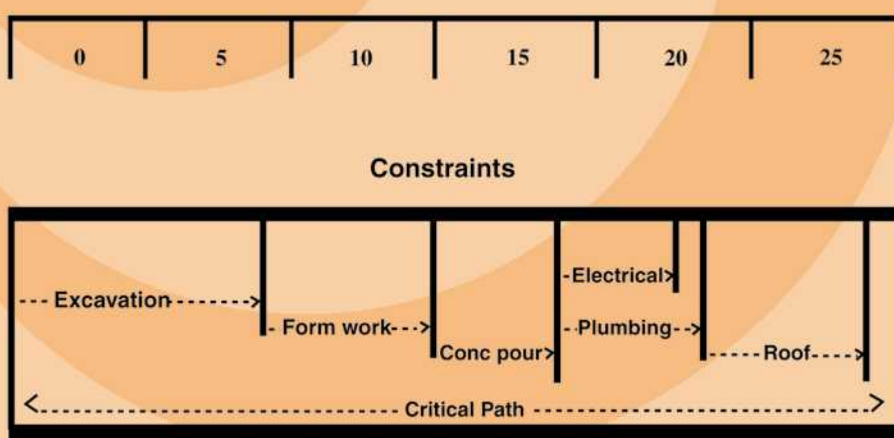
Project Scheduling Handbook



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Project Scheduling Handbook

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This book is dedicated to the 21st century American builder. The buildings that you work on and bring into existence will be a legacy lasting decades beyond your lifespan. You are constructing the buildings for our children's children. Someday you will drive away for the last time and other people will live there, but it will always be *your* house.

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Foreword

Today's builder must constantly upgrade his or her skills in order to stay competitive and take advantage of new technologies in construction techniques. Consistently, in my line of commercial construction development work, I see project owners pleased with the profitability of modern techniques of project scheduling. Times have changed, and this industry has changed too. Nowadays it seems that change is a daily part of my business. Moreover, these new technologies are in use everywhere in modern construction and one must master them to remain competitive. I say this because you, the builder interested enough to pick up this book and check it out, must realize that the entire construction industry has changed drastically from the old days and old ways, just as all businesses must change, to survive in the 21st century. This book will help you learn how to make the techniques of project scheduling work for you in future projects. What you will learn from this reference book today is real-world application stuff that you can use on the job tomorrow.

The energy present in today's construction projects makes the air feel charged with electricity. Decisions relating to expenditures of thousands of dollars are made instantly, every hour of the day. The sofa at the end wall is not for sitting on, it's for catnapping, until the action starts going 'round the clock as the completion date nears. Everywhere you look, computer terminals display computerized Critical Path Management (CPM) programs running at breakneck speed. Fast-tracking isn't just a type of project scheduling; it's a way of life when projects turn profitable. And fast-track (like all types of project scheduling) depends on fundamental, by-the-numbers checklist.

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Talk to any builder these days, and chances are he will tell you how worried he is about the big builders in town taking all the work, because he knows the large companies have greater buying power when hiring workers, buying materials, and marketing homes. Large companies also spend less on construction loans, and those that are corporations have access to stock and bond markets for fundraising, bypassing bank construction loans completely. Home building has always been a competitive business, but the structure of the building industry is fairly stable, despite some large companies' financial success and small-volume builders failing in times of recession. Small-volume builders (those starting 25 units or fewer a year) accounted for 30% of all residential builders in 1995, a share that has remained relatively constant for the last two decades. Large companies (those starting 100 units or more a year) account for 70% of all builders. Their share of housing starts edged up steadily during the last years of the '90s. The small builder has no choice anymore. To survive, today's builder must be savvy in the options in project scheduling.

For a construction project to have profitability, time is everything. Time *is* profit. Profitable use of time in project scheduling is the difference between your company's healthy income this year and being history next year. Multitrack project scheduling is one way we professionals manage to get a competitive leg up on production time. And one of the best professionals I know in next-step project scheduling is the author of this book. This edition will definitely be on my shelf and if you're serious about carving out a successful career as tomorrow's builder, my advice to you to grab a copy of this very special book in a hurry before they sell out.

Chad Simmons, President
Simmons Engineering Company
Silicon Valley, California, U.S.A.

Preface

Project sheduling and production management is one of the most profitable careers within the modern American construction industry. Although lenders, owners, contractors, developers, project teams, inspectors, designers, engineers, suppliers, and a host of others all play integral parts in the construction process, the project scheduler is instrumental in making the production schedule either profitable or a financial disaster. As a licensed and certified construction management professional for two decades now, I see this business from the inside out. Because the construction industry is so competitive, one must be both aggressive and smart to be successful.

This book/software package is unique in that it addresses the professional techniques of project scheduling as never before. The software included in the book contains the essential sorts (summary reports) of a CPM network schedule, which are integrated to provide a working network schedule incorporating program logic. You enter the data, the computer does the work. Use of this type of software program, and repeated exposure to this book, will make the reader more efficient and more marketable in professional project scheduling. The skills learned from this book can be applied by any project scheduler of production-type project execution.

In today's fiercely competitive business world, there is no room for mediocrity. Being experienced and able to do the job just aren't enough anymore. Costs of materials and labor must be bid tight, and there's not much margin there to work with. So *time*, is the only factor left to manipulate for producing profit. Accordingly, today's profits in construction projects are being made by superior modern systems of project scheduling. Even the best project planning and management cannot overcome the lack of a skillful project scheduler. In modern residential, commercial, industrial, and public works construction, it is the project scheduler who is pivotal in bringing the project into existence, *on time* and *on budget*.

The construction industry has changed dramatically in the last decades from companies that once dominated their markets by size, bidding, and bonding power to the modern, lean, downsized companies of today that use strategic personnel in definitive career positions for operations management, and contract out all the field work to licensed subcontractors. In the trades, these contractors are called *paper contractors*, because all they handle is paper. We also call them smart. No tools, no trucks, no employees. Their success formula is simple: tight bid + lower overhead = they get the job. They make the profit through fast-track production running CPM scheduling. These types of paper contractor companies are currently enjoying a large growth in the construction industry because of their efficiency in construction project execution.

I have earned my living in the construction industry from apprentice to journeyman to foreman to contractor, and I have seen many changes that foreshadow even bigger changes in the years to come as we accelerate toward the future. Of all the materials we build with today, 75% have been invented within the last 50 years. Of those, 80% were invented in the last 10 years. It is estimated that, of all the things we will be building with by the year 2025, 90% haven't even been invented yet. Graphite composite plastics that are stronger than steel, air-entrained lightweight concrete, and ultralight metal alloys are all space-age technology being used in modern construction today—and even as you read this, the clock on their obsolescence is ticking. *Paradigm* is a word that means the currently accepted parameters of any specific thing, such as an industry. The construction industry's paradigm is changing as fast as the clouds above your head. More important, as Alvin Toffler so correctly stated in his prescient book, *Future Shock*, the *rate* of that change is accelerating exponentially.

Worldwide, in residential construction, American Platform Framing is the accepted standard of excellence in homebuilding. After serving as an estimator and consultant for the insurance industry's reconstruction efforts after both the 7.6 Loma Prieta earthquake of 1989, and the 7.8 Northridge–Los Angeles earthquake of 1993, and having witnessed the devastation first-hand, I now understand why the rest of the world sends their building officials and industry representatives to the United States to learn our methods of construction.

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Contents

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1

Construction Contract Law

CONTRACT DOCUMENTS

One of the dominant factors that emphasize the importance of construction contract environments is the highly competitive nature of the construction industry today. The contract documents are the legally binding agreements and addendum among the parties of the construction project. The major difficulty in contract environments is that, on balance, the greater percentage of project delays will be the result of some kind of error in judgment of design or deficiency in the project schedule. Whether it's the failure to secure complete contract specifications information, mistakes in the contract documents, or inconsistencies on the part of the project management team, a large portion of delay claims will indicate an expensive mistake by someone.

The parties to a construction contract may be of either gender and may be singular or plural, such as individuals, partnerships, or corporations. However, traditionally, the American Institute of Architects uses singular, masculine pronouns as the accepted standard in text. Because this is the accepted legal industry standard, the author also uses this writing precedence but wishes to make absolutely clear to the reader that, although women traditionally have made up only a small fraction of construction management professionals, this fact has been changing in recent years. Because America is as big and diverse as it is, and this publisher is a marketing leader worldwide, some regional terminology needs to be clarified before we begin.

On the West Coast, the construction project team member that oversees production is called the Project Manager (PM). On the East Coast, the construction project team member that oversees the construction production is

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called the Construction Manager (CM). On the West Coast, the construction project team member that develops and oversees the project schedule is called the Project Scheduler (PS). On the East Coast, that project team member is called the Production Coordinator (PC). On the East Coast they call it wallboard, on the West Coast we call it drywall. The list goes on and on. Logically you understand, we construction management professionals do this just to confuse people starting out in the business and keep all the work to ourselves. Regardless, this book is written in West Coast terminology.

Construction contract law is a mirror of financial reality. If you want to see how the liability in contract law works, just watch where the flow of money goes. Money is the yardstick of both authority and responsibility, and in "lawyerese," responsibility means liability. There are various levels within the construction project's chain of command. Any person or organization with a financial interest in the project is called a *vested party*. Any contractor who works on the project has *lien rights*. The first, or primary, level in the chain of command consists of the vested parties in the project, and the top slot here starts with the generator of funds, usually the bank. This entity financing the project heads the pyramid. Next come the owner and the project team, consisting of the designer or architect who drew up the plans, followed by any registered engineers who were consulted on a commission basis regarding structural design analysis.

These primary parties, such as the architect or engineers, may have subcontractors or consultants who would be junior to them in authority. Next comes the project manager, who may be one of these engineers or may be a construction management professional from another field. These parties may also have subcontractors or consultants working for them. Then comes the project scheduler, followed by the site superintendent, and then field personnel. The project team assistant staff finishes out the primary chain of command in construction contract law.

The secondary level of chain of command in the project includes the workers who improved and built the project. These are lien holders, starting with the general, or prime, contractor, then followed by the subcontractors. The third level in the chain consists of the equipment and material suppliers of the subcontractors. These parties are also vested in the project by their lien rights, which provide for legal grounds of foreclosure in the event of nonpayment. In essence, the subcontractors and suppliers are extending credit to the project and hold what is legally termed "a cloud on the title," which are foreclosure rights in the event of payment default, just as with a mortgage company.

By the time a construction contract has been executed, the owner has already taken full advantage of the available competition to get a low price for work that is shown and specified. The prime contractor is normally responsible for meeting "job conditions," but only up to a point. That point is when a "request for information" (RFI) or a "request for clarification" (RFC) becomes ambiguous as to the degree of additional work that is beyond what was anticipated and that results in extra cost and time. The contractor had to assume the most competitive method to construct the unclear details to get the job, that is, to bid on what is shown and not price what is not shown. This practice eats up the prime contractor's profit in no time. This classic architect–contractor separation is clearly stated in the disclaimer of AIA Document A201, *The General Conditions of the Contract for Construction*, which states, "The Contract Documents shall not be construed to create any contractual relationship of any kind between the architect and the contractor."

So construction contract documents always begin with the financial bond and written contractual agreement between the owner and the project's design professional. This contract agreement details the plans and specifications of the project's construction. These two entities are the first two of the project's vested parties. Two major professions are further within the design disciplines: the architect and engineer. Engineers are then further broken down into structural or civil disciplines. In the construction contract environment, architectural services usually extend beyond the phase of the building's design and the production of plans and drawings. An equally important contractual task of the architect begins after the owner has approved the building design, cost estimates, and project schedule.

Upon approval of the plans and specifications, the architect incorporates his or her design into the package of articles termed "contract documents." These documents are a collection of related drawings, plans, specifications, legal notices, and contracts contractors use to bid on a project. The drawings, plans, and specifications must be in compliance with the building code in the jurisdiction where the project is located. The architect normally also presides over the bidding, assists in selection of a bidder, and aids in establishing contracts between the owner and the contractor. The architect, in essence, becomes the agent of the owner. The final and equally critical service the architect provides is overseeing the construction of the project. This includes the interpretation of the contract documents when necessary, assisting the prime contractor in his dealings with the owner, and ensuring that all contracts are being expedited in accordance with the plans and specifications and that all contractual obligations have been satisfied by all parties to the contract.

An architect's drawings are the main source of instruction for construction of a building and serve as the basis of the contract documents. The more specific and detailed the drawings are, the fewer the problems that develop during construction. Drawings must be complete, comprehensive, and clear so the architect, owner, and builder can have a basis for contractual understanding. Architectural drawings are of two general types: those used in discussion with the customer, and those used by people who construct the building. The first group consists of preliminary sketches (for discussion) and display drawings (for conveying the design to the public). The second group, often called "working drawings," gives engineers and contractors plans to work of off on the job site.

In working drawings, schedules are lists of specifications for details that recur, or repeat themselves, in a project. Equipment schedules have no connection with a planned time sequence (which is the usual meaning of the term "project schedule"). All windows and doors are typically listed in specification tables on drawings, with each opening numbered on the drawing and in the table. Because the specifications for framing and finishing may vary from one opening to another, it is more practical to table the data for each. Contract documents include a full set of construction drawings and plans that include various types of drawings. Normally, a set of drawings for new construction will include the following plans: site plan, plan view, cross sectionals, foundation plan, floor plan, elevations, and mechanicals.

Legally, contract documents refer to all the documents that are part of a construction contract. Generally, construction contracts can be broken down into three categories, though they are not necessarily arranged in the same order on each job. These categories are as follows:

Part I: Bidding and Contractual Documents

Notice of invitation to bid
Instructions to bidders
Proposal bid forms
Bid sheets
Contractor certificates (licensing and surety bonds)
List of subcontractors
Bid bonds
Noncollusion forms
Agreement contract
Performance bonds
Payment bonds

Part II: Conditions of the Contract

General conditions
Supplementary general conditions

Part III: Specifications and Specifications Addenda

Architect or design professional herein provides technical sections covering the various parts of the project

Each of these items has further details, but an in-depth examination of each is beyond the scope of project scheduling responsibility and falls instead in the lap of the owner and project team. The architect or design professional is responsible for supplying technical specifications as well as the design plans. These contract specifications and their addenda are added to the contract's general conditions to explain in detail the various responsibilities of the architect or design professional regarding the review and approval of shop drawings, as well as the parameters of design to production liabilities. Contract documents include all this information to prevent unclear or incomplete details specifications from causing delays in the project schedule.

For the purposes of project scheduling, reviewing the general conditions, specifications, and specifications addenda is a critical step to ensure contingent activity workarounds and that long-lead items do not burn up valuable float time, thereby placing the project's completion date in jeopardy. Prime contractors also need to function within the general conditions responsibility as they subcontract to the related activities subcontractors for each contract specification, per plans and specifications.

Architect Responsibility

Upon building department approval of the plans and specifications, the architect incorporates his or her design into the package of articles that then becomes the contract documents. As stated previously, these documents are a collection of related drawings, plans, specifications, legal notices, and contracts all contractors use to bid on a project. Any deviation from the contract production schedule is cause for a construction claim for the owner, architect, or builder. These are countered by a change order in the construction contract that is generated and paid for by the owner. In reality, it's usually the contractor versus the owner/architect team. This is why: The architect normally also presides over the bidding, assists in selection of a bidder, and establishes contracts between the owner and the contractor. The architect, in essence, becomes the agent of the owner.

The final and equally critical point to understand here is that the architect provides overseeing of the construction of the project. This includes interpreting the contract documents when necessary, assisting the owner in his dealings with the contractor, and ensuring that (1) the contractor is expediting the project schedule in accordance with the plans and specifications and (2) that all contractual obligations have been satisfied by the contractor.

Once assigned as his or her agent by the owner, the architect assumes what is called *agency of representation*. This means the architect speaks for the owner in decision making and has the power to authorize expenditures, or incur debt, on behalf of the owner.

Engineer Responsibility

During the construction planning process, an architect may retain consultants to supplement his or her own skills and to deliver a more complete, well-coordinated service to his or her client. The architect is trained in the integration of building systems (i.e., structural, mechanical, electrical, etc.) and has basic knowledge and design skill in each of these areas. However, on structural or geotechnical problems he or she will rely on the design capabilities of specialists in these engineering areas. In some architect offices, the engineers are placed on retainer or under contract for services. In large offices the staff usually includes one or more of these design professionals in a variety of disciplines.

The major distinction in construction law between architect and engineer runs along generalist and specialist lines. Each is a true professional, certified and licensed through examination. The engineer, however, is focused on an exhaustive study of a single technical area such as structural, civil, geotechnical and soils, or mechanical engineering. Both these design professionals have a contract authority the project scheduler should know.

Contractor Responsibility

There is usually any number of ways to complete a given project. The original bid will likely anticipate one reasonable sequence of construction that is apparently achievable, given the technical and time requirements. Assuming proper design workability of the architect's responsibilities, the contractor is to anticipate the various components that will eventually make up the total project. Their constraints and interrelationships will be determined, and the project planning will be completed. Time tables are then developed, and the calendar is imposed to transform the plan into a project schedule. Besides the strict technical requirements of the work itself, responsibilities of contract execution by the contractor will generally fall within these following 13 categories:

1. Duty to inquire
2. Reasonable review
3. Plan and schedule the work
4. Lay out the work
5. Supervise, direct, and install the work
6. Adequate workmanship
7. Correction of patent errors
8. Coordination of all parts of the work
9. Review, submit, and coordinate shop drawings
10. Contract payments

11. Adequate insurance
12. Adherence to safety standards
13. Warranty of clear title

Owner Responsibility

Disclaimers of owner responsibilities and warranties are frequently found in many contracts. While these must be clearly understood if they do exist, they may often be overly ambitious in their attempt to shift the owner's responsibility onto the contractor. Owner responsibility disclaimers should, therefore, be scrutinized very closely. When not barred from a specific contract, the law imposes several warranties, duties, and responsibilities on the owner, whether or not they are specifically highlighted in the contract language. They include

1. Using sound discretion in evaluating the qualifications of low bidders
2. Maintaining and preserving the bidding system integrity
3. Funding the work
4. Providing all surveys describing physical characteristics on the site
5. Securing and paying for easements and authorizations
6. Warranting the adequacy of the plans and specifications
7. Warranting the suitability of furnished materials
8. Disclosing superior knowledge
9. Offering prompt action on clarifications (RFC) and change orders
10. Providing final interpretation of the documents
11. Cooperating
12. Assuming ultimate responsibility for the design professionals

General Conditions

"Boilerplate" is a nautical term that refers to the strong, often thick material (usually steel) that forms a pressure vessel, such as a boiler. In a construction contract, the general conditions are like boilerplates that provide containment precedence for dispute resolution among the parties of a project, by anticipating most of the areas of discussion or dispute that might arise and providing for an orderly method of resolving each case. In construction contracts, the general conditions serve to boilerplate the vested interests of the owner and lender, by providing prearranged avenues of precedence in order to keep the production in motion during times of dispute resolution. Every liability, possibility, and probability is identified, critically analyzed, and prepared for. Contingency planning, insurance policies, and bonds are obtained as collateral for every dollar of investment in the project.

In addition to the working relationship provisions they contain, the contract's general conditions are not limited to the production portions alone. Typically, all things that are bound into the contract's general conditions are considered part of the primary contract document. These include the bid bonds, agreement contracts, performance and payment bonds, and conditions of the contract. By law, construction contracts encompass general conditions, plans, relative contract documents, specifications, and the technical specifications addenda.

CONTRACT SPECIFICATIONS

Contract specifications are not limited to the technical portions alone. Typically, everything contained within the specifications document(s) is referred to as "the specifications." These may include the notice of invitation to bid, the bidding documents, bid bonds, agreement contracts, performance and payment bonds, noncollusion affidavits (where applicable), conditions of the contract, technical provisions of the contract, and provisions of the contract project schedule. If you encounter plans calling for a book of standard specifications by reference, this may signal a specifications writer who was not proficient at detailing specifications. Use caution here. Every construction manager, project scheduler, contractor, and inspector who has some years in the business has encountered contract specifications that were questionable at best. (I'm being generous here because this is an understatement. Construction professionals will tell you that specification writers are not always knowledgeable in all the subjects they are writing specifications for. Sometimes they're just flat wrong.)

If the responsible subcontractor does not catch an error in the specifications before the work is done, the project schedule will be pinched by the dispute resolution necessary to resolve the situation. It happens and is one of the things you need to be aware of that can stall an otherwise viable project schedule. A comparison of the finish schedule with the specification index will expose potential duplications and/or omissions. It will indicate whether the design process was completed in an organized and sequential manner, or put together by different people who never worked together. Any discrepancy discovered in this review would be fairly obvious.

Comparison of the specifications to the finish schedule includes analysis of the schedule's headings against the categories included in the technical specifications. You're looking to confirm that each item is noted and accommodated in the technical specifications and that each item is included only once. Should any discrepancy or duplication be discovered, the architect or design professional must be immediately notified of the error. Some design professionals have tried to limit the extent of their liabilities by including exculpatory clauses in the specifications addenda, which usually read something like this:

> Plans and specifications provided are complimentary. The contractor is responsible to provide all work shown, whether or not adequately described in these specifications, and all work described in the specifications, whether or not specifically indicated on the plans, to code compliance and current accepted workmanship standards.

If you see something like this in the specifications addenda, cringe. You're reading what project managers call a "weasel clause." The design professional was not an expert in that technical specification and/or didn't research it thoroughly enough. And if it wasn't worked out in the design process, the only other place it can be worked out is in the field construction, blowing your production milestones and costing lots of money.

Specifications and their addenda are needed in the contract documents to provide comprehensive technical explanations of production systems and their function. They must be complete for the production process to flow smoothly. If there is an absence of clear definition and delineation of these responsibilities, claims and lawsuits are the outcome. As a member of the project team, the project scheduler needs to be aware that the courts have held that the basic design responsibilities listed below are considered the architect's contractual obligation, whether expressed or implied, within the contract specifications or specifications addenda:

Code compliance
Technical accuracy of all documents
Production of all plans and specifications
Specific design (not to be substituted for design criteria)
Interpretation of the documents
Standard workability of design, as per specs
Shop drawings submittal review and approval
Prompt and timely response in review approvals so as to not delay work
Evaluation of the work
Due diligence in judgment and professional expertise

In addition, the courts have held that the first responsibility of the design professional is to indicate clearly and completely all work in sufficient detail, on the plans and specifications, as to adequately describe the parameters of each specification. So this ultimate responsibility to comprehensively and adequately describe each construction specification lies with the design professional who generates the plans and specifications, regardless of any exculpatory clauses. Disallowing such clauses, the courts have held that design professionals are ultimately responsible for technical specifications and

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their related responsibility identification. The field contractors send requests for information (RFI) from the job site back to the designer for anything overlooked or incomplete in the specifications. When too many RFIs are sent back to the architect, that signals to any experienced developer that it's time to hire another architect on the next project.

Remember that specifications are not limited to the technical portions alone. Typically, everything contained in the specifications document is referred to as the specifications. These may include the notice of invitation to bid, the bidding documents, bid bonds, agreement contracts, performance and payment bonds, noncollusion affidavits (where applicable), conditions of the contract, and technical provisions of the contract. Contract documents, by law, encompass plans, relative documents, and specifications.

SHOP DRAWINGS

Shop drawings are detailed blueprint and schematic drawings that describe how a subcontractor plans to install and/or manufacture the project's equipment components that relate to his specific activity. They are prepared by the activities' subcontractors and suppliers and are used in the contract to show how their installed equipment and work will meet specifications established by the structural engineers and the architect.

Under the most common arrangement in current contract conditions, the prime contractor (or project manager) and the architect share the responsibility for shop drawings review. The shop drawings reviewed by the prime contractor reveal if the equipment to be installed and the work to be done will meet the design criteria. The prime contractor then stamps them with his approval and sends them for processing to the structural engineers and architect. These design professionals will then also review and approve the shop drawings and return them to the prime contractor. In doing so, the design professionals authorize the work to proceed in the manner detailed in the submitted shop drawings, or corrections needed to be resubmitted.

It is at this point of contractor–designer reviews that areas of responsibility must be made clear to all parties. If these contractor and designer responsibilities are not spelled out in the contract conditions, the lack of responsibility will delay the shop drawing approval process. Each party will be free to decide for itself how much responsibility it wishes to absorb. Obviously, the answer is as little as possible. Often, the subcontractors include less information than the designers require. The design professionals then return the submitted shop drawings to the prime contractor for correction and withhold authorization to proceed pending additional shop drawings.

The same condition exists with the design professionals, in that they also wish to limit their professional liability and attempt to narrow the scope

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of their shop drawings reviews in the contract. The combination of both parties' shirking responsibility contributes to substandard shop drawings. This leads to increased confusion among all parties, resulting in exactly the opposite effect—the assumption of even more liability. The courts have held that it cannot be argued that the contractual roles of the structural engineers or the architect are in an evolutionary phase created by changing contract structures. The legal precedence here is that the design professional's responses can compromise the thoroughness and attention to detail necessary for public safety in using the construction. Prime contractors often try to place much of the burden on the design professionals. This, in turn, invites confusion and substandard construction, ultimately leading to dissatisfaction at every step of the process. Historically, this effect increases liability for both the design professionals and the prime contractor.

The architect is normally responsible for approving shop drawings and reviewing them for their conformance with the original design concept. The difficulty lies in the fact that there seems to be no clear or consistent description of precisely what the designer's responsibilities in the shop drawing review and approval process include. To make matters worse, some design firms treat the shop drawing approval responsibility with less importance than it truly deserves. While it may be true that many designers do understand the critical nature of information incorporated in shop drawings, and treat them with respect and proper attention, some do not. Time and expense pressures in some design offices create a temptation to assign the shop drawing review task to a junior member of the staff, with lesser experience in such matters.

In this case, the likelihood of errors in detecting deviations from conformance with the original design concept increases. This lack of clear definition and assumption of approval responsibilities has left many design offices, and their respective liability insurance companies, practically determining for themselves what their responsibilities will include. In addition, many architects and engineers have attempted to limit their liabilities by avoiding the use of the word "approved" in their shop drawing remarks altogether. Contract conditions phrasing like "No Exceptions Taken," "Furnish as Submitted," "Examined," or the real cute one currently making the rounds, "Not Rejected," have now become the rule rather than the exception. Moreover, the shop drawing stamps have been supplemented with elaborate language explaining what is and is not being done, in an effort to define the review process and minimize the design professional's liability.

There is legal opinion, however, that supports the idea that the designer's stamps may actually increase his liability if their contract obligations for shop drawing review exceed the limits of the language included on the stamp. The owner and contractors rely on the designer's approval responsibilities as defined in the contract. If a designer operates in a narrower view as defined in the loose language on a stamp, it is a clear admission that the designer is doing less than he or she is contractually obligated to do. The courts have upheld that expostfacto language in review stamps do not relieve public safety concerns in contractual obligations.

Beyond the basic designer/contractor approval responsibility clarification, another project scheduler's concern regarding shop drawings is designer response time. Common language in construction contracts notes that a designer will "review and approve shop drawings with reasonable promptness so as not to cause a delay in the work." "Reasonable response" is another term that lacks precision. "Reasonable" becomes defined by trade practice in the project's geographic location. If nothing better is available in the existing contract language, establish the definition of "reasonable time" at the very first job meeting. Ten working days (except in unusual or adverse conditions) is standard. It's always best to pin it down early.

To emphasize the precise requirement, indicate on each submission transmittal the exact response date that approval of the respective item is required by before the project is impacted. A review of the specifications may establish the procedures for shop drawing submissions. Is there a special stamp required with the project name, and other identifying data that must be used on each shop drawing submission? If so, the stamps will have to be procured. How many copies of shop drawings are required for submission? How many copies of product data or equipment catalog sheets are required for submission? How are samples to be handled? Are all the types of shop drawings to be sent to the architect, or will structural drawings be sent directly to the engineer with an information copy only to the architect? All these procedures should be clarified in the contract general conditions.

LONG-LEAD ITEMS PURCHASE ORDERS

Give attention to the longest delivery items (long-lead items) on the schedule to see which ones fall on the critical path. If there are several large field-erected items with varying completion dates, you might even break the most important item into individual activities to track the latest one on the project schedule. The same critical analysis applies to time-critical subcontracts.

Control in the project schedule requires that long-lead items have their purchase orders confirmed in advance by all associated subcontractors. Purchase order copies should be supplied by subcontractors and suppliers, in advance, to the project scheduler, to maintain adequate lead time between ordering and confirming the order in the project schedule along with delivery within critical event windows in that activity. When shop drawings are sent to the architect or engineer, a note should be entered on the accompanying transmittals, indicating whether any are to be expedited or if there is an order of importance. The project manager must monitor the shop drawing log from time to time to make sure that the drawings are being cycled in a timely manner.

The shop drawing log should show what action has been taken on each drawing when the drawing is returned. Although the transmittals forwarding the copies and the transmittals accompanying the returned drawings will be the documents of record, the shop drawing log will highlight the activity. The log should contain a column showing the disposition of the drawings after the designers have reviewed them. If any drawings were disapproved, they would probably be returned to their originator. If approved, they will be distributed to their originator, with copies to any concerned subcontractors, a copy to the field, and one for the office file.

LEGAL ASPECTS OF THE PROJECT SCHEDULE

The courts historically have not used consideration of time in project schedules as affecting judgments in construction litigation lawsuits. This is due to the tendency in the last couple of decades for frequently delayed construction projects to end up in extremely expensive litigation. Timely completion of the project schedule depends on proper performance by the many participants as well as optimal conditions for performance, such as weather or union labor strikes. Today, with all the utilities and fiber-optic mainline cables buried underground along with God only knows what else, encountering any unanticipated subsurface conditions is the kiss of death. Inspections, excavations, and soil remediation are just a few of the costly delays that can result. Delayed performance due to encountering unanticipated subsurface conditions has been held by the courts to be invalid grounds for termination of the contract. This means the owner and project team continue to eat it financially. Delayed performance is also unlikely to create legal justification for the owner's refusal to pay the contractual compensation. At this point, the owner is typically left with inadequate damage recovery. Insurance policies, and bonds to protect damage recovery in such cases, are extremely expensive and typically put the project out-of-budget and therefore make it not viable.

Similarly, delayed payment by the owner is less likely to automatically give the contractor a right to stop the work or terminate its performance. Finally, a strong possibility exists that a performance bond that does not expressly speak of delay will not cover delay damages. These damages will then be contested, and it falls to the project scheduler to prove the validity and job logic of the project schedule. Computation of delay damages is also different. If the owner does not pay or the contractor does not build properly, measuring the value of the claim is, relatively speaking, simple. If the owner does not pay, at the very least, contractors are entitled to interest. If the contractor does not build properly, the owner is entitled to the costs of correction or the diminished value of the project.

Delay creates serious measurement problems in project schedules. The owner's basic measure of recovery for unexcused contractor delay is lost use of the project. The contractor's basic measure of recovery for owner-caused delay is added expense. Lost use is difficult to establish in noncommercial projects. Added expense is even more difficult to measure. Because of measurement problems, each contracting party, whether it pictures itself the potential claimant or the party against whom the claim will be made, would like a contractual method to deal with delay claims, either to limit them or to agree in advance on amounts. This does not mean that time is not important in construction. The desire to speed up completion, due to money investment pressures, is what employs the professional project scheduler.

Traditionally, two schedules are initially purposed for any project. The general contractor supplies a version suited to his company's timing for profit, and the owner supplies one suited to his timing for profit. The key factor for these two schedules to merge successfully is how close each is to the critical design, procurement, and construction of all aspects of the project. Once the schedule is completed, it needs to be "cooked." This term means a critical analysis of the schedule by the project scheduler and the construction manager. At this point, the schedule is debugged by using "what-if" scenarios through the critical paths of production. These first editions of the schedule are generalized overlays, called "macros." Macros are then redesigned to reflect sequential activities' interdependencies and events time scaling. Important events and individual phase completions are noted as milestones.

Owners typically tend to be overly optimistic about all activities happening with no problems, their project schedules showing an unrealistic and often unachievable project completion date. On the owner's schedule, activities are strung together in a tight series, with each activity's closing event also being listed as the starting event for the next activity. In this type of configuration, all activities lie on one critical path. This makes for a network diagram with little or no flexibility in scheduling float allowances, which is the primary area in which a project scheduler makes adjustments. Contractors' schedules, conversely, show free float time in their subcontractors' related activities to serve their own work schedule, usually with no free float linkage to overall project total float. Obviously, neither of these two schedules will be adequate.

What invariably happens in a real-world field application is that the initial activities burn up all available total float, and any emergency float time is then borrowed from the succeeding activities, leaving little or no float time along the critical path. This always results in the condition of production and cost overruns, because contractors do not want to lose the bid and will often accept an unrealistic deadline, hoping that they can pull a rabbit out of the hat somewhere along the line.

AIA Document A201, Section 3.10.1, requires the contractor to submit its construction schedule for the information of the owner and the architect. The schedule must provide "for expeditious and practicable execution of the Work." The contractor's failure to conform to the most recent schedule constitutes a breach of contract under Section 3.10.3. Contracts prepared by experienced public or private owners, particularly private owners under the influence of their lenders, usually prescribe much greater detail and take greater control over the contractor's schedule.

This condition can manifest itself in language requiring that the project schedule be on a form approved by the owner or the owner's lender; that each monthly schedule specify whether the project is on schedule (and if not, the reasons why); that monthly schedule reports include a complete list of suppliers and fabricators, the items that they will furnish, the time required for fabrication, and scheduled delivery dates for all suppliers; and that the prime contractor hold weekly progress meetings and report in detail as to project schedule compliance.

Similarly, the Engineers Joint Contract Documents Committee (EJCDC) takes progress much more seriously than does the AIA. For example, the EJCDC's Number 1910-8, Section 2.6, requires the contractor to submit, within 10 days after the effective date of the contract, an estimated progress schedule, a preliminary schedule of values, and a preliminary schedule of submittals. The finalized schedule must be acceptable to the engineer, and Section 6.6 requires the contractor to submit, for acceptance, adjusted progress schedules. The approved finalized project schedule becomes a contract document. For more details on EJCDC contract standards, see Appendix C.

OUTSIDE DELAYS

Referring to Fig. 1.1, you will find that the daily field reports have columns for weather delays. An inclement weather system passing through your area that turns out to be a toad floater will also delay outside activities, such as excavation, grading, paving, and placement of concrete. These are considered constraints of practical limitations and must be factored as such in the project schedule.

The reasons are twofold. First, time cushions must be installed within total float, to provide allowances in practical production parameters. And second, AIA Doc A201, Section 4.3.8.2 (which is the section dealing with claims), requires the contractor to document "by data substantiating that weather conditions were abnormal for the period of time and could not be reasonably anticipated" before the contractor can receive a time extension

Your Company Name Here — **Daily Field Report**

Prepared For:	*Your Client's Name Here*		
Project:	*Project's Name Here*	Page: 1 of	
File Name:	*Your Computer File Name Here*	Data Date:	*Date of Report Input*
Description:	*Project Description Here*	Run Date:	*Printout Date of Current Copy*
Our Invoice:	*Your Company's Job Number*		
Client Invoice:	*Owner's Job Invoice Number*		

Date:	*Today's date*	**Temp**	*Begin/End*	**Critical or Principal Activity Completed:**
Phase #:	*Phase project is in*	**Wind**	*Dir/mph*	
Filed by:	*Site Supervisor preparing field report*	**Sky**	*Clr/Cldy*	
		Precip	*% Rain*	
Visitors:	*Visitors to the site today (other than regular workers)*			
Reason for Visit:	*Why are they here?*			
Work Force:	*Who were the labor force present today?*			
classifications:	*What were their project's employment classification?*			
Activity performed:	*What was done by each of the above?*			
Equip on-site:	*What equipment is on-site today?*			
Equip work performed:	*What was done by each of the above?*			
Items received:	*Items received at jobsite today*			
Items sent:	*Items sent from jobsite today*			
Location of work performed:	*Where exactly in the project this work was done*			
C.O. number:	*Change order numbers if any*			
Problems:	*Problems or delays encountered today by Site Supervisor*			
Comments:	*Solutions proposed by Site Supervisor*			
Copy to:	*Project Manager* *Project Scheduler* *Owner*			

FIGURE 1.1 Daily field report.

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for weather conditions. Section 4.3.8.2 further requires that the contractor document that the weather conditions "had an adverse effect on the scheduled construction."

The overall precedence concerning project schedule delay is found in AIA Doc A201 Section 8.3.1, which states

> If the Contractor is delayed at any time in the progress of the Work by any act or neglect of the Owner or the Architect, of an employee of either, or of a separate contractor employed by the Owner, or by changes ordered in the work, or by labor disputes, fire, unusual delay in deliveries, unavoidable casualties, or any causes beyond the Contractor's control, or by delay authorized by the Owner pending arbitration, or by other causes which the Architect determines may justify delay, then the Contract Time shall be extended by Change Order for such reasonable time as the Architect may determine.

This section delineates the parameters of acceptable and enforceable delay claims submitted by the contractor. These requirements can make it difficult for a contractor who does not keep detailed weather records to claim a time extension for adverse weather conditions. They reflect the AIA's belief that weather generally is a risk assumed by the contractor and that only in extraordinary circumstances should weather be the basis for a time extension in the project schedule. The legal documents the courts use to determine judgments in weather-related claims are a Daily Inspection Report (DIR) and a Quality Assurance Report (QAR). If the contractor or owner is unaware of these documents, then certainly you, the project scheduler, should be. And you should implement them on your client's behalf to protect your schedule.

Another reason for not granting a time extension is the single contract system's objective of centralizing administration and responsibility in the prime contractor. Only if subcontractor-caused delay is specifically included should it excuse the prime contractor. This needs to be stated within the contract specifications to protect your project schedule's default through circumstances beyond your control. The independent contractor rule, though subject to many exceptions, relieves the employer of an independent contractor for the losses the latter wrongfully caused.

Prime contractors assert that subcontractors are independent contractors because the subcontractor is usually an independent business entity and can control the details of how that activity is performed. Even so, the independent contractor rule does not relieve the employer of an independent contractor when the independent contractor has been hired to perform a contract obligation and, under that employer's direction, the party suffering the loss caused by the independent contractor is the party to whom the contract obligation was owed.

Another portion of contact law affects the project schedule, and that is AIA Doc A201, Sections 4.3.3 and 4.3.8.1, which cover time extensions in construction contracts. These usually provide a mechanism under which the contractor will receive a time extension if the project is delayed by the owner or by designated events such as those described in the contract specifications. Increasingly, contractors make large claims for delay damages. As a result, it is becoming even more common for clauses in public works contracts to attempt to make the contractor assume the risk of owner-caused delay.

Public entities are limited by appropriations and bond issues, so they must contract in advance for the full cost of the project. To do this, many public entities use the disclaimer system for unforeseen subsurface conditions. Similarly, they wish to avoid facing claims at the end of the project, based on allegations that they have delayed completion or required the contractor to perform its work out of sequence. Repeated here for ease of reference are the management techniques for limiting delay claims in a project schedule.

The *first* management technique is to require written notice by the contractor to the owner or project team if any events have occurred that later will be asserted as justifying delay damages. This method currently takes preference in the industry, as it provides warning of potential claims in time for someone to do something about the situation in the mediation dispute-resolution stage, and resolve it at the activity level. Typically, this notice is stated to be a condition precedent to any right to delay damages. Historically, although the courts have not looked favorably on such issues, noncompliance with a notice provision can be the basis for barring a claim for delay damages, and because it's a contractual obligation it can "bulletproof" the situation as well as is currently possible without undue and unjustifiable constraint on the contractor.

The *second* management technique is to deny the delay damage problem outright by not setting up notice conditions or specifying what can be recovered. The method is to configure the contract with no-damage or no-pay-for-delay clauses. Such clauses attempt to place the entire risk for delay damages on the contractor, and to limit the contractor to time extensions. Generally, such clauses are upheld but not looked on favorably by the courts and much less by contractors. A current modification on the "no-pay"or "no-damage" provision clauses is to provide that the contractor can recover delay damages only after a designated number of days delay by the owner.

LEGAL NOTICES

During the project schedule's timeline, certain legal notices must be filed and tracked. The primary reason for this is litigation protection from nonpayment of services. When an activity subcontractor is not paid by your project's prime contractor, that subcontractor can file a mechanic's lien and/or stop notice at any time after ceasing to perform labor or furnishing materials, and until 30 days following the notice of completion or issuance of a notice of cessation. A prime contractor, on the other hand, if not paid, can file a mechanic's lien within 60 days after notice of completion or issuance of a notice of cessation. Let's look at each legal notice closely.

Notice of Completion

The project owner normally files a notice of completion within 10 days after the project is completed. This legal notice restricts the number of days within which a contractor can file a lien against the property. This should also equate to a milestone in the project schedule that marks the ending event of the project production and the starting event on project closeout. Once this is filed, contractors should do no more work. The courts have held the criteria to determine the completion of work to be

1. The occupation or use of a work of improvement by the owner
2. The acceptance of work by the owner
3. If there has been a cessation (stoppage) of labor on the job for a period of 60 days without a notice of any kind being recorded which constitutes a legal completion

Notice of Cessation

This is the legal notice used if, for any reason, the job has been stopped because of a union strike, trucking strike, labor dispute, labor shortage, or a similar reason. It cannot be recorded until there has been a cessation of labor for 30 days, with the exception of force majeure.

Notice of Nonresponsibility

A project owner files this notice in a conspicuous place upon the property within 10 days after obtaining knowledge that work that was not ordered is being done. This notice must also be recorded with the county recorder in the area of jurisdiction wherein the property is located, giving notice that the owner will not be liable for any accident or injury that occurs.

Preliminary Notice

Preliminary notice is a contract document filed by subcontractors and suppliers within 20 days of beginning their activity on the project. On residential and commercial jobs, preliminary notice is sent to the lender, the owner, and

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the prime contractor by registered or certified mail, or is delivered in person. On public jobs, notices are sent to the awarding authority representing the public agency and the prime contractor. Preliminary notices are filed to establish the subcontractors' and suppliers' rights of lien and stop notice. Although no company may file a lien on a public works job, because the property in question is public property and cannot be liened, subcontractors and suppliers on public works jobs do have stop notice rights in the event of delay in progress payments. However, if preliminary notice is filed late on a public works job, all stop notice rights of the contractor are lost.

Subcontractors and suppliers must file preliminary notice within 20 days of their beginning work on their specific activity within the project schedule. Therefore, it is mandatory that every contractor doing any activity within your project schedule, with the exception of the prime contractor, give its notice not later than 20 days after it has first furnished labor, services, equipment, or materials to the project's job site. The prime contractor does not give a preliminary notice, due to the fact that its contract with the project owner is the first (or prime) contract and serves as preliminary notice.

The purpose of preliminary notice is to notify those vested parties of the project who never have a direct relationship with (and often never see) the activities subcontractors who do the work. One of your bar sorts should track submission of these legal notices, and one of your timeline sorts should track their time tables. Contract law statutes require that if any work is done by any of your project's subcontractors for over $400, the subcontractor be subject to disciplinary action by the Contractors License Board for not filing this legal notice. If notice is given later than 20 days on a private job, the contractor may not recover the value of work done at more than 20 days of his activity construction from the date of the notice. Lien rights are lost as to anything furnished more than 20 days before serving of the notice.

An activity subcontractor not having a direct contact with the prime contractor, other than a laborer, must, as a necessary first step to the validity of his stop notice rights, give a written notice to the contractor and the public body (awarding authority) concerned, within 20 days after he has first furnished labor, services, equipment, or materials to the job site. This notice takes the form of preliminary notice. Contrary to the law on private jobs, if the claimant on a public works job lets the first 20 days of activity work elapse without filing preliminary notice, the said contractor loses all stop notice rights forever. But that contractor still has a legal right of action and can sue against the bond and the bonding company, since all public works jobs are bonded. These public works bonds protect all those involved in the project construction from nonpayment for their services.

A 90-day public works preliminary notice is necessary to enforce a claim on a payment bond on public works jobs. It is required in public works projects by subcontractors and suppliers to the prime contractor, within 90 days after furnishing labor, materials, or services.

Mechanic's Lien

A mechanic's lien is a lien upon the project's real estate to secure the compensation of those who have been directly instrumental in the improvement of such property. This is a critical factor of final payment for the services of a professional project scheduler in that, should the project go over budget and contractors or materials suppliers not be paid in a progress payment, mechanic's liens filed may halt the production process. The project may wind up in litigation, and your invoices for your services may go unpaid. In such a case, if you are an outside-service-contracted scheduling consultant, you may need to file a mechanic's lien to secure payment for your services.

Wage earners do not have lien rights, but materials suppliers, contractors, and laborers have a lien upon the property upon which they have bestowed labor or furnished material for the value of such labor done and materials furnished. The legislature provides, by law, for the speedy and efficient enforcement of such liens. Mechanic's lien law is of particular interest to all persons in the building and construction industry, in as much as the value of labor performed and materials furnished to any building or construction project are debts, the payment of which can be secured by a lien binding the real property as security for the value of the labor performed and materials furnished.

A suit to perfect claim of lien, or *lis pendens* in lawyerese, binds the real property for the value of the labor performed and materials furnished similar to the manner in which a mortgage or deed of trust secures the payment of a loan or note.

A claim of lien means a written statement, signed and verified by a claimant or his agent, containing all of the following:

A statement of his demand after deducting all credits
The name of the project's owner or reputed owner, if known
A general statement of the kind of labor or materials furnished
The name of the owner, or developer, by whom he was employed
A description of the job site sufficient for identification

A claimant is one who has made any site improvement at the request of an owner or his agent (architect, engineer, prime contractor, etc.) and has a lien upon such owner's property for work done or materials furnished. Project scheduling consultants fall into this category. The first step in establishing a lien right for anyone (with the exception of the prime contractor or workers working for wage) interested in establishing a lien right is to file a preliminary notice. If an invoice from a material supplier contains the required information, it may serve as preliminary notice.

Mechanic's liens are rights under the state's constitution and are liens on the property for "value of the labor done and materials furnished." A mechanic's lien is a legal means of recovering payment for works of improvement and site improvements by contractors, subcontractors, laborers, and suppliers of materials, including, but not limited to, new construction, construction alterations, tenant improvements, additions (works of improvement), repairs on almost any structure, or demolishing or removing improvements (site improvements). Mechanic's liens attach to both the structure and the land on which it sits. The requirements for mechanic's liens against the project are

Commencement of work, however slight. There must be actual visible work and/or delivery of materials to the job site.

It must be shown that labor and materials became a fixture on the land and that they are of a structural and permanent nature.

Work must be done at the request of the owner, or his agent, contractor, subcontractor, architect, builder, etc. Knowledge by the owner of the construction is grounds enough for judgment.

If an owner of a structure or property records a notice of nonresponsibility within 10 days after knowledge of the construction, no mechanic's liens will apply against him unless he is the one ordering said work to be done.

Liens are filed with the county recorder's office in the county and jurisdiction in which the project is located. All original contractors, subcontractors, or suppliers who have previously filed preliminary notice can file liens. Preliminary notice is a required prerequisite by law in order to file a mechanic's lien. These liens must also be verified by the claimant (the contractor or supplier) to be true and accurate and, if not correct, are considered void, therefore unenforceable by the courts. They must be filed no later than 30 days after notice of completion by subcontractors and no later than 60 days for prime contractors. If no notice of completion is filed, then all have 90 days from their finish date to file. Once filed, liens must be perfected in 90 days from the date the lien was filed. This is called a "suit to perfect lien," and it forces foreclosure of the property by court judgment of default of payment. However, the law allows the claimant to grant extensions of the foreclosure for up to one year.

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Just having the mechanic's lien right and filing the required preliminary notice in a timely manner do not guarantee that the contractor will get paid. They simply mean the contractor has a "cloud on the title," the same as a mortgage or grant deed holder. For the contractor to get its money, it must do exactly what a bank would do: foreclose. Foreclosure requires a lawsuit to perfect a particular claim of lien, and it must be commenced within a period of 90 days immediately after the date of filing of the particular claim of lien. Liens and the perfection of liens must be filed with the county recorder in the area of jurisdiction wherein the project is located. If the contractor is late on this, the contractor loses. In fact, if the contractor is late on any of these legal notice filings, the contractor loses. Construction contract law holds a licensed contractor to a higher level of accountability and responsibility. A project scheduler, working for a contractor, can't stand up in court and say, "I don't know, I must have overlooked my filing dates."

For a licensed contractor to get its money and perfect a lien, it is necessary to file a lien foreclosure action within 90 days of recording the claim of lien. A suit to perfect lien, which establishes a court date to sue for foreclosure on the property to settle claims of unpaid money due the contractor, is this necessary second step. If more than 90 days is needed in which to foreclose, credit should be given to the project owner. Within 90 days after an offer of extension, a contractor must foreclose or file for an extension. The contractor is the only entity that has the right to give the owner an extension for up to one year. Recorded extensions may be granted to the owner by the above procedure, but the contractor must foreclose within a year after work is completed. The action should be brought to trial within two years after commencement of suit to perfect lien.

Notice to Owner

The contract document, notice to owner, describes in nontechnical language, in clear and easy-to-understand words, the state's mechanic's lien law and the rights and responsibilities of both the owner and the contractor. This document also advises the owner to require payment and performance bonds from the contractor to protect the owner from the contractor's not finishing the job and not paying its subs and suppliers. A surety bond is an insurance policy that has been taken out to guarantee this event will not happen.

A performance bond is an insurance policy underwritten by an insurance company to ensure that the contractor will perform the work as contracted. If the contractor abandons the job, the insurance bond will cover the cost of another contractor's coming in and finishing the job. A payment bond likewise guarantees the owner that the contractor will pay his subs and suppliers. The contractor must give this document to the owner before signing the contract. If it is not included or attached to the original contract, the contract is invalid. This is a legal technicality big enough to nullify claims made against the owner.

Stop Notice

A stop notice is filed by suppliers or subcontractors who have previously filed preliminary notice in a timely manner, to the holder of funds (public agency, owner, or lender). It is a legal notice to request that funds be withheld from the general contractor. Stop notices can be sent on public or private jobs. The stop notice is used on public works jobs in place of a lien, because public property cannot be liened. Any activity contractor, except the original (prime) contractor, may serve a stop notice.

A stop notice is a "lien on funds." It is a legal notice to the awarding authority or the holder of funds by a subcontractor (claimant) to withhold from the prime contractor in order to satisfy claims for labor and materials furnished to the prime contractor. When a subcontractor (specialty contractor) has contact directly with anyone from the awarding authority or government agency, the subcontractor is then the original (prime) contractor and is subject to the provisions of the law relating to original contractors.

Stop notices must be verified by the owner to be true and correct. However, the claimant on a stop notice is the contractor, not the owner. To obligate the holder of funds to withhold funds, the stop notice should be bonded for 125% of the amount of the claim. This is called a *bonded stop notice*, and it is the heavyweight champion of contract documents. A stop notice stops the flow of money into a project, and things get critical quickly. Upon receipt of a stop notice, the lender may withhold funds from the owner or prime contractor. Upon receipt of a bonded stop notice, the lender *must* withhold funds from the owner or prime contractor.

Both require a lawsuit to force actual payment. Neither mechanic's liens, stop notices, nor payment bonds impair the contractor's right to court, but rather are legal aids to recovery. Only subcontractors and third parties, such as suppliers, use the stop notice. It is usually more effective than a mechanic's lien because it is used to withhold a specific amount of money from the prime contractor, which the subcontractors claims he or she is owed. Because the stop notice is used to force the lender (or holder of funds) to withhold a disputed amount of money, the subcontractor can be assured that, if any money is left in the account, it will be held until the dispute is resolved.

A stop notice is the only single means to force payment on a public works job. Public property cannot be liened, so in the event that a contractor

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needs to serve a stop notice on a public works job, he must send it to the awarding authority that is the project coordinator for that public works job. A bonded stop notice ensures compliance by the construction lender to withhold funds from the prime contractor to satisfy the amount claimed by the subcontractor or supplier. Without the bond, the holder of funds is not obligated to withhold the money.

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2

Preconstruction Planning

PRODUCTION PLANNING OVERVIEW

Before we define modern project scheduling and that management position within the construction industry, it is necessary to explain the career's evolution and get a sense of how it came into existence, because of needs unfulfilled by traditional construction management techniques. Professional project scheduling evolved because of the inherent time-management inefficiencies in the traditional construction process of the 1960s, which culminated in the late 20th century with an national industrywide crisis in which most projects, both public and private, were running way over budget and long past their scheduled completion dates. The second biggest government building ever constructed, the Federal Triangle Project in Washington, D.C., is 400,000 square feet, second in size only to the Pentagon. The production ran four years behind schedule and doubled its original cost. The project served as a glaring example of this national industrywide crisis of most capital projects greatly exceeding both their budget and their scheduled completion date.

This problem has become so widespread that funders of capital projects in the mid-1980s began to demand that cost-effective methods be instituted in new types of construction management techniques before more capital projects would be funded in the future. At the time, many contractors and some architects were not trained in critical path management and were unable to use efficient new management skills, just at the time when the industry's changing paradigm demanded nothing less than skillful use of those new project scheduling skills. The need for a project scheduling specialist surfaced. The project scheduler career further evolved to counter the fact that architects and design consultants have built a reputation over the last two decades for not focusing accurately enough on the projected costs of labor and materials. Specifically, they have often been guilty of underestimating the project's production management costs to the project developer.

If you are an architect and that last sentence angers you, tough. You guys brought it on yourselves and you'd better wake up to the total costs involved for your clients, which means analyzing everything connected to your designs that is going to cost your client money to produce. Owners and their representatives that make up the project team were understandably concerned about this historical tendency of architects to take as little responsibility as possible for developing cost-tracking audit trails, producing network schedules, monitoring the project's subcontractor payments, or developing the project's quality control plan. All these project production control things, which make or break a project after it has left the designer's hands, have been traditionally left up to the owner by the design professionals. Something had to give, and owners began looking to hire those trained in project scheduling for cost protection. Presto ... the job of the project scheduling specialist appeared.

That said, in all fairness, I also need to point a finger at the other professionals involved in the project production: the building and specialty contractors. Activities subcontractors also have a long track record of operational deficiencies in their part of the traditional construction management process. Some contractors lacked up-to-date skills in modern computerized construction techniques or the ability to understand and work with network project schedules. Some contractors understood the basics of network scheduling but didn't think the new ways of project planning and production scheduling were important enough to invest money in and update their businesses. Eventually they were operating old-fashioned business infrastructures that couldn't handle the increasingly more complex and detailed network project schedules coming down the pike every day. Building contractors simply didn't keep up with change. If you're a building contractor and that last sentence angers you, tough. I'm a licensed building contractor too, and I know for a fact we're just as guilty as the design professionals in not looking after the client's needs as closely as we do our own. A lot of us builders have the attitude that we know it all and are resistant to change, eyeing it suspiciously like a rattlesnake as it keeps creeping closer.

This head-in-the-sand attitude by contractors has also cost owners money in the past and has brought forth still more need for a professional project scheduler to counter the lack of new technology usage by contractors. Something had to give, and owners began looking to hire those trained in network project scheduling for protection from extra work orders and delay claims. Everyone loses when the project winds up in litigation except the lawyers. (Now I've probably ticked off the lawyers, too, ...)

Additionally, in the past decade, as this accelerated rate of change swept through the construction industry, the jobs of project managers became more and more generalized. They were swamped between 14-hour days of managing the daily production and, in addition, interfacing with all the parties involved in the project. Suddenly there were simply not enough hours in the day for one person to physically handle all these duties and develop, administer, and track the project schedule as well. Hiring professional project schedulers and delegating the workload of developing and administering network project schedules was the logical outcome. Now, with a firm lock on the future, the professional project scheduler career is in full bloom. It is a sunrise career opportunity on the threshold of a bright and profitable future. Humans will always continue to build, and the world will always need professionals to plan and manage project production.

Even with today's sophisticated computer technology, there are no shortcuts for deleting a human project scheduler. If it were easy, everybody would be doing it and it wouldn't pay so well. Although it takes a conceptual mind trained in critical thinking, and an experienced hand in the ways of the construction industry, some standard operating procedures (SOP) will help you prepare for this job. These procedures will teach you to build your data into logic systems, sequentially interacting with each other, and by using dedicated project scheduling software, to organize your critical thinking to identify potential production bottlenecks. Following established scheduling SOP teaches you to make use of the workarounds, alternatives, options, constraints, and accelerators in critical path management as the *time manipulation* tools of the professional project scheduler. In today's fiercely competitive business world, profit comes only to those who master the art of project scheduling with flexible time management.

Because the current environment is so competitive, many companies have seen their profitability decline in the past years. But some companies continue to record superior rates of growth. These successful firms have recognized that work environments and the nature of the business have changed, and they have moved to accommodate these changes. The construction industry learned a hard lesson as a result of the recessions of the late 1980s: Increases in the cost and complexity of doing business dictate that all costs must be tightly controlled to preserve profits. This means that, if a construction project is going to be completed on time and earn a profit, the project schedule must be developed in a tight and error-free manner. There is no longer any room in the schedule for contingency extras or absorbed costs.

Accordingly, because the project schedule is not standardized but changes from project to project, this book and integrated software have been compiled from years of collective professionals' experiences to provide you with the type of flexible controls you need to accomplish your project scheduling and bring your project into existence on time, within budget, and at a professional level of technical quality. To provide professional reference, this book is structured in the current job logic sequence of American construction industry standard CSI format to reflect real-world job precedence of professional project scheduling.

At the real-world application level, events never go as simply or easily as they appeared to on the drawing board or computer program. What looked good on the drawing board rarely translates easily to production in the field. At the field production stage, good project scheduling equates to how closely your planning of all the tasks and activities of the project's production relates to the real-world application tasks involved in making it happen. The owner is always going to look at you and think, is the project on schedule and is production going well? Is your scheduling of the related construction activities adequate? Are the production problems that invariably pop up being solved quickly by this project schedule? Is contingency planning needed but was overlooked? Are the production milestones being reached soon enough to protect my investment?

All this is important to keep in mind, because each project is a unique creation with contractual start and finish dates, and a strict cost budget that must be adhered to realize any profit and to avoid litigation. The cost overruns and completion date delays that were so pervasive in the past are no longer tolerated in any production environment. Companies that don't tighten up efficiency and modernize their operations to meet the new construction industry paradigm will not be around next year.

But these were not the full extent of the problems that led to the creation of professional production project scheduling. In addition to the aforementioned deficiencies in the old ways of construction management, a traditional problem has been the organization of project teams. Project teams typically are made up of people who have limited or no experience in working together as a team. This may be their first time working together, and possibly the last. Or perhaps there are hidden problems from the past among these people. One never knows. So these constraints that we do know of make project scheduling very difficult, and those constraints that we are unaware of behind the scenes can sometimes make project scheduling similar to tap dancing in a rattlesnake farm. Yet it can be very profitable for the professional project scheduler skillful enough to do it. These are well-paid construction project schedulers who have learned to manipulate time with contingency workarounds. And in the construction industry, time really is money. Control the time and you control the profit.

All construction projects, be they residential, commercial, industrial, or public works, are complex to some degree, with larger projects being monumental in terms of the amount of the activities and tasks involved. Industrial projects involve thousands of activities and hundreds of contractors and suppliers, on multiple critical paths network scheduling. For a project to be completed on time and on budget, all work (which is broken down into tasks, activities, then phases of completion) must be carefully planned and scheduled in advance. The project scheduler then "cooks" the schedule with integrated computer software programs, looking for any long-lead items and all production bottleneck potentials. If all the activities would simply follow each other in consecutive order, the job of project scheduling would be easy enough for the owner to handle without hiring a professional project scheduler. In smaller residential jobs, project scheduling is part of the general contractor's job. However, even small residential construction contractors get busy when many bids come through at once, and they can soon be swamped with workload. For the bigger jobs to be contracted profitably, a good CPM project schedule is a necessity.

Because of the complexity of modern construction techniques, and the high degree of specialization and licensing within construction management, owners frequently retain professional project schedulers to plan, develop, and operate the project's production schedule. The experienced project developer knows that (1) licensing and registration laws require certain contractual portions of the project to be done by persons possessing designated licenses and that (2) other portions of the work will be delegated to other employees of that firm or to outside consultants retained by the project management firm. Project schedulers are generally considered personal consultants hired by either the owner or project team. A client who retains a scheduling professional does so because the client is impressed with the professional skill of the scheduler, or the firm that scheduler represents. Today's large project developers generally specify that specialized project scheduling work be done by highly qualified specialists, often hired as consultants beyond the parameters of the project team.

Profit margins in the construction industry during these last lean decades have shrunk from 20%–3%, forcing contractors to take on more jobs to make the same annual income. Because of this, project schedulers have seen an increased demand for their services from contractors as well as owners, a modern window of opportunity due to high competition for a low margin. This also will continue well into the foreseeable future. The old days of many contractors relying on time and materials extra work orders from fat, drawn-out projects are long gone. And today's commercial projects are now unfundable without network project scheduling.

Since each project is unique, the production tasks and activities will be vast and different with each project. It follows, then, that production planning is uniquely complex for each project. However, the SOP for production planning detailed within this chapter are the fundamentals upon which all successful project scheduling is based. Your adaptation of these procedures, and mastery of the accompanying software, will provide you the foundation of modern project scheduling.

SCHEDULING FUNDAMENTALS

A project schedule is the contractual network diagram of the project's planned activities, their sequence determined by job logic, the contractual time in working days required for completion (activity duration), and the conditions necessary for their completion (contract specifications). It is also a contract document linking the lender, developer, prime contractor, and subcontractors. It serves, within the contract specifications, to advise the lender and developer of any unsatisfactory progress in any activity's production, and as a strategy to the prime contractor and activities subcontractors of the jobs they must accomplish within their contractual timeframe.

It is accepted industrywide that use of network project scheduling in modern construction projects is the difference between success and bankruptcy. Production planning using critical path management (CPM) has proven it to have these three distinct fundamental advantages in project scheduling:

1. CPM scheduling provides instantaneous monitoring of the production.
2. CPM scheduling increases the productivity and efficiency of the production.
3. CPM schedules are contract documents that stand up in court to prove or deny contractor delay claims.

Now let's first back up a bit and start at the beginning, by defining production planning and project scheduling. In the conception stage, preproduction planning is the process of carefully considering all the activities of the project's development. We group them into phases, list them, then graph them. This is then followed by the production planning scheduling stage, whereby one determines the steps required to accomplish each activity, then lays out those steps in a logical production sequence. We call this job logic. Many things influence *job logic*. For example, trades subcontractors availability, fabricated items' delivery dates, or perhaps a trucking strike could delay long-lead items' delivery at the last moment. So if delivery in your area could be a potential problem, the delay would delay other activities and thus influence the job logic or activity sequence for your area.

Next comes the project scheduling phase, using the fundamentals of network project scheduling to coordinate the many tasks, activities, and phases necessary to bring that project into existence. Then the numbers are crunched and the project schedule is cooked, which means to apply critical analysis to debug the system. When the schedule is authorized by the lender and owner, the project begins, and the project scheduler now starts doing cost tracking and audit trail procedures. The professional project scheduler now also begins doing quarterly trends analysis, to see how the project schedule will do next quarter and to determine what changes are needed now. When the client asks the scheduler, "How are we doing?" the professional scheduler has the answers for both now and the next quarter—both the problems *and* the solutions.

So in this secondary analysis stage, scheduling fundamentals begin by the proposed schedules being broken down into its fundamental components to look like this:

1. You figure out who's going to do what, then you assign a name, number, and the responsible subcontractor to each activity.
2. When are the activities' start and stop dates? How much of the total project will be completed when they finish? Which activities are critical to total project completion?
3. Where in the schedule do their tasks and activities fall? Any slack time or leeway between their starts and finishes?
4. With whom do their activities interact? Link those subcontractors in job logic.
5. What activities will take the longest to complete?
6. Identify all long-lead items (items that have to be fabricated or custom manufactured with a long delivery time).
7. Identify for close monitoring all subcontractors with long-lead items in their activity.

The crucial part of successful project scheduling, however, is the methodology you use to complete these tasks. Profitable project scheduling requires knowledge of network scheduling and the use of modern computer CPM programs. The traditional old ways of handwritten spreadsheets and day planners are long antiquated, although there are still scheduling companies around that offer hand processing for certain types of projects. But the computer by far is today's professional project scheduling workbench. And integrated software products configured with dedicated program logic are the scheduler's tools. You must prepare for tomorrow's profit by mastering the technology of today.

Project scheduling always contains a dichotomy, or duality, that is a strange combination of clean, conceptual, theoretical planning, which then must be carried out in a real-world field application production that is sometimes much akin to a fistfight in a mudhole. Seldom are the two conducive to easy production; not for anything larger than, say, a doghouse. (Unless, of course, the doghouse is located in a flood plain or earthquake area. Then engineering plans, environmental impact studies, and building permits will be required.)

But therein lies the job description for the professional project scheduler: Take the owner's project that looked good enough on computer to get the bank to fund it and develop a production schedule that will build it profitably in the real-time world amidst heavy competitive business combat. And then, of course, there are always the hidden factors in the business world, such as behind-the-scenes egos and power plays revolving around money, that one must learn to manipulate. Although you will never see that last sentence on a construction contract, you must be adept at these business survival skills also.

Currently, what is evolving in the construction industry is a situation wherein the project manager is working 14-hour days, handling field reports from site supervisors, overseeing contractors, managing activity operations, and interfacing with regulatory agencies and the project team as the owner's agent. More and more, a separate project scheduler is hired to take on responsibility in developing the production schedule, overseeing the same, and reporting progress to the project manager, owner, project team, prime contractor, and subcontractors through specialized computer summary reports for each, called *sorts*. Obviously this means more work, longer duration of jobs, and more annual income to the astute CPM project scheduler. Today's professional project scheduler also negotiates for a healthy percentage of profits if he or she brings it in under budget, before deadline, or both. This type of incentive profit sharing is a sizeable source of potential income for the professional project scheduler.

Modern CPM project scheduling has evolved from traditional monthly planning calendars that were used in combination with handwritten data spreadsheets and is based on two types of flowcharts called bar charts and velocity diagrams. In scheduling fundamentals, we refer to velocity diagrams as *S-charts*. They show the established schedule of total tasks and activities graphically as well as record progress along the way. Traditionally, they have proven themselves to be the most useful and functional methods of graphing the project schedule out visually, with hand spreadsheets handling the data flow for summary reports.

But bar charts are inadequate for network scheduling, because of their lack of phase interrelationship float (scheduling leeway or slack time) capability. This results in a lack of control over the critical path of the total work to be performed. Traditionally, the prime contractor's experience and intuition filled in this shortcoming. Naturally, one can intuitively grasp that this kind of situation will quickly get out of control with more contractors added to the formula. And lack of control always equates to lack of profit.

The S-curve chart is a better scheduling tool because it shows the various activities linked by their interrelationships and tasks' interdependence existing throughout the various sequential phases of the project. Although the S-chart is a better system for scheduling smaller construction jobs and linear time-scale projects, it does not provide time-scale manipulation. And time-scale manipulation is the control domain of CPM project scheduling.

CPM computer programs are much more efficient scheduling systems because of their instantaneous mathematical calculations, error-free, that "wash through" adjustments in other critical areas, like float and phase interactivities. CPM computer programs are configured with program logic, further providing the critical analysis of time-scaled activities sequence by interaction on network diagrams. The analysis is done by critically evaluating the summary reports of these interactions in the program's sorts. When network diagram software systems are used in conjunction with bar charts, the resulting CPM management control system is the basis of modern project scheduling. Currently in the construction industry, CPM control is a contractual requirement, usually appearing in the contract specifications in virtually all commercial, multiresidential, and industrial construction. And although CPM was designed for the construction industry, it functions extremely well in other businesses that deal with production, such as product manufacturing, distribution centers, and the semiconductor industry.

Critical path management network scheduling fundamentals require that each activity within the project have its own timeframe requirement, and usually cannot start until preceding activities have been finished. There may be other activities, however, that can be carried on simultaneously because they are entirely independent of one another, such as plumbing and electrical. "Dovetailing," or interlinking, these activities and their duration events efficiently requires skillful time management planning in the project schedule. A typical construction project involves many varied activities, and tasks within those activities, that are interdependent with one another as well, as other activities that are totally independent of each other.

When the production phases, showing all the activities, are interrelated on a network diagram, they create a multilane highway of activities moving toward completion. It also shows their individual time durations, as well as their relationships with their preceding and succeeding activities. When the entire project's tasks and activities are superimposed to provide the big picture, it quickly becomes evident to the observer that CPM project scheduling is a difficult and complicated project management function.

It has traditionally been the project manager's responsibility to oversee and evaluate prime contractors' construction schedules to determine whether the subcontractors are finishing by their contractually required dates. However, this responsibility is now falling within the project scheduler's domain, as construction profits become more closely tied to time manipulation techniques.

PROGRESS SCHEDULE REGIMENTATION

Planning the regimentation of a production schedule serves to set the precedence for all milestone events and their relative events and durations falling within the production schedule. These are arranged in chronological order to visually reflect the project's job logic. This type of sequential task completion listing is known as progress schedule regimentation. Progress schedule regimentation should include

All meetings, both home office and field
Progress inspections, both municipal and site supervisor
Engineering and testing requirements
All long-lead items' delivery dates and purchase orders from subs
Equipment delivery dates
All submittals due dates
Prime and subcontractors' progress payments schedule
Project phases completion dates

At this stage of the preconstruction project schedule planning, your agenda should be to compile a complete list showing all milestone events and their respective dates. These should include all meetings, prime and subcontractors' progress payment schedule, progress inspections and testing requirements, equipment delivery dates, long-lead items' delivery dates, submittals, and project phases completion dates.

As contracts are awarded, all the subcontractors should be asked to submit their own activity schedules to see how they fit into the overall project schedule and to submit a list of proposed shop drawing submittals and delivery dates of the equipment after receipt of approved drawings. When these schedules are received, the project scheduler must review them to ascertain that the equipment delivery dates fit into the overall timeframe of the job. If they do, then they should be incorporated into the bar chart schedule and distributed to all subcontractors. Subcontractors should be given the complete project schedule containing their portions of work, and they should be asked to comment on the length of time and sequences allotted to them. With their input initially and regular updated status reports, the project schedule will be more accurate.

Once the scheduler has identified the activities work items at the subcontractor microcosm level, the activities listed on the primary report file (Sort by Activities) are then broken out from the Sort by Activities timeline and transposed onto the accelerated S-chart timeline. This, in effect, shifts the production network into double-time. What happens at this transposition point of superimposing the Network Timeline S-chart on the Sort by Activities bar chart is the point in your development of the schedule where this opens up details subtasks and work items within the activities and, thus, windows of float. The duration events opening and closing begin to build a graphic fabric that should reflect the job logic. Bottlenecks appear and workarounds are developed. The overlaid events and milestones become workable and the job logic of the network schedule flows in an organized manner.

The most common cause of a project schedule's failure to meet its cost budget is design-construction contracting in the design-lump-sum bid contract. Typically, the owner turns over too much decision-making authority by not separating the design phase from the quantity estimated takeoffs. The prime contractor at this point is not only the authority in the fieldwork but is also in charge at the administrative level. Without shared control over all aspects of production, the natural tendency is for the contracting parties to fall into an adversarial rather than a cooperative mode. Such a scenario harms all participants, especially the owner. Owners must make their own overall project schedule to check on the viability of keeping the strategic end date. Then they must keep track of the overall project float to see that each major project contributor uses only the float that has been allotted to that activity. If a float is shifted for any reason, the total project float must be evaluated in the new context.

PROJECT PRECON MEETING

The prebid meeting of all vested parties in the contract to iron out details of production scheduling is (on the West Coast) called the "precon." During the precon, the project scheduler must ensure that all work contracts specify that ordering materials will be done after contractors review plans and specifications.

Visiting a job site is not sufficient to see all the details of the job. If materials or items are allowed to be ordered on an "as-needed" basis, delays will occur if the materials or items are unavailable or on back order. The project schedule, no matter how well done, will be handicapped if this important step is not taken at the precon.

BID AWARD PRIOR TO COMMENCEMENT

Certain things must occur once the best bidder has been determined to protect the optimistic environment for the project's production schedule. Prior to awarding the contract, the project team holds the precon meeting with all contractors. At the precon meeting, they

1. Closely evaluate the job logic of subcontractors' schedules when they are presented for approval. Check their float numbers against the master project schedule. Look for numbers in the timescale that don't add up.
2. Make subcontractors prove that any overly optimistic projections are realistic within the master project schedule.
3. Don't allow any prime or subcontractors to use up their allotted float early in the master schedule. Cushions and margins for error should be held back until the finish event and, preferably, not used at all.
4. Monitor their schedule reports carefully; check each report for accuracy, move quickly on any discrepancy.
5. Establish precedence for checking actual progress in the field.

The project scheduler prepares an operational production schedule that the project manager uses for the weekly scheduling meetings held in the field office, so the operational schedule must be detailed in activity and subactivity reports to serve that objective. Operational schedules have a more detailed work breakdown structure than an owner's schedule and are better suited for accurate field reports.

Once the contract is awarded, the project begins. Now everyone involved will be playing beat the clock with your project schedule. Buckle up and be ready to ride tall in the saddle when it comes time to ramrod your schedule. From the moment the chute opens until the pay bell rings at the end, it'll be a busy rodeo.

SHOP DRAWINGS LOG

A shop drawing log should be started so that when the shop drawings start arriving from subcontractors and suppliers, each drawing can be properly logged into the computer for tracking. Not only will a log of shop drawing activity allow a project scheduler to keep track of what drawings have been received; it will also show where the drawings have been sent and how long they have been there. The project scheduler needs to prod each subcontractor and supplier to submit their drawings promptly. At the first job meeting, the major subcontractors and/or material suppliers should be requested to submit a preliminary shop drawing submission schedule.

The log should include the major pieces of equipment for which shop drawings are required, and the anticipated date when each drawing will be submitted. The subcontractor and/or supplier should also include the approximate delivery date of equipment after the approved shop drawings have been returned to them. Once shop drawings have been received, the next hurdle is getting them approved in a timely manner. The project manager and the owner should review the incoming shop drawings before the project scheduler logs them into the computer, to determine whether they conform to the project specifications and requirements. If compliance is questionable, contact the party who made the submission to reexamine the shop drawings to verify contract specifications. If there are deviations, it might be best to note them before submitting the drawings to the architect. At this point the project manager must establish credibility with the architect and engineers and must show that the shop drawings are being reviewed for compliance with the plans and specifications and are not merely being passed through without any scrutiny whatsoever.

TRANSMITTALS

A typical shop drawing is used on all long-lead and fabricated items. In addition, a separate file should be kept for each trade that will be submitting large numbers of drawings, such as structural steel, plumbing, HVAC, sprinkler system, and electrical work.

Several software programs on the market today allow the project scheduler to create a fax modem transmittal forwarding the shop drawing to the architect or engineer and transferring this information automatically onto a shop drawing log. The information inserted at the time of preparation is stored and transferred to the shop drawing log. Although the shop drawing log contains material from various subcontractors, separate computer files and summary report sorts can be created for individual trades.

Care must be taken to discern which subcontractors should receive informational copies of shop drawings. For instance, when a mechanical subcontractor is being sent an approved copy of its boiler shop drawing, the electrical contractor should have an informational copy in order to confirm the line voltage requirements. All too often a piece of equipment is ordered with electrical characteristics at variance with the voltage requirements shown in the drawings. If an error such as this can be caught in the shop drawing stage, there may be little or no additional cost involved to make the equipment compatible with the building's electrical system.

PROJECT SCHEDULE PLANNING

Everyone has his own style of doing things. If you've been doing this awhile, you have your own ways and procedures that work for you. If not,

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this is the basic way of going about preconstruction planning of your network schedule:

1. Create milestones in the timescale. Thorough project schedule planning here establishes expectations for activity start and finish events and float for your project schedule. It requires project-wide conception and project team commitment to milestone events.
2. Establish production schedule priorities. Project schedule planning requires you to consider primary activities critical to the project, policies for ensuring those activities will be done within that window, contingency plans if they aren't, resources dedicated to unscrewing the situation, and information about the activity's relative importance to the starting event of the succeeding activity.
3. Predict problems. Project schedule planning should predict problems and production bottlenecks in activities and operations. List them out. This invites the creation of controls and evaluation procedures.
4. Solve those problems. Project schedule planning here allows you to evaluate what doesn't work and to consider what might be done to make it work. With a plan detailing your assumptions and expectations, it is much easier to identify what went wrong when problems arise in the project schedule. Even guessing here will allow you to check and improve areas of concern within the schedule. This impresses owners immensely.
5. Profitability. Project schedule planning needs to look at cost and cost control to force consideration of the activities' costs and the owner's cost before committing funding resources. Here the best plan tends to be progress payments' linkage to phase milestones. It imposes a payment upon successful completion of each activity on time and on budget contingency upon each activity subcontractor. This also allows for the inspection of workarounds.
6. Motivation. Thorough project schedule planning also encourages a fuller participation from the project team and motivates everyone concerned, including you, to put forth his best efforts to a positive outcome in the project schedule.
7. Cost control. Project schedule planning controls costs by creating a specific type of report sorts for each project team member. The project manager and site supervisor need periodic reporting, the bank or lender needs audit tracking, the owner wants similar comparisons and cost-effectiveness evaluations. This is a big area of concern to all owners and is one of the major advantages to the owner of having a professional project scheduler on the project

team, because architects and design professionals traditionally have shown casual attitudes toward cost control for owners.

8. Schedule development. Project schedule planning is the only way to put milestones into the operational phases of the schedule accurately. It requires considered decisions from the owner and all members of the project team, rather than planning through default. Project schedule planning should focus on balancing activities completion needs, demands for resources, and milestones timescaling.

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3

Project Scheduling Systems

SYSTEMS FUNDAMENTALS

A project schedule becomes operable when the scheduling system has a functioning network diagram of all the activities of production. Working flowcharts with all job logic sequences developed, plus total durations required for completion added, create a network timeline. A project schedule's primary purpose is to keep the production activities on schedule. However, much useful data from the schedule can be used in other ways for added cost-efficiency in many areas of project production. As we have seen, critical path management increases productivity, efficiency, and time management, thereby reducing overall project cost.

The fundamentals of the system can be illustrated by a simple project such as a room addition. The activities could be as simple as starting and finishing dates for the foundation, walls, and roof. A more complex project, such as the entire residence, will add phases of activities completion. These phases serve as benchmarks in construction completed to date and according progress payments to the activity subcontractors. In scheduling systems fundamentals, these benchmarks of phases completion are called *milestones*. Financial milestones set by the lender are typically tied to the dates progress payments are due.

Systems fundamentals of project scheduling came into being on capital projects in the early 1940s with preplanned, written schedules. During World War II, the military began to develop its own type of project scheduling to deal with multiproject management of many different types of project contractors. The first is an activity duration estimate system developed by the

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military, called PERT, which we will examine later. In the civilian market, two traditional systems have evolved from hand spreadsheet methods: bar charts and logic-diagram-based schedules. Both methods are used extensively and interchangeably in both project planning and actual construction work. Naturally, each method has its advantages and disadvantages.

Bar charts are the simplest form of project scheduling and have been in use the longest of any of the systems we have available today. They offer the advantage of being cheap and simple to prepare, they are easy to read and update, and they are readily understood by anyone with a basic knowledge of the construction business. They are still in wide use today, even as one of the final sort reports of computerized CPM scheduling systems. The main disadvantage of the bar chart is its inability to show enough interactive relationships between all of the activities on larger, more complex projects.

Figure 3.1 is an example of how visual data overload doesn't allow for one clear path made up of many smaller paths to become apparent. In the bar chart illustrated here, there is no critical path method of scheduling. Simple job logic of placing the activities in order of their construction sequence was used. Note how the many activities have been condensed into single group bars to get the complete chart to fit on one page. Any time you condense something by compressing it into something else, you lose control over that item. In network scheduling, the approach is just the opposite. We "explode" the activities, subactivities, tasks, and work items out into a network so that each has complete tracking and controlling. Each of the macroactivity bars in Fig. 3.1 needs to be broken down into a series of individual tasks, to control the microactivities within the macroactivity. Only by having control at those levels will we have ultimate control of the macroactivity.

The bar chart here shows macroactivity progress, which is useful and will suffice on small jobs, but no interrelationship between the activities that would allow for alternate routes if progress hits a bottleneck. This ability to switch paths is crucial to critical path management. It's much like tap dancing in a minefield: You can't stop moving or you lose. If project production stops, everyone loses. So it's in everyone's best interest that things keep moving to a timely completion. Bar charts, such as that shown in Fig. 3.1, have no capacity for contingency planning. And your job as the project scheduler is to be ready to pull a rabbit out of the hat by having a workaround ready to go if a production activity encounters a bottleneck. So this type of bar chart is useful, but it is not enough.

This example has excellent comparison and completion capabilities, and bar charts have a number of other very useful methods of processing data. Note that some of the activities finish ahead or behind where they would in smooth progression. This is vital information and must be tracked accordingly, but no option exists in Fig. 3.1 for critically analyzing the activities' interrelationship or doing something about them. CPM offers those options

Certified Consultants — **Bar Chart by Early Start**

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Project:	***Corporate Facilities Remodel***
File Name:	*26-242-955*
Description:	*Phase One Remodel*
Our Invoice:	***95-143***
Client Invoice:	***4112 FR-1***

Data Date: *12 May 95*
Run Date: *03 Jul 95*

Activity Number	Activity Description	JAN 6	13	20	27	FEB 3	10	17	24	MAR 3	10	17	24	31	APR 7	14	21	28	MA 5	12	19
00010	Subsurface Investigation	xxx	xxx	xxxx																	
00100	Instructions To Bidders		xxx	xxx	xxxx																
00200	Information Available To Bidders		xxx	xxx	xxx	xxxx															
00300	Bid Forms		xxx	xxxx																	
00400	Supplements To Bid Forms			xxx	xxx	xxxx															
00500	Agreement Forms				xxx	xxxx															
00600	Bonds And Certificates					xxx	xxxx														
00700	General Conditions					xxx	xxx	xxxx													
00800	Supplementary Conditions						xxx	xxx	xxxx												
00850	Drawings & Schedules						xxx	xxx	xxx	xxxx											
00900	Addenda & Modifications							xxx	xxx	xxx	xxxx										
01010	Soils: Reports & Remediations							xxx	xxx	xxxx											
01020	Allowances								xxx	xxxx											
01025	Measurement & Payment									xxxx											
01030	Alternates/Alternatives								xxx	xxx	xxx	xxxx									
01040	Coordination									xxx	xxx	xxxx									
01050	Field Engineering										xxx	xxx	xxxx								
01060	Regulatory Requirements											xxx	xxx	xxxx							
01070	Abbreviations & Symbols												xxx	xxx	xxxx						
01080	Identification Systems												xxx	xxx	xxxx						
01090	Reference Standards													xxx	xxx	xxxx					
01100	Special Project Procedures														xxx	xxx	xxxx				
01200	Project Meetings															xxx	xxx	xxxx			
01300	Submittals																xxx	xxx	xxx	xxxx	

FIGURE 3.1 Bar chart by early start.

and, if float is used correctly, also offers the time management necessary for critical path workarounds. Our example here shows the strategic dates for starting and finishing major portions of the overall project, along with a few milestones. Intuitively, one can grasp that there is little or no ability to control changes or manipulate time-scale interlinkage between activities in such macroactivity grouping.

Control comes at the microgrouping, or individual task, level. Manually generated bar charts and spreadsheets that cover the whole project involve a lot of detailed record keeping and summary reports, which soon absorb too much of the project manager's time to allow managing the field end of the project's production work properly. This means, in our example, that each bar would also need another series of bars to show subactivity tasks within each activity noted.

For example, under the contract phase, the Supplementary Conditions bar chart might have a large quantity of subactivities covering workplace safety requirements, public pedestrian barricades, or specific traffic control plans. These would all be individual activities in CPM on a larger project. But showing the production activities and their subactivities in that sort of detail could easily take 20 pages of bar chart schedules just to list all those phases-related construction activities, subactivities, tasks, and work items.

The primary reason for the cost overruns and late completions of projects in the 1960s was this lack of control over the project's scheduled timeline. This became a focal point of change for more efficient construction management. Delay overruns on commercial and industrial projects can run into millions of dollars. Bar charts used up to that time proved inadequate. Scheduling larger projects in that sort of detail, with bar charts like the example in Fig. 3.1, simply does not offer the time manipulation advantages of modern critical path management.

Computerized CPM makes up for bar chart's inherent disadvantages by interlinking activities and producing integrated progress summary reports called sorts that contain specific current data, instantly available to any end user on demand. By first monitoring and recording production activities progress on each production development activity, computerized CPM then integrates the data through the sorts, some of which produce progress reports in a bar chart sort. Experts are saying that in a few short years we'll have remote terminals the size of credit cards to input this data from a foreman's pick-up back to a host computer in the office that does instantly the summary work.

PERT SCHEDULING

The PERT scheduling system was developed in the military for government production scheduling control while contracting with multiple and different types of defense contractors. PERT (Program Evaluation Review Technique) is a scheduling system that uses inside and outside figures to make a best-guess estimate on each activity duration.

These "guesstimates" are then strung together by the prevailing job logic. In the PERT system, the elapsed time of an activity is calculated by assessing an optimistic activity finishing event date and a pessimistic activity finishing event date, then calculating an average duration of the activity. This average time is then used as the only factoring used for activities durations in the network schedule.

This "inside and outside best-guess estimate" will work for averages in data processing, but PERT serves no other scheduling functions in modern construction project management. Accordingly, most modern CPM software programs for construction projects do not include the PERT-type scheduling system, but instead use the data from precise activity events, both early and late, calculate with all four of those factors, then average the duration. Float can also be taken into account. The proper selection of the elapsed duration times for the work activities is an important part in preparing an accurate CPM network schedule, because exact events determine the exact activity duration times, which in turn directly affect the critical path and succeeding activities float times. The PERT system does not offer these scheduling advantages.

In the PERT system, generalized time estimates for activities throughout the total project are made, with a timing leeway built-in cushion allowed for optimism or pessimism of activities duration. However, the linkage of activities and establishing a critical path through a PERT system is very difficult to establish and impossible to maintain workaround options in the event of changing critical paths. To be accurate in event time estimating, the project scheduler breaks out all activities into manageable units of time. The elapsed-time estimate is based on the unit labor and materials quantities taken off the project's specifications, which are used to estimate the project cost. This quantitative survey estimate contains a wide variety of bidding pre-estimated information, such as cubic yards of import fill or excavation, tons of structural steel, numbers of block masonry units, and cubic yards of concrete.

That information combined with previously recorded labor and material costs from the company's own records or activity subcontractor is used to calculate the expected elapsed-time duration for each activity. The unit number to be used as a computation factor is then adjusted for delay by factoring in prevailing local conditions, such as seasonal inclement weather, variations in delivered materials costs, area union labor rates, trucking strikes, etc.

Note the way that "etc." just hangs at the end of that last paragraph. Looks nice and easy, doesn't it? And it sure was easy to write. Just dropped it on the page. But in real-life application, any etc. in that last paragraph will cost thousands of dollars of unrecoverable lost profit. Part of the project scheduler's job is to know and account for the unpredictable events that will delay the schedule, such as inclement weather or materials shortages. Just because it was ordered doesn't mean you're going to get it on time. Follow-up on every line item is part of the job for a professional project scheduler.

SCHEDULING PHILOSOPHY

The dichotomy between scheduling planning and real-world construction execution are the two main factors affecting the preparation of the project schedule. Practical limitations of the project's production must be established, then prepared for in the planning stages. We call this conception and critical thinking stage *scheduling philosophy*. Once the project commencement occurs, the basic ground rules for its construction schedule must have already been established. These ground rules will address the scope of construction phases, materials procurement procedures, contingency critical paths planning, and long-lead items procurement.

These ground rules will be different in specifics with the job logic of each project, but large or small, they will all be determined by following basic scheduling philosophy. Scheduling philosophy refers to the selection of the scheduling system. The questions that must be answered prior to the first scheduling meeting will determine the scheduling philosophy, which in turn will determine the production contracting basis. Scheduling philosophy uses critical analysis to determine

- The scheduling management needed for CPM
- Identification of critical path activities
- Workarounds (alternative option activities that can be substituted if a critical path activity hits a bottleneck)
- Job logic (sequence of activities)
- Timing of schedule recycling
- Contractual requirements for progress reporting from field supervisors
- Assignment of CPM-trained personnel to areas of production responsibilities

Typically, it is the project team's responsibility to establish the scheduling philosophy, critically analyze their decisions, and then get owner approval of the scheduling system selection. The scheduling philosophy must be a cohesive decision among all vested parties because changing the system later during the project's phases is disruptive of the production continuity and, accordingly, very costly.

The scheduling philosophy should also account for the start-up sequence of the various activities making up the production phases. Activities that start up first must also be the activities that finish first. The project schedule must also interlink with the other major project considerations, such as design and long-lead items procurement. That is easy enough where, traditionally, the design is completed before the project goes to construction bidding.

But in other production execution modes, such as fast-tracking, design should be 30 to 50% complete if a reliable CPM schedule is to be developed and executed. By getting this advance start on a project without a finished project design, error is obviously probable if the operation has not been done previously to provide accurate activities duration.

FIELD SCHEDULING

Even a detailed CPM schedule with a comprehensive work breakdown structure is not an adequate tool for controlling the daily progress of the activities in the field. Field scheduling is necessary to coordinate reporting data with the main scheduling system. On smaller construction projects, the production progress milestone schedule may be the only one used. Sequential completion of phases is simple enough on small jobs and usually will be adequate.

On larger projects, however, the project schedule also functions as the basis for making more detailed weekly work plans in the field, for each major activity. In either case, the approved project schedule will, in turn, determine the type and detail of the field scheduling the owner and the prime contractor use to set the production phases milestones and monitor the projected schedule progress versus the actual completed progress. Detailed field scheduling is necessary continually throughout the entire project production to interlink the two for critical analysis and control.

Complete detailed field planning makes the most efficient use of field manpower on the priority list of tasks within those activities required to meet the CPM milestone dates. This detailed planning first concentrates on those items of work that are on the critical path, then on secondary activities that are noncritical. The field scheduling personnel of the project team are responsible to the project manager for planning the construction activities each week for the following week. Field schedulers list sequentially the work activities that are scheduled to be completed by the following week. This list of pending activities is then discussed in the weekly scheduling meeting with the project manager, project scheduler, prime contractor, major subcontractors, chief field engineer, and site superintendent all present. The project manager and/or the project scheduler typically chairs these weekly meetings.

Prior to the meeting, the site supervisor will have checked to see that all the necessary labor, materials, and equipment are on site to perform next week's scheduled work. The site supervisor will then report production readiness or deficiencies at the meeting. After the meeting, the weekly task lists are distributed to all responsible personnel, so the activities subcontractors can plan weekly production execution. Scheduled work not completed in the previous week is also examined at the meeting, and plans are made to bring those activities up to speed. The outlook for the next two weeks is critically analyzed and projected. The project scheduler then prepares the longer-range quarterly field scheduling plans by checking the critical CPM milestone dates four weeks ahead, and plotting the appropriate courses for the next quarter.

PROPOSAL SCHEDULING

The project schedule first comes under serious discussion by the contractors when the bidding documents or the request for proposal (RFP) arrives at the individual contractor's office. The RFP or bidding documents contain a section devoted to the construction schedule. Usually the documents ask the contractors to develop preliminary bar chart schedules showing the major construction activities (and their durations) in the contractors' proposals. The purpose of that request is to get the contractors to look at their strategic end dates in general terms to see if they are still feasible. The owners use the contractors' preliminary bidding schedule to compare it with the schedule the project team has developed. This is typically the project team's first opportunity to get the activities subcontractors' professional opinion as to how long the activities' construction work will actually take. This is then compared to projected scheduled duration and adjustments made accordingly.

Now, the contractors are not paid for doing this; it's just part of the business. So typically, contractors don't like to spend much time developing construction schedules during the bidding process. At this point they are not assured of getting any contracts. The only exception to this reluctance of contractor input is when the selection of that activity contractor may depend on a previous track record of being able to meet a tight completion date. This is normally the case in "fast-track" project production execution. Then the contractor's schedule becomes a bidding edge that is worth the extra bidding expense to the contractor. In the case of fast-track projects, the contractor's proposed schedule will undergo intensive examination by the project team during bid openings and must be viable within the owner's project schedule.

At this proposal stage, the project scheduler must evaluate the schedule in relation to the contracting plan and the construction technology available to improve the production timeline. For example, there could be company policies affecting the contracting plan that could be changed for this project to improve this particular project schedule. If they are, both the owner's project team and the prime contractor determine if the proposed changes are

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viable and then review the new suggestions. This is the same procedure for substituting construction technology improvements that will shorten an activity's completion duration.

As the project scheduler, you must be aware of where the "hot spots" are that will make or break you. Proposal scheduling is a critical juncture of one of the hotter spots. Here you must show your experience and critical analysis to the project team. At this point, project schedulers must make their opinions known to the owner, client, or project management team if they disagree with what is being developed in the proposal scheduling. The next stage is the schedule going into contract, so not voicing any intuitive concerns at this juncture will appear to others as consent to the proposed terms and conditions that will be going into the contract as contractual obligations. Speak now or forever hold your peace.

SCHEDULING SYSTEM SELECTION

The selection of the scheduling system we are going to use in running our project's production is understandably crucial to overall success. To be cost-effective, the selection must consider the following criteria:

- Size and complexity of project
- Scope of services required
- Sophistication of users (owner, project team, field personnel, subcontractors, etc.)
- Available scheduling systems
- Owner preference
- CPM scheduling costs versus savings
- Contract schedule specifications

Your company's experience with its present systems is an important factor, because using a system with which your people are familiar and that has proved itself reliable on similar projects improves manpower time-efficiency in operating the system. Introducing a new system on a project already in progress causes more problems than it solves and is often the kiss of death. Accordingly, the curve of cost-effective schedule control usually goes *down* upon initial introduction and use of a new CPM system, until the system becomes comfortable and familiar to those who use it. Logically it follows then, that the time for training personnel in the use of any new system is *before* operations commence.

The minimum hardware requirements for a computerized CPM network schedule are an IBM-compatible 486 PC of 640K or better memory, an 80-megabyte hard disk or better, and a laser printer. Presentation graphics require a plotter, but that is not essential to doing a decent job of schedule

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control. The cost of the program's training is the hidden factor in the scheduling cost budget, and this depends on the experience and degree of computer literacy of the project team. But regardless of the cost, training is crucial to the success of systems implementation. If a CPM system is not run by CPM-trained personnel, it will not be cost-efficient.

The cost-effective savings in using a computerized schedule come from the generation of much more relevant and usable data than is possible with bar charts. Data generated by a computer has a lower unit cost than labor-intensive, hand-generated data. However, if untrained personnel are processing that computerized data, the system is not being used to its fullest advantage and will not prove to be cost-effective in the long run.

INTEGRATED SYSTEMS

Computerized project management consists of integrated project controls. These include planning, scheduling, and performance-measurement aspects. These controls have to encompass the basic business parameters of progress payments and time billing, computer-assisted design (CAD), cost and time estimating, cost databases, job cost, equipment and inventory costing, procurement, contract document control, and administration. All these facets must be integrated to "wash through" automatically to the primary levels of the project's accounting, which are AP (accounts payable), AR (accounts receivable), and PYRL (payroll).

Even though your project schedule is only one factor in the entire project process, you can see how important it is and how it will influence all the other factors. So just being aware is not enough. You must understand the link between the project schedule and costing areas to see the big picture and appreciate the pivotal nature of your project schedule. A fully integrated CPM system will have most, if not all, of the following components:

Minimum computer hardware and peripherals noted previously
Scanners, digitizers, monitors, printers, plotters, video, CD-ROM, telecom linkage modems
Connectivity
LAN (local area network), WAN (wide area network)
Accounting and job costing program
Estimating program
Contract document control program
Procurement program
Planning, scheduling, and performance measurement milestones
Computer-assisted design (CAD)
Network timeline scheduling program

Today, with personal computers tied together in local area networks (LANs), project schedulers can completely replace expensive and cumbersome mainframe and minicomputer project management systems. Modern CPM software provides the ease of use of personal computers while improving communications among project team members who need instantaneous access to project data, files, and summary reports. Project scheduling data stored on file servers can be made accessible to any member of the project team who needs data retrieval immediately. This instantaneous data retrieval for several end users is termed *multiuser server functionality*. These modern types of systems provide controlled, concurrent access to project files, so that the entire project team has select capabilities for scheduling, resource management, cost control, and summary reports (sorts).

Project team members aren't always in the same office, on the same floor, or even in the same town. They may even be in different states while the project work is taking place. They don't necessarily work the same hours or schedules, may not be in the same time zones, and aren't always available by phone or modem when some other member of the project team needs them. But by using a multiuser LAN system, they can get in touch at a regularly scheduled time and can stay up-to-date regardless of their individual work schedules or geographic locations. The key to any project schedule's success (beyond activities duration control and phases time management) is consistency—through common reporting specifications and sort formats that are understood and workable by all responsible project team members.

Systematic reporting to those who are responsible for production is essential. When time-scale interlinking of production activities must be changed to reflect a new critical path, multiuser server functionality is the type of sort system that fills the bill. Combined with a software tracking system, the scheduler can then provide computerized audit trails of budget expenditures to date and cost tracking reports to analyze how effectively that money was spent.

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4

CPM—Critical Path Management

NOMENCLATURE

Professional project scheduling is built on the fundamentals of the critical path method, or critical path management as it is has evolved to be known as in the industry. Critical path method refers to identifying bottlenecks in the production process and then building a production timeline through them, using the total duration of those activities that will take the *longest* to complete as the basic timescale. Critical path management is the methodology for managing those timeline paths efficiently, by manipulating time management of the interlinkage of activities durations and contingency workarounds. It is a scheduling system that allows the project scheduler to achieve improved time control over a project's production phases. Additionally, an audit trail and cost tracking can be incorporated into the system to provide a reasonably accurate estimate of timeframes required for those or similar activities in future projects.

CPM typically works best in straight-line, time-scaled productions in any business where the timelines can be estimated with a fair amount of certainty. The modern network scheduling software programs are essentially a combination of CPM and S-charts. Critical path management is the most accurate computerized system of network scheduling yet developed. It allows production managers, developers, owners, and prime contractors to achieve control in the following critical areas of project scheduling:

They can figure out where they stand right now in the project.
They can determine where to expect production bottlenecks.

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They can decide what to do next.
They can begin changes today to keep the project on track.

In the construction industry, repeat business does not just come from simply building something well. The companies that get repeat business do so because they manage projects in ways that protect their clients. CPM scheduling tells the owner where he stands, not only financially but also in terms of issues, problems, and resources on the project. Ultimately, that's the biggest concern to most owners. CPM has proven itself by adding more bottom line to owners' investments. In larger projects, such as multiresidential, commercial, industrial, and public works, CPM is mandated by contract.

All production activities will affect each other in either direct or indirect linkage. CPM fundamentals require that a critical activity must be finished before the succeeding critical activity can start. Noncritical activities and those of similar trades, such as roughing in the plumbing and electrical work, can proceed simultaneously. One of the objectives in critical path management is to find the order in which the phases of critical activities must be completed. Those designated as critical activities begin by being assigned to the production activities that will take the longest to complete and are crucial to the production timeline. By tracking these activities, attention is automatically drawn also to those areas where it is most essential to avoid production delay.

When bottlenecks occur in the schedule, those activities and their subactivities on the critical path must be handled first, while those delays off the critical path can be addressed secondarily. This is especially true if a particular activity has zero or negative float. Delays along the critical path begin affecting total project duration. Critical paths may change as production bottlenecks are broken, as critical subactivities are changed, or when new problems surface.

CPM is currently is the only production scheduling system that covers all the phases of a project and allows the project schedule to manipulate timeