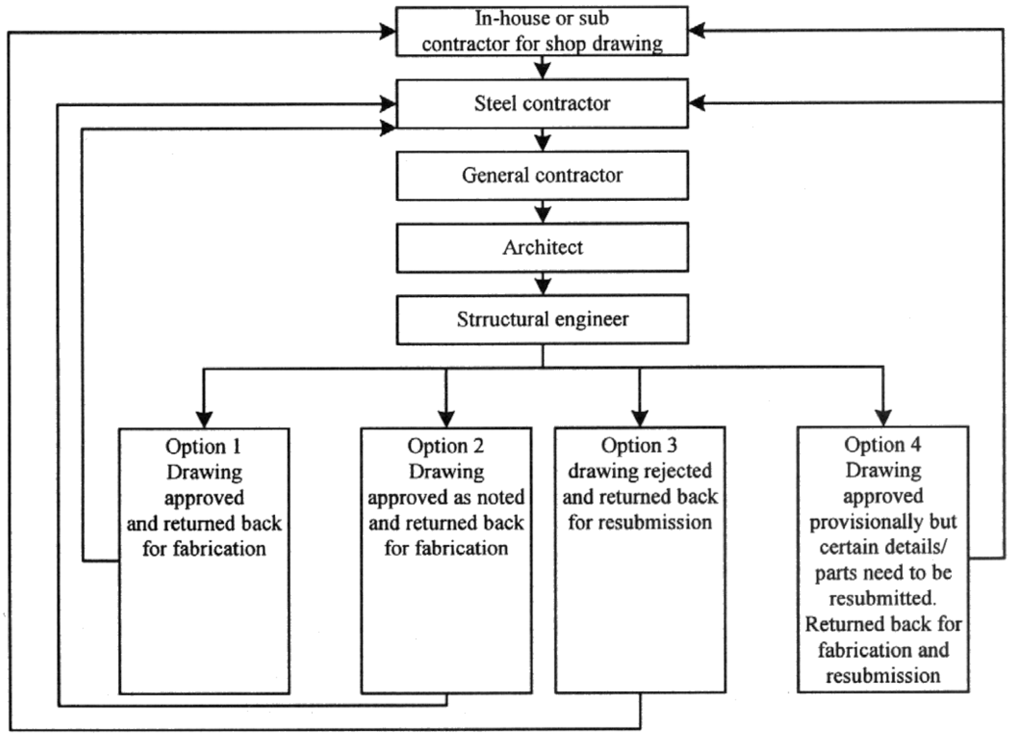


Figure 2.8 Shop drawing approval process

Impact of Erection Methods on Overall Project Schedule. The erection method depends on the shape of the building, such as horizontal or vertical structure. If the building is as high as three stories and spread over a comparatively large area, the erection can be performed simultaneously at more than one location. By executing the erection at more than one location, time can be saved and the schedule may be compressed. The consideration of vertical versus horizontal structure should be given considerable weight when scheduling the project. Two buildings requiring the same amount of structural steel but having different types of structure, one horizontal and the other vertical, will have substantially different erection schedules. Erection can be carried out in one of two ways:

1. Vertical slicing for a horizontal building: In this method the structure is divided into vertical segments. After the erection of one segment, the next section (slice) is started. Vertical slicing has a relatively slower erection sequence but utilizes manpower and equipment efficiently

2. Horizontal slicing for a vertical building: This method is adopted for tall buildings. In this method the building is divided into horizontal segments. It is a faster operation, but can be slowed because of equipment maneuverability

2.14 Areas Requiring Special Attention

The process of developing a detailed and accurate schedule is helpful for the steel contractor to foresee problems related to on-time and on-budget work completion. It can also provide insight into possible solutions to these problems. Resulting from discussions with the Industry Technical Committee, areas requiring special attention related to steel construction were identified as follows:

Delays/problems due to steel subcontractors and lower tier subcontractors:

Delays due to non-availability of materials
1. Material shortage
2. Production delay
3. Delivery delay
4. Uncommon size/types

Limitations of fabrication shop capacity
1. Delays in earlier projects
2. Over booked fabrication shop

Labor shortage and/or disputes
1. Erectors
2. Fabricators
3. Strikes

Shop drawing production
1. Over booked detailer
2. Delay in earlier projects

Lack of capability to accommodate special requirements
1. Special painting requirements
2. Rolling of materials
3. Special surface preparation
4. Galvanizing

Transportation problems
1. Over booked
2. Coordination

Problems caused by lower tier subcontractors
1. Delays by deck supplier
2. Delays by deck erector
3. Delays by joist supplier
4. Delays by other lower tier subcontractors and suppliers

Delays /Problems due to others:

Shop drawings and project scope changes
1. Before shop drawings are prepared
2. During shop drawings preparation
3. After shop drawings are prepared

Fabrication and scope changes
1. Before fabrication
2. During fabrication
3. After fabrication

Shop Drawings Approval
1. Incomplete design drawings
2. Communication delay
3. Over-committed designers

Foundations
1. Improperly located foundations
2. Timely completion

Anchor rods
1. Improperly located anchor rods
2. Realignment time and cost

Site conditions
1. Material storage
2. Erection space
3. Movement of crane
4. Soil stabilization and preparation
5. Removals of obstructions, e.g., power lines, stones, etc.

Special permits and requirements
1. Special delivery requirements
2. Special storage requirement
3. Special hoisting requirements

Design and construction of other trades
1. Issuance and completeness of design drawings
2. Shop drawings by other contractors
3. Information about size and location of openings
4. Timely completion of work by other contractors

Others
1. Change order finalization
2. Financing
3. Payments
4. Jurisdictional disputes or strikes

Helpful Solutions

1. Coordination drawings, early decisions by owners, and early coordination among design disciplines allow mechanical and electrical subcontractors to mark their details on E-sheets during pre-detailing coordination meetings.
2. Fabrication before approval of the shop drawings should be avoided or limited to common simply framed pieces.
3. Provide detailed schedule:
   GC to all subcontractors
   Steel subcontractor to lower tier subcontractors
4. Early agreement on erection sequences. (Do not change erection sequences). Involve steel subcontractor early in the project and use their input to select designer team and details. Use value engineering when possible.
5. Download of structural drawings to fabricator's computer from the structural engineer, cuts both shop drawing and fabrication time. The steel detailer can work faster and more efficiently by using the computerized steel detailing programs.
6. Computer numerically controlled (CNC) fabricating equipment can be used to speed fabrication and free the fabrication shop for the next job. Similarly, automatic and semi-automatic welding processes can be used to speed welding operations.

2.15 Summary

Scheduling of a midsize building project can serve as an effective training tool for students in construction management and construction related programs. Module Two provides detailed information on the process of steel construction leading to the development of CPM network diagrams and bar charts. Module Two also highlights the use of the schedule as a project management tool. It demonstrates the use of activity codes to categorize scheduling activities within various sub-phases by responsibilities. The impact of the steel schedule on the overall project schedule is also discussed Finally, this module outlines possible problem areas that a scheduler must be aware of to produce realistic schedules.

Questions for Classroom Discussion

1. Outline the major steel construction activities for a midsize building project.

2. How are activity codes for sub phases and responsibilities useful in preparing a construction schedule for steel construction?

3. How can the shop drawing approval process cause time delays if not managed properly?

4. What are some of the areas related to steel construction that may require special attention? How will you anticipate or solve some of these problems with the help of effective scheduling?

5. Discuss two major erection methods and their impact on the steel construction as well as the overall project schedule.

6. What major sub-phases can be defined for the steel construction phase of a midrise building project?

7. Discuss opportunities for early input by the steel contractor that the GC should take advantage of while scheduling the project.

8. Discuss the time compression potential of major fabrication related activities for steel construction of a building project.

Notes

STEEL ESTIMATING

2.16 Introduction

Estimating of structural steel can be a complex activity because of the variety of members, member sizes, applications, fabrication requirements, detailing, and connection types. Erection methods, equipment used, and project conditions also play significant roles in pricing of structural steel. Systematic estimating approaches can, however, serve to make the job of the estimator easier. An overview of steel estimating techniques, as well as a discussion of factors influencing the cost of steel construction are presented in this section. This material is intended to provide construction management students with an appreciation for the issues that impact costs and quantity surveying methods of structural steel.

2.17 Introduction to Estimation

Accurate estimation of steel requires specialized knowledge of fabrication and erection methods. The general contractor (GC) or construction manager (CM) would not normally have the expertise to conduct accurate detailed quantity takeoffs and estimates. The general contractor or CM usually works closely with the steel subcontractor to obtain pricing. Ultimately, final pricing of structural steel will be a function of the steel contractor's bid price and any negotiations that the two parties may undertake.

Many general contractors, construction managers, and design-builders have significant experience with the use and subcontracting of structural steel framing. As a consequence, they will have a project and bid data base which may be drawn upon to evaluate the steel contractor's price quotation. The contractor may compare the steel contractor's price quotation with average square foot costs for steel or with average costs per ton, based on past similar projects. Some published guides, such as the R.S. Means Building Construction Cost Data series contain tables which provide average tonnages for a variety of standard building types. Figure 2.9 indicates that for midrise office buildings with average beam spans and typical live loads, the structural steel should weigh approximately 10 lbs per square ft of building area.

Building Type	No. of Stories	Avg. Spans	LL #Per S.F.	Lbs Per S.F.
Steel Framed	1	20' x 20'		8
Manufacturing		30' x 30'	40	13
		40' x 40'		18
Office Bldgs	0-10			10
	10-20	Varies	80	18
	20-30			26
	Over 50			35

Figure 2.9 Structural steel weights per square ft. floor area for building types
(Adapted from 1998 Means Building Construction Cost Data, R.S. Means)

These approximate methods may yield initial estimates that are accurate to within 10-20% of the actual price for standard building types, with average conditions. However, if atypical or special conditions exist for the building type, the estimate will not be very accurate, unless the general contractor is sufficiently experienced in judging the impact on pricing of these unique conditions. Pricing of steel is highly dependent on the details of the design. The steel contractor can be very useful in helping to assess the impacts of special project details and conditions. The general contractor should develop a close working relationship with the steel contractor in order to take advantage of this expertise.

2.18 Preliminary Conceptual Estimating

During the initial design and planning phase of the project, the owner frequently requires the architect, structural engineer, construction manager, or design-build firm to furnish conceptual budgetary estimates. These estimates may be for the purpose of evaluating the cost of alternative systems (such as concrete or timber), or for preparing an overall budget for the project. Based on information provided by the owner, such as building type, overall quality level, size of floors, number of stories, height of stories and time and location of construction, the design or construction professional will be able to prepare conceptual estimates, using square foot and volumetric methods, cost data from past projects, or published data. When individual systems are to be conceptually estimated, the steel fabricator can be very helpful in assisting the design or construction professional in assembling conceptual costs. Fabricators are increasingly becoming involved early in the conceptual phases of the project, particularly as construction management and design-build project delivery methods gain popularity with owners. For standard building types such as office buildings or warehouse facilities, once the basic building characteristics discussed above and the structural bay size and design loads are established , the structural engineer or fabricator can readily determine the preliminary beam and column sizes, as well as lateral bracing and connection requirements for the project. This preliminary structural design, coupled with the fabricator's cost data, can allow for more accurate conceptual estimates.

Conceptual or preliminary estimating methods should always carry a contingency. Because the estimate is based only on partial information, all of the project conditions are not likely to be known at the time the conceptual estimate is prepared. It is important to document the scope of work and project conditions which were initially assumed, in preparing the conceptual estimate. Building designs frequently change during the development of the project, and it is important to monitor any changes in the conceptual design or in the performance criteria, and to adjust the conceptual estimate accordingly. A clear statement of assumptions can help alleviate disputes about project scope and budget at later project stages.

2.19 Bidding: The Subcontractor's Role

During the bidding period, the general contractor will divide the building project into subcontract workscopes. These workscopes should be carefully defined so that work intended to be included in each subcontractor's workscope is clear to all parties. The general contractor may decide to award a single subcontract for the steel portion of the project or to break the steel into multiple subcontracts. For example, it is fairly common for miscellaneous metals or metal fabrications to be furnished by a separate supplier or subcontractor and therefore not be included in the structural steel contractor's workscope.

When the subcontract workscope and contract documents are received by the steel contractor, the steel contractor should thoroughly review the project plans, specifications, contractual conditions, project site conditions, and correlate the information. The steel contractor may prepare a work breakdown structure illustrating all of the steel component types for the project. This work breakdown structure serves to illustrate the elements which will need to be addressed in the detailed estimate. The steel contractor will need to determine the items for which to seek lower tier subcontractors or suppliers. For example, the steel contractor (who is primarily a fabricator) will seek subcontractors for erection. Steel joists and metal decking will be purchased for the project from suppliers. The steel contractor will need to determine whether the steel will be supplied by a rolling mill, steel service center (warehouse) or from the steel contractor's own inventory. After deciding which portions will be subcontracted, the steel contractor will develop lower tier subcontract workscopes and seek price quotations from these contractors.

The steel contractor will conduct detailed estimates for the portion of the subcontract that the steel contractor retains, and will evaluate competitive offers from lower tier subcontract bidders. Evaluation of the lower tier subcontract bids will be based on price, quality, schedule, and working relationships. The steel contractor will assemble a final price for the total subcontract workscope combining the steel contractor's portions of the work with that of selected lower tier subcontractors.

Upon receipt of the steel contractor's subcontract proposal, the general contractor will evaluate competitive offers from the various steel contractors and decide which steel contractor to utilize. Figure 2.10 below illustrates a flow chart of the bid process.

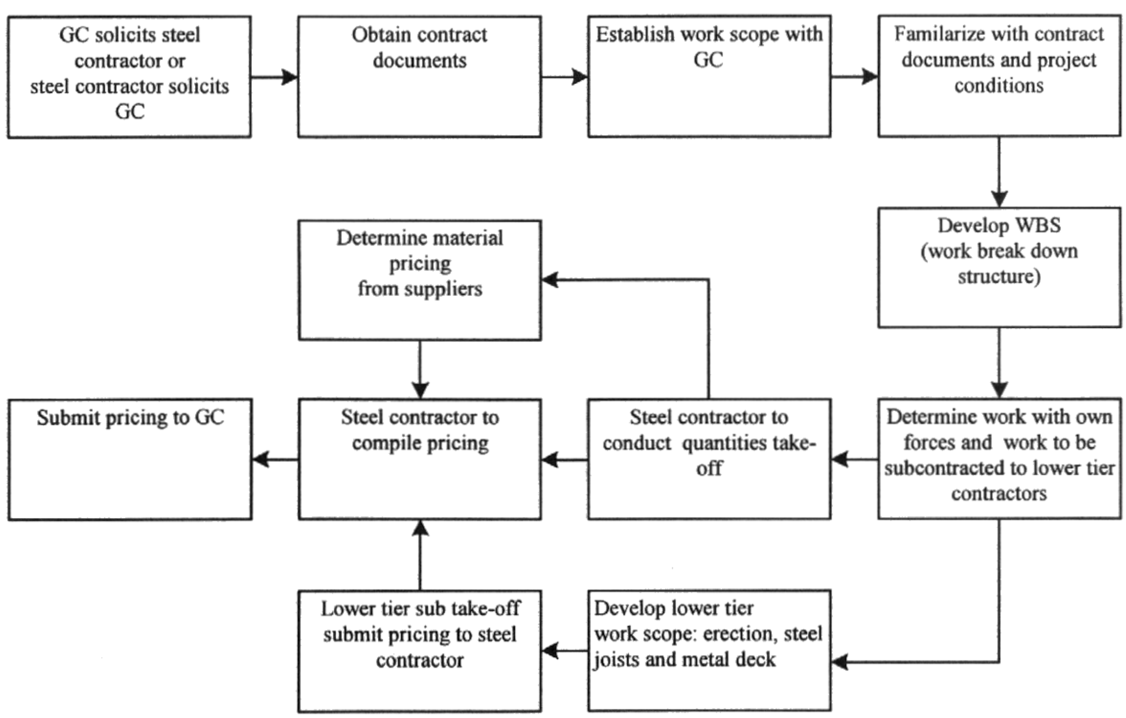


Figure 2.10 Flow chart of bid process

2.20 Quantity Takeoff Methods

Unlike the general contractor who will estimate steel using approximation methods, the steel contractor's estimator must undertake a very careful quantity takeoff of each separate element with its corresponding shape and size for the entire steel frame. Each element, shape, bolt, clip, etc. will need to be accounted for. Beams and columns will typically be recorded separately because the fabrication requirements for these components will vary. In addition, the connections, fabrication, material characteristics, weld requirements, and finishing requirements for each member will need to be identified and tallied. Because of the complexity of this task, most steel contractors have developed systematic methods for taking off steel.

The takeoff must begin with a careful review of the project plans, specifications, contractual requirements, and project conditions. The estimator should review all plans, including the structural, architectural and mechanical sheets. All documents should be correlated to obtain a complete understanding of the project, including administrative and procedural requirements. Because architects and engineers have individual styles of organizing information on the plans, the estimator must quickly adapt to the symbols, sheet arrangement, and level of detail on the set of plans being worked with. The thoroughness of the plans will vary frequently from project to project, making the estimator's job more difficult. The estimator may need to contact the structural engineer or architect to obtain clarifications on what was intended in the design.

After the plans have been carefully reviewed and the estimator understands the project, the estimator will begin the takeoff of the elements in the project workscope. A useful tool in structuring the takeoff is to develop a master checklist or a Work Breakdown Structure (WBS). Section 2.8 discussed the scheduler's activity based WBS; similarly the estimator may find it useful to create a WBS, but one that is take-off item based. The estimator's WBS lists the components which are included in the workscope and serves as a check list of elements to estimate. Figure 2.11 illustrates a sample WBS for estimating.

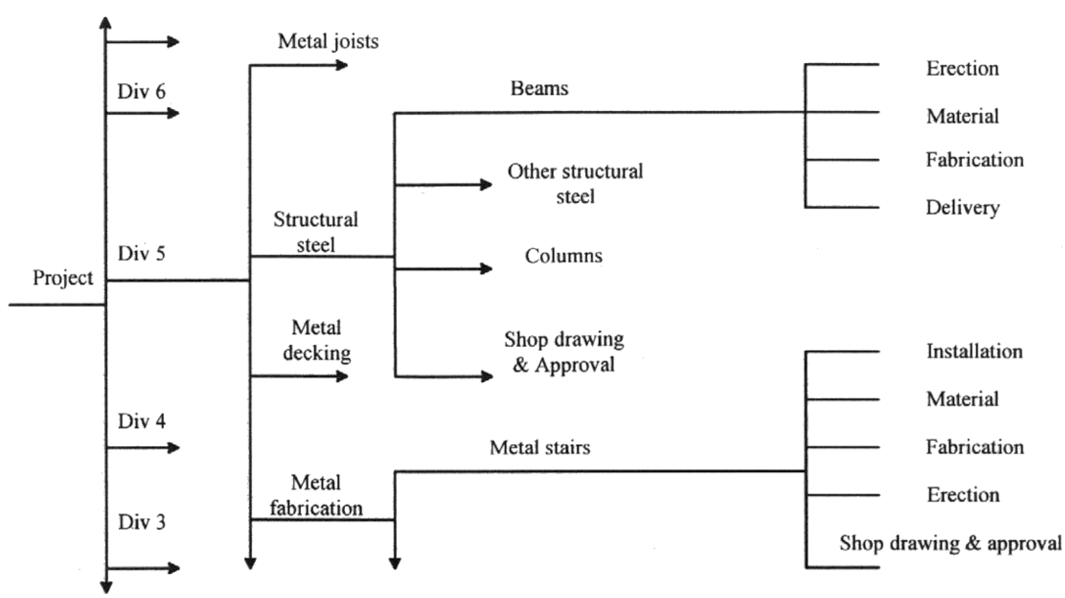


Figure 2.11 Estimator's work breakdown structure

Each structural steel contractor will have a systematic method for quantity takeoff of the steel elements. Frequently the estimator, project manager or other estimators will need to review the estimate; therefore, the steel contractor should have a well-established sequence of taking off and recording the elements. This is important so that all users will be able to decipher the estimate and correlate the estimate with the plans. For example, one method is to takeoff the elements using a standardized order such as all first floor north-south beams, starting with the western most row and then proceeding with the next north-south row until all first floor north-south beams have been recorded. The estimator would then proceed to east-west beams. By using a common system for sequencing the takeoff, elements will not be missed. Every element should receive an identifier for later reference. The estimator may use the structural steel beam and column line identifiers on the structural plans, or may establish other identifiers using the steel fabricator's standard practice.

The characteristics of each element should be recorded. For example, when taking off beams, the estimator should record each beam number identifier, span, shape and size, as well as the connections and any attached plates, angles, stiffeners, etc. Any special fabrication, cambering, bending , special painting, galvanizing or finishing requirements will also need to be noted. Some fabricators will use specialized steel estimating computer programs and spreadsheets to catalog the information. Figure 2.12 shows a sample takeoff sheet.

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Structural Shapes - Warehouse Angles - Warehouse Plates - Warehouse Tubes - Warehouse Other Shapes - Warehouse

Page#	Item#	Qty	Sh	Dimensions	Length	Grade	Type	F	Weight	UnitCost	Cost	Lbr/Pc	Labor mh	Sq/Ft
1	5960	1	C	12 x 20.7	32'-0	A36	A	U	662#	$0.00	$0	0.70	0.70~	94
1	5970	1	W	18 x 35	24'-0	A572-50	D	U	840#	$0.00	$0	1.81	1.81	118
1	5980	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	5990	1	W	24 x 84	32'-0	A572-50	D	U	2688#	$0.00	$0	4.55	4.55	222
1	6000	4	L	3 1/2 x 3 x 5/16	1'-9	A36	AA	U	46#	$0.00	$0	0.06	0.24~	8
1	6010	1	CO	HOSPITAL ROOF FRAMING							$0		0.00	
1	6020	1	W	18 x 35	32'-0	A572-50	D	U	1120#	$0.00	$0	2.24	2.24	157
1	6030	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	6040	16	W	18 x 35	32'-0	A572-50	D	U	17920#	$0.00	$0	2.04	32.59	2509
1	6050	64	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	528#	$0.00	$0	0.05	3.20~	87
1	6060	6	W	18 x 35	32'-0	A572-50	D	U	6720#	$0.00	$0	1.84	11.05	941
1	6070	24	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	198#	$0.00	$0	0.05	1.20~	33
1	6080	1	W	18 x 35	32'-0	A572-50	D	U	1120#	$0.00	$0	2.24	2.24	157
1	6090	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	6100	2	W	18 x 40	32'-0	A572-50	D	U	2560#	$0.00	$0	2.53	5.06	316
1	6110	8	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	66#	$0.00	$0	0.05	0.40~	11
1	6120	11	W	18 x 40	32'-0	A572-50	D	U	14080#	$0.00	$0	2.33	25.63	1737
1	6130	44	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	363#	$0.00	$0	0.05	2.20~	60
1	6140	4	W	18 x 40	32'-0	A572-50	D	U	5120#	$0.00	$0	2.23	8.94	632
1	6150	16	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	132#	$0.00	$0	0.05	0.80~	22
1	6160	7	W	18 x 35	32'-0	A572-50	D	U	7840#	$0.00	$0	2.14	14.96	1098
1	6170	28	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	231#	$0.00	$0	0.05	1.40~	38
1	6180	1	W	18 x 35	32'-0	A572-50	D	U	1120#	$0.00	$0	1.94	1.94	157
1	6190	4	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	33#	$0.00	$0	0.05	0.20~	5
1	6200	4	W	18 x 40	32'-0	A572-50	D	U	5120#	$0.00	$0	2.43	9.72	632
1	6210	16	L	3 1/2 x 3 x 5/16	1'-3	A36	AA	U	132#	$0.00	$0	0.05	0.80~	22
1	6220	8	W	14 x 30	14'-0	A572-50	D	U	3360#	$0.00	$0	1.81	14.48	505
1	6230	32	L	3 1/2 x 3 x 5/16	0'-9	A36	AA	U	158#	$0.00	$0	0.04	1.28~	26
1	6240	2	W	14 x 22	24'-0	A572-50	D	U	1056#	$0.00	$0	1.81	3.61	188
1	6250	8	L	3 1/2 x 3 x 5/16	0'-9	A36	AA	U	40#	$0.00	$0	0.04	0.32~	7
1	6260	1	W	16 x 36	24'-0	A572-50	D	U	864#	$0.00	$0	2.17	2.17	118

Figure 2.12 Sample takeoff sheet

Connections for the various members will have a significant impact on fabrication and material costs, therefore, each connection will need to be described and designed. Larger fabricators utilize specialized computer programs which allow the estimator to enter a connection type or class for the connection, when inputting the beam or column information. The computer will be used to determine fabrication requirements and labor hours.

In addition to the main members, the structural steel contractor will also need to takeoff steel items which are attached to the frame, such as spandrel frames and bracing, screed angles, bent plates, framing for floor or roof openings, etc. These elements can add considerable fabrication time as well as tonnage to the project.

The steel contractor may also have in the workscope miscellaneous loose structural steel items and metal fabrications. These miscellaneous items may include lintels, bearing plates, anchor bolts, rods and other pieces of steel which will be installed by other contractors, such as the mason. Some of these components will not be shown on the structural plans and may only appear on the architectural plans. Support for roof top units and other mechanical equipment may be detailed on the mechanical sheets and may be in the structural steel contractor's workscope. Therefore, the estimator must carefully review the architectural, structural and mechanical sheets. Fabrications such as metal stairs, ladders, handrails, guardrails, floor grating, ornamental metals, and expansion joint cover assemblies are also specified in CSI Division 5 Metals, and may need to be estimated for the project.

2.21 Costs Included in the Fabricator's Estimate

Once the steel contractor has taken off the quantities, the steel contractor must determine the pricing to fabricate and to deliver the individual items to the site. Costs which will need to be included are indicated below:

1. Costs including applicable sales taxes and mill certification of structural steel material from the mill, warehouse, or fabricator inventory
2. Freight for shipping steel material from the mill or warehouse to the fabricator's plant
3. Costs of preparing shop and erection drawings, including engineering if required, plus printing and distribution
4. Costs of fabrication of the structural elements, including connections and special processes such as bending or cambering, etc.
5. Finishing the members, including cleaning, shop painting, or galvanizing
6. Costs of independent testing, if required by the contract documents
7. Handling, storage, and loading costs at the fabricator plant
8. Field verification and surveying anchor rod locations
9. Shop testing and inspection, if required; (estimator must verify who pays for independent testing)
10. Shop expenses, including general overhead, supervision, plant and equipment, etc.
11. Freight for shipping fabricated elements to the project site
12. Product liability insurance
13. Bonds (if required)
14. Subcontracted items such as, steel joist and metal deck supply
15. Profit plus general sales and administrative overhead

Source: Adapted from Walker's Building Estimator's Reference Book, 24th Edition

Figure 2.13 below represents a sample estimate summary sheet from a midsize fabricator indicating the estimating summary categories used.

PROJECT: ______ MILES TO SITE 40 ESTIMATE # Q

ESTIMATOR: ______ STR STL TONNAGE: 0 TONS

DESCRIPTION: ______ JOIST TONNAGE: 0 TONS

F.O.B.- ______ MISC TONNAGE: 0 TONS

TOTAL 0 TONS

ITEM	WEIGHT	QUANTITY	UNIT PRICE	PRICE
MILL A36 GRP I			$23.00	$0
MILL A36 GRP II			$25.00	$0
MILL A572 GRP I			$23.00	$0
MILL A572 GRP II			$25.00	$0
PLATE			$40.00	$0
BENT PLATE			$40.00	$0
ANGLE			$27.00	$0
CHANNEL			$27.00	$0
TUBE			$50.00	$0
PIPE			$45.00	$0
ANCHOR BOLTS			$0.00	$0
L.I.B. BOLTS			$0.85	$0
STD H S BOLTS			$0.65	$0
STUDS			$0.55	$0
PAINT MATERIAL	R=1 W=2		$20.00	$0
GALVANIZING			$0.27	$0
MISC				
MISC				
MISC				
TOTAL WEIGHT	0 #	TOTAL MATERIAL COSTS		$0
MATL $ PER CWT	$0	PLUS 6% TAX		$0

SHOP LABOR & TRUCKING COSTS				
STRUCTURAL	0.00	HOURS / TON		
MISC				
MISC				
MISC				
CARTAGE JOBSITE	3	X TRUCKING	$50.00	$0
CARTAGE OTHER		X TRUCKING	$50.00	$0
CLEANING HOURS	0			
TOTAL LABOR	2	HRS x RATE	$50.00	$0
SHOP PRICE / TON	$0	TAX ON LABOR		$0

BLAST CLEANING SP 6			
0.5 HRS/PIECE X	PIECES		
$9 /MAIN PIECE	0 PIECES	BLAST MACH	$0
MISCELLANEOUS			$0
MISC			
TOTAL CLEANING COSTS			$0

ENGINEERING			
SUB DETAILER	+ IN HOUSE	10%	$0
IN HOUSE HOURS	0 HRS	$50.00	$0
PRINTING			$0
DESIGN HOURS	0 HRS	$75.00	$0
ESTIMATING HOURS	0 HRS	$58.00	$0
TOTAL ENGINEERING COST			$0
	ENGINEERING COST $ / TON		$0

	TOTAL F O B COST	$0
Rev. 1/28/99	STRUCTURAL STEEL FOB / TON	$0

ERECTION	I.W. HOURS	
STR STL	0	$0
MISC IRON		
DECK ERECTION		
SHEAR STUDS F&I		
HORIZ STUDS F&I		
INSPECTION		
SUB MARK UP		
A B SURVEY		
MISC		
MISC		
TOTAL ERECTION COSTS		$0
0 BOLTS / TON	ERECT $/TON	$0

SUBLET TAXED ITEMS	
JOISTS	
DECK	
GRATING	
MISC	
MISC	
MISC	
MISC	
MISC	
MISC	
TOTAL TAXED ITEMS	$0
PLUS 6% TAX	$0

SUBLET NON-TAXED ITEMS	
MISC IRON - F & I	
DECK - F & I	
STAIRS - F & I	
ROLLING LABOR	
MILLING BASE PL	
MISC	
MISC	
MISC	
TOTAL NON-TAXED ITEMS	$0

TOTAL SUBLET ITEMS	$0
2.5% S & A	$0

SUMMARY	
ESTIMATE SUB TOTAL	$0
PROFIT	$0
PRODUCT LIABILITY	$2.5
F.O.B. TAX	$0
TOTAL ESTIMATE	$0
P & P BOND -	$0
TOTAL ESTIMATE W/ BOND	$0
WEIGHT (#) PER SQUARE FOOT	0.00
PRICE PER SQUARE FOOT	$0.00
PROFIT $/ SHOP HOUR	$0
TOTAL ESTIMATE COST /TON	$0

Figure 2.13 Sample estimate summary sheet

PROJECT: 0   TONS 0   IRONWORKER HOURS INSURANCE CODE A

0

NO	HOISTING OPERATIONS	QUANT	STD.	CREW HOURS	CREW SIZE	TOTAL HOURS
1	SET-UP & DISMANTLE CRANE		0.75	0	4	0
2	UNLOAD TRUCKS - STRUCTURAL		0.75	0	4	0
3	UNLOAD TRUCKS - JOISTS		0.75	0	4	0
4	UNLOAD TRUCKS - DECK		0.75	0	4	0
5	UNLOAD & HOIST SHEAR STUDS (PALLETS)		7.50	0	4	0
6	COLUMNS		9.00	0	4	0
7	BEAMS		7.50	0	4	0
8	BRACING		0.75	0	4	0
9			0.75	0	4	0
10			0.75	0	4	0
11			0.75	0	4	0
12			0.75	0	4	0
13			0.75	0	4	0
14			0.75	0	4	0
15			0.75	0	4	0
16	ROOF FRAMES		7.50	0	4	0
17	TRUSSES		3.00	0	4	0
18	JOISTS		15.00	0	4	0
19	FASCIA FRAMES		7.50	0	4	0
20	X ANGLE BRACING		6.00	0	4	0
21	BUNDLES OF LOOSE MATL		75.00	0	4	0
22	**SECONDARY SUMMARY**	0	0.75	0	4	0
23	UNLOAD & HOIST STAIR /FLOOR		0.75	0	4	0
24	ROOF DECK SQ'S		90.00	0	4	0
25	FLOOR DECK SQ'S		45.00	0	4	0
	TOTAL HOISTING HOURS			**0**		**0**

NO	COMPLETION OPERATION	QUANT	STD.	HOURS	SIZE	HOURS
1	H S B - 3/4" STANDARD		9.00	0	1	0
2	H S B - 3/4" DIA. L.I.B.		18.75	0	1	0
3	BOLT JOIST ENDS		6.00	0	1	0
4	FW JOIST ENDS		7.50	0	1	0
5	FW BTM CHORD EXTENSIONS		6.00	0	1	0
6	FW HORIZ BRDG POINTS		18.00	0	2	0
7	SETS OF X BRDG - FW OR BOLT		6.75	0	2	0
8	FW & ALIGN FACIA FRAMES		0.36	0	3	0
9	FW & BOLT K B @ FACIA FRAME		7.50	0	3	0
10	FW BEAM MOMENT CONN ENDS		0.38	0	2	0
11	FW BEAM CONN ANGLE TO WALL PL		0.75	0	1	0
12	FW COLUMN SPLICE		0.38	0	2	0
13	EXPANSION BOLTS		6.00	0	1	0
14			0.75	0	1	0
15			0.75	0	1	0
16			0.75	0	1	0
17			0.75	0	1	0
18			0.75	0	1	0
19			0.75	0	1	0
20			0.75	0	1	0
21			0.75	0	1	0
22			0.75	0	1	0
23	**SECONDARY SUMMARY**	0	0.75	0	1	0
24	STAIR / FLOOR, INCL HR		0.38	0	1	0
25	SAFETY CABLE - LF		36.00	0	1	0
26	PLUMB CABLES - EACH		2.63	0	2	0
	TOTAL COMPLETION HOURS					**0**

IRONWORKER HOURS		**0** HOURS
15% SUPERVISION		**0** HOURS
10% WEATHER TIME		**0** HOURS
TOTAL IRONWORKER HOURS		**0 HOURS**

LABOR HOURS INCLUDING WEATHER TIME	
CRANE OPERATOR HOURS	**0** HOURS
CRANE OILER HOURS	**0** HOURS
COMP OPERATOR HOURS	**0** HOURS
WELDING MACH OPERATOR	**0** HOURS
TOTAL ERECTION MAN HOURS	**0 HOURS**

LABOR COSTS INCLUDING WEATHER AND TRAVEL			
IRONWORKER HOURS	$30.35	PER HR	**$0**
CRANE OPERATOR	$31.35	PER HR	**$0**
CRANE OILER	$23.50	PER HR	**$0**
COMPRESSOR OPER.	$22.50	PER HR	**$0**
WELD MACH OPER.	$22.60	PER HR	**$0**
TOTAL LABOR COSTS			**$0**

EQUIPMENT COSTS INCLUDING WEATHER		
SAFETY CABLE	0 LF x$0.75	**$0**
TOUCH-UP PAINT	0 TONS x$70	**$0**
CRANE	$0.00 PER HR	**$0**
ASSIST CRANES INC OPER. & OILER		
CARTAGE IN & OUT		
MATS	RENTAL & CARTAGE	
MISC		
MISC		
MISC		
TOTAL EQUIPMENT COSTS		**$0**

TOTAL ERECTION COSTS	**$0**
PRICE PER TON	**$0**

Figure 2.13 Sample estimate summary sheet cont'd

The seven-story project case study (documents included in Appendix A) utilized 1,330 tons of structural steel and averaged approximately 10.35 lbs of structural steel per square ft of building area (256,900 square feet). The structural frame used 26,000 bolts. Table 2.3 shows the project cost breakdown for the structure.

	Cost	% of Total
Structural Material (raw)	823,579	36%
Fabrication Labor	389,132	17%
Detailing Labor	78,389	3%
Erection Labor	415,889	18%
Deck Material	323,125	14%
Deck Erection Labor	82,368	4%
Stair Fabrication and Erection	145,200	6%
Total	$2,257,682	100%

Table 2.3 Structural steel cost breakdown for case study project

2.22 Special Estimating Issues for Fabrication

The cost of furnishing fabricated steel to the job includes the costs of the raw material, detailing, approvals, fabrication, finishing, delivery, as well as the costs of administrative procedures, profit, and overhead. The costs associated with fabrication will not only be impacted by the amount of material, but also by the type of material and shapes called for in the design, as well as the complexity of the connections and other fabrication. The steel fabricator's estimator must be skilled at quantifying and characterizing each piece of steel for the project. Some of the issues which will impact the fabricator's pricing are discussed below.

Mill Steel vs Warehouse Steel. The estimator must determine the source of the raw steel material to be fabricated for the project. Steel supplied from the mill will generate savings for raw steel, compared to ordering from a steel service center (warehouse). The estimator will need to contact the mill or warehouse to determine the latest pricing for steel. Costs of taxes and delivery to the fabricator's plant should also be included. Raw steel accounted for approximately 36% of the total cost of structural steel for the case study. Most of the steel material for the case study project was purchased directly from the mill.

Material Type and Strength. The estimator must determine the type of steel specified and a producer of the shapes indicated on the plans. At the time this manual was prepared (1999), the majority of steel shapes for smaller buildings were typically A36 steel. The use of recently introduced higher strength A992 grade 50 steel is highly recommended as it can provide increases in strength and therefore a reduction in member size. Also A992 grade 50 steel is available in all wide flange shapes and normally at no cost increase. Only large size sections might require an increase in cost; however, that is normally offset by savings due to the member's increased strength.

Weight/Cost Economies. Most midsize to large fabricators can handle relatively large steel shapes and sections. While the cost of steel is related to the weight of the member, it is also related to the amount of fabrication and erection required for the structure. When taken together, it is sometimes possible that frame costs can be lowered by increasing beam spans and reducing the number of columns. The increase in beam weight, size, and the cost necessary to accommodate the longer span, may be more than offset by a reduction in column costs, fabrication, and fewer number of pieces to be erected. Also, overall savings may sometimes be obtained by using heavier members and eliminating stiffeners and other strengthening plates. Refer to the AISC Design Guides.

Shop Drawings and Approvals. Shop drawings for steel can become quite detailed. For complex frame designs with specialized fabrication requirements, the process of producing the drawings can be very labor intensive. For the case study project, the production of these drawings accounted for approximately 3% of the total structural steel cost, which is about average for a midsize office building. Shop drawings are either produced in-house with the fabricator's own detailers or contracted to an independent steel detailing firm. In either case, the estimator will need to make a judgment regarding the costs of shop drawings based on experience or pricing from the detailer. The purpose of the steel shop drawings has been previously discussed in Project Management Module One and in the scheduling portion of this manual (Module Two).

Fabrication and Connections.
Fabrication of the steel members includes handling the member in the shop, laying out and setting up the piece, cutting to length, making cuts such as beam copes, drilling, punching, welding, bolting, etc. Each element of the structure will generally receive some fabrication. The estimator must evaluate the time and material required for each element of fabrication. Most fabricators will have developed guidelines for determining labor hours for various standard types of connections and fabrications. The estimator will characterize the type of fabrication necessary for the piece and utilize the fabricator's labor standard for that particular type of connection. Unique or specialized details which are not typical, may require the estimator to consult directly with the shop personnel or engineering staff to determine the methods and costs for fabricating a particular connection. Fabrication labor represents a significant cost and accounted for 17% of the structural steel costs for the case study project.

Fabricator's Equipment and Shop Operation. The fabricator must assess the economy of fabricating the pieces in-house or to subcontract portions to other shops. Shop setup and capacity, other simultaneous projects, and shop expertise dictate whether the element will be fabricated in-house. Large shops may find that they underutilize their shop equipment by fabricating small and time-consuming components, such as bending plates and fabrication of specialized items such as metal stairs and pipe railings. They may prefer to subcontract this work to smaller shops, thus preserving shop capacity for larger work. The fabricator should maintain close working relationships with smaller specialty shops which may be able to provide this specialty work.

Painting and Finishing. The estimator must determine from the specifications, the type of surface coating required for the project. Painting and finishing requires that the surface be cleaned, usually by shot blasting or wire brush, prior to painting. Finishes may range from shop priming with rust inhibiting primers, to galvanizing, or in some instances, finished painting for specialized architecturally exposed steel projects. The shop setup will determine whether the fabricator finishes the piece in-house or sends the piece to a separate entity, such as a galvanizing company. The cost of the finishing material, as well as the shop labor to prepare and apply the coatings will impact this portion of the steel price. With special finish coatings, increased care and time may be required in handling and touch-up in order to maintain a high quality finish.

Bolts. The fabricator furnishes all of the bolts to be installed by the fabricator in the shop, and those bolts installed in the field by the erector; 26,000 bolts were used in the case study project. Bolts are purchased from a supplier and must be furnished in the quantities, sizes, types, and strengths necessary for the connection. High strength A490 bolts may be used for heavier connections and standard A325 bolts used for typical and lighter connections as specified by the Research Council on Structural Connections (RCSC). A307 bolts will be used for some minor connections. Bolts may need to be fully tensioned for some slip critical connections, thus adding more erection labor. The fabricator's estimator will need to determine the number of bolts of various types and sizes. By determining the type of connections and their number, the estimator can typically determine the number of bolts either by using a steel estimating computer program, or by experience based on the number and the size of the pieces being connected, as well as approximate counting. The AISC Code of Standard Practice requires that the fabricator furnish an additional 2 percent of each bolt size (diameter and length) to the erector. Table 2.4 below is reprinted from the AISC Manual of Steel Construction and indicates material available for bolts.

BOLTS, AND THREADED PARTS
ASTM Specifications

TABLE I-C. MATERIAL FOR ANCHOR BOLTS AND TIE RODS

	ASTM Specification	Strength, Ksi			Maximum Diameter In.	Type of Material[b]	Headed or Unheaded
		Proof Load	Yield (Min.)	Tensile (Min.)			
Bolts and Studs	A307	—	—	60	4	C	H
	A325[a]	85 74	92 81	120 105	½ to 1, incl. 1⅛ to 1½ incl.	C, QT	H
	A354 Gr. BD	120 105	130 115	150 140	¼ to 2½ incl. over 2½ to 4 incl.	A, QT	H, U
	A354 Gr. BC	105 95	109 99	125 115	¼ to 2½ incl. over 2½ to 4 incl.	A, QT	H, U
	A449	85 74 55	92 81 58	120 105 90	¼ to 1 incl. 1⅛ to 1½ incl. 1¾ to 3 incl.	C, QT	H, U
	A490	120	—	150	½ to 1½ incl.	A, QT	H
	A687	—	105	150[c]	⅝ to 3 incl.	A, QT, NT	U
Threaded Round Stock	A36	—	36	58	8	C	U
	A572 Gr. 50	—	50	65	2	HSLA	U
	A572 Gr. 42	—	42	60	6	HSLA	U
	A588	— — —	50 46 42	70 67 63	To 4 incl. over 4 to 5 incl. over 5 to 8 incl.	HSLA, ACR	U

[a]Available with weathering (atmospheric corrosion resistance) characteristics comparable to ASTM A242 and A588 steel.
[b]C = carbon
QT = quenched and tempered
A = alloy
NT = notch tough (Charpy V-notch 15 ft-lb. @ −20°F)
HSLA = high-strength low alloy
ACR = atmospheric corrosion-resistant
[c]Maximum (ultimate tensile strength)

Notes:
ASTM specified material for anchor bolts, tie rods and similar applications can be obtained from either specifications for threaded bolts and studs normally used as connectors or for structural material available in round stock that may then be threaded. The material supplier should be consulted for availability of size and length.
Suitable nuts by grade may be obtained from ASTM Specification A563.
Anchor bolt material that is quenched and tempered should not be welded or heated to facilitate erection.
Threaded rod with properties meeting A325, A490 or A449 Specifications may be obtained by the use of an appropriate steel (such as AISI C1040 or C4140), quenched and tempered after fabrication.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

Table 2.4 Bolts and threaded parts
(AISC Manual of Steel Construction)

Shop Welding. Many of the fabricated components will be welded or bolted in the shop with connections prepared for bolting in the field. All welds should be made according to the provisions of the American Welding Society (AWS), Structural Welding Code and AISC specifications. Certain standard types of welded joints are prequalified by the AWS and are exempted from special testing and qualification. Amounts of weld for a particular connection are a function of the loads, type of weld joint such as fillet or full penetration, and the dimensions of the weld such as weld length and effective throat. Welds may be continuous or intermittent. Some welds require multiple passes of the welder to build up sufficient weld material. Figure 2.14 shows the standard welded joints symbols used to describe weld joints.

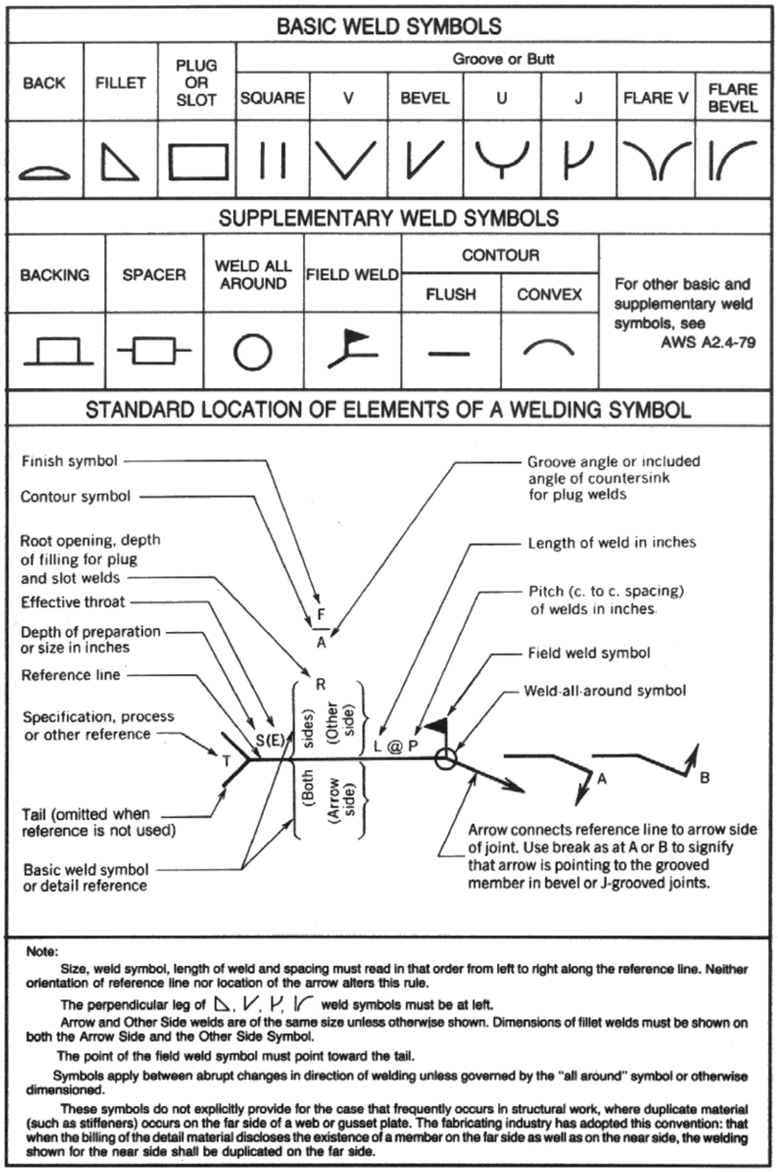

Figure 2.14 Welded joint symbols
(AISC Manual of Steel Construction)

Welding methods used in the shop vary among fabricators, but may include shielded metal arc, submerged arc, gas metal arc, and flux core arc welding. Generally, the welding method is left up to the fabricator, providing it meets the requirements of the design and complies with the AWS Structural Welding Code. Selection of the welding method is usually a function of the shop equipment and preference. Large shops may utilize automated welding operations. Shop welding is usually more economical than field welding because of the availability of welding equipment and jigs within the shop.

Estimators generally work with the fabricator's predetermined labor hours for typical welded connections. Estimating of specialized welded connections may require the estimator to consult with the shop or engineering personnel to determine labor hours.

Mill or Shop Inspection Costs. Typically, mill tests are performed to establish that the material is in compliance with ASTM specifications. If required by the contract documents or by the fabricator, the mill will provide test reports. These test reports are normally accepted by the fabricator as evidence of compliance with the American Society for Testing and Materials (ASTM) standards.

Occasionally the contract documents will require special testing or certification beyond that normally provided under standard industry practice. Costs for special testing of shop paint thickness, weld quality, or surface preparation, etc. should be identified and included by the fabricator in the estimate. The specifications may also require welding inspectors to be AWS/CWI certified by the American Welding Society.

Loading, Storage, Delivery, Transportation. Costs of loading, handling, storage, and delivery of fabricated steel items to the site need to be determined. Refer to section 2.6 for information on these activities. The estimator must determine the mode of transportation as well as travel distance, number of loads, and sequence of delivery when estimating these costs.

Metal Decking. Metal decking will normally be purchased by the fabricator from a metal deck supplier. Metal deck for the project will vary with the application. Deck span, rib or corrugation configuration, length and depth, material type and strength, finishes, etc. will all impact deck costs. The fabricator will usually work closely with the deck supplier to determine the quantity of the different deck types. The fabricator will receive a price quotation from the deck supplier, which is included in the fabricator's overall price. Metal deck material accounted for 14% of the case study steel contract.

Steel Joists. Steel joists can offer significant savings for long spans, such as in roofs. Typically the joists are purchased from a steel joist supplier who fabricates the joist for the project. Joists carry a letter and number designation signifying compliance with the Steel Joist Institute's (SJI) standards for load carrying capacity and span. The fabricator will obtain price quotations from the steel joist supplier for the project and incorporate this pricing into the overall pricing.

Architecturally Exposed Structural Steel. Architecturally exposed structural steel presents some unique fabricating, finishing, handling, and quality control measures for the fabricator. Connections and finishes are frequently detailed for their artistic expression as well as for strength. The fabricator may be required to fabricate nonstandard details, increase the amount of grinding, as well as alter standard surface preparation methods. Special coatings may be expensive or difficult to apply.

Careful handling and touch-up may be required. Sometimes architectural or engineering specifiers may have unrealistic expectations for tolerances and finish quality that can be achieved in the fabricator's shop. The estimator must recognize the special requirements necessary for architecturally exposed structural steel and include appropriate costs in making the estimate.

2.23 Costs Included in the Erector's Estimate

The erector must analyze the project to determine the cost for assembling the steel frame. The erector may be a subcontractor to the fabricator-steel contractor, or the steel contractor may conduct both fabrication and erection operations. The steel erector not only determines the number of pieces and their sizes, but will need to examine closely how they are to be installed. The building size, height, footprint, project type, site conditions, and construction sequence will heavily influence the equipment, methods, and duration necessary for the installation. Certain connections such as moment resisting connections, or field welded connections will increase the labor hours for installation. The erector may include the following costs when estimating for erection of the steel:

1. Verification of anchor rod layouts and elevations (if required)
2. Equipment, cranes and hoists, (including mobilization, setup, and removal)
3. Unloading steel at site
4. Lifting and assembling the steel
5. Temporary shores, and bracing for both self-supporting and non-self-supporting structures
6. Costs of maintaining safety
7. Making all field bolted and welded connections
8. Leveling , plumbing and final tightening of bolts
9. Metal decking supplied to fabricator installed by metal deck subcontractor
10. Shear studs furnished and installed by subcontractor
11. Demobilization
12. Overhead and profit

Source: Adapted from Walker's Building Estimator's Reference Book, 24th Edition

Similar to the fabricator, the erector's estimator must carefully review the project plans and specifications to determine the number and character of pieces to be installed. This includes number of bolts, amount of field welding, special installation requirements, testing, and inspection requirements. Some fabricators will make their quantity takeoff for pieces and bolts available to the erector, which may serve as a check for the erector's estimator; however, this practice will vary from fabricator to fabricator. In addition, the erector must work closely with the general contractor or construction manager to determine the project conditions, site layout, construction schedule, and construction sequence. The type of equipment for lifting and hoisting must be determined based on the loads and site configuration. Crew productivity must be determined based on the project conditions.

Most of the erection cost will be time dependent. Labor productivity, erection duration, and equipment rental or ownership costs are highly impacted by factors which do not show up on the plans. Although there are some general industry rules of thumb for estimating productivity of the erection crew, estimating of erection is largely empirical and based on the erector's many years of experience. Generally, an erection crew may be able to erect from 10 -20 tons or 50 pieces of steel per day on a simple one crane typical building with no special conditions to slow productivity.

Crew size is generally controlled by the project characteristics and union work rules, The crew would normally include a foreman, 4-6 ironworkers, a crane operator, and a crane oiler. The crew may also include a welding foreman, welders, and weld machine operators. Labor rates, including fringe benefits, are typically established by the local union agreement or by market conditions in nonunion areas.

Safety is an important component of steel erection. Methods for maintaining fall protection, safety netting, temporary railings, temporary shoring, as well as equipment operation, personal protective devices and clothing, etc. must be established and followed. Pricing for maintaining safety must be included. Refer to Section 1.12 for a discussion of safety issues.

Costs for surveying of anchor rod locations and plumbing the structure must be determined. Anchor rod locations should be checked by the erector prior to delivery of steel in order for the foundation contractor to correct elevations and center-to-center locations prior to arrival of steel. If required by the contract, the erector may be responsible for correcting misplaced anchor rods if steel is placed on them.

The cost for erection of structural steel and metal deck represented 18% and 4% respectively of the total steel construction cost for the case study project.

2.24 Special Estimating Issues Concerning Erection

Building shape and size, site conditions, and construction sequence all have a very large impact on the cost of steel erection. Building shape and size will dictate the number and type of cranes and hoisting equipment to be used for the project. Tall structures may require the use of stationary tower cranes. Horizontal structures require the use of crawler cranes or truck mounted mobile cranes. In some instances, the general contractor may provide a climbing crane. The lifting devices may be owned by the erector or may be rented for the project. In any case, the equipment required for the project must be determined, and costs for mobilization, rental, maintenance, financing, fuel, operation and labor must be calculated from the anticipated duration of use.

The duration of steel erection will be impacted by the above factors, as well as the characteristics and complexity of the installation and connection methods used. Some of the special issues that the erector's estimator must consider are discussed below.

Connections. Field connections are typically bolted for non-moment resisting frames and may be heavily bolted or welded for moment resisting frames. Field welding generally adds to the labor cost of erection, but costs are project specific. Bolting will usually be a more economical form of erection. However, the form of connection is usually a function of the structural design and is not normally a choice that the erector controls. The estimator must keep in mind the attachment methods and the types of connections in determining the labor estimate. When welding is the specified method of attachment, the erector must weld in accordance with AWS welding standards, and must furnish and install weld material in accordance with the erection drawings.

Metal Decking. Many steel erectors subcontract with a metal deck erector for installation of metal deck. Metal deck is usually installed by welding to the structural steel; metal deck erectors may be more efficient at installing this portion of the structure, thus freeing up the steel erector's crew for installation of the main steel elements. Decks must be installed on lower floors prior to framing subsequent floors in accordance with OSHA Sub Part R, or alternate fall protection must be installed by the erector. The erector should work closely with the deck erector to coordinate the schedule and establish this lower tier subcontract pricing. Metal deck installation was installed by a separate deck erector for the case study project and accounted for 4% of the total steel construction costs.

Shear Studs. Shear studs used for composite floor deck systems are typically installed by a separate shear stud subcontractor, who also furnishes and installs them. The erector estimator will generally seek price quotations for this portion of the work and will include this cost in the overall subcontract price.

2.25 Economy of Steel Construction and Methods for Reducing Costs

There are many potential economies to using a structural steel frame. Economy begins with an efficient design and layout by the structural engineer, and can be maintained or increased during fabrication and erection by careful coordination and communication by all parties. Site layout and construction sequencing will influence equipment requirements and costs, as well as the speed of erection. Early ordering of mill steel and a well orchestrated shop drawing and approval process can yield significant savings of time and its associated costs.

In a general contract form of project delivery, the steel contractor may be limited in changing the structural engineer's structural design. However, the fabricator can influence costs through connection detailing and may be able to suggest more efficient methods for achieving the desired results. In construction management and design-build project delivery methods, the steel contractor may be in a position to provide early input into the design which may lead to more economical designs.

AISC has published a variety of documents that present design methods for steel and ways to design efficient structures. These publications, together with discussions with fabricators and erectors have been used to prepare the following list of cost-saving measures. Construction managers and design-builders can suggest the following ideas in the early design stages of the project or during concept evaluation:

1. When possible, the use of repetitive members of the same length and size will allow for easier shop drawing development and approval, and shorter shop setup, fabrication, and erection times. There may be times when increasing the weight of some members to maintain repetitivity may be justified in order to save fabrication time.
2. The use of larger column spacings and beam spans will reduce the number of connections to be fabricated and erected, as well as foundation costs.
3. The use of high strength A992 Grade 50 members will reduce member size and handling costs. This material generally is available at no increase in cost over A36 steel.
4. Continuous beams or cantilevering over the top of columns to support adjacent beam ends will reduce beam sizes and weight.
5. Simplification of connections can save significant amounts of fabrication. For example, the use of complex moment resisting frames rather than braced frames, will add significant fabrication and erection labor costs to the structure.
6. The use of Load and Resistance Factored Design (LRFD) methods in lieu of Allowable Stress Design (ASD) methods can yield savings of 3-5% for some structures, depending on the loads and layouts.
7. Simplifying the connections of attached items such as curtain walls can save labor costs.
8. Expensive finishing methods such as galvanizing or special painting requirements should be avoided when possible. The specification of special coatings will add significant cost to the project. Preparation of the surface, painting, handling, and paint touch-up, are all increased by the use of special coatings. Where architecturally exposed steel is to be used on the project, these coatings may not be avoidable. However, fabricators should be

consulted during preparation of specifications to determine the appropriate coatings and their ability to apply them. When steel is to be completely enclosed, painting may not even be necessary.

9. Early ordering of steel from the mill instead of using steel from a steel service center.
10. Steel shapes which have cost premiums should be avoided when possible. Some structural shapes, such as bent plates and tees require fabrication to achieve the shape. The use of angles instead of bent plates may save project costs.
11. Avoid connections which require extensive field welding when possible. When the design is such that field welding is necessary, connections should be designed to avoid awkward or overhead welding angles.
12. Site layout and configuration, as well as construction sequencing, are important elements in establishing the type of equipment and the time required to erect the structure. Close coordination by the erector, fabricator, and contractor in project planning for construction can increase the efficiency of the erection crew and consequently reduce erection costs.
13. The quality of the contract documents has a significant impact on the ability of the estimator to determine precisely what is required for the project. Incomplete or poorly detailed plans require the steel contractor's estimator to guess at the designer's intentions. To be protected from risk of future modifications or (bulletins), the estimator will naturally increase the price.

2.26 Published Sources of Estimating Data and Estimating References

Pricing of structural steel, like most materials, will vary with supply and demand and general market conditions; therefore, the estimator should maintain frequent contact with mills and steel service centers to obtain current pricing. Students who may not have access to actual price information could utilize the most current pricing from RS Means Building Construction Cost Data or, Walker's Building Estimator's Reference Book to obtain approximate ranges of prices for standard items. Industry sources such as Engineering News Record, published by The McGraw-Hill Companies publish quarterly or annual cost reports which may also be helpful in assessing how prices are changing.

2.27 Summary

Costs for steel construction are highly dependent upon specific steel details and project conditions. Because the structural frame can represent a significant portion of overall project costs, durations, and sequencing, knowledge of steel estimation methods is important for students interested in managing construction projects In this portion of Module Two, a discussion of the steel estimator's overall approach to estimating steel was presented. Specific items included in the fabricator's and erector's estimates were emphasized. Factors that may influence the fabricator's and erector's pricing were also addressed. Finally, methods for reducing and controlling costs were introduced.

Questions for Classroom Discussion

1. How does the steel contractor’s level of estimating detail differ from that of the general contractor? Why is it difficult for general contractors to prepare accurate detailed estimates?

2. How do project site conditions impact the cost of steel erection?

3. Give examples of detail types, materials or specification requirements that impact the fabricator’s estimate.

4. How does the source of steel for fabrication impact cost and time of the project?

5. What are the proportionate values (costs) of raw material, fabrication and erection for a mid-rise steel framed project?

6. How can a construction manager or design builder work with the steel contractor to establish useful conceptual budgets?

7.. What value engineering suggestions would you recommend for steel design and construction?

Notes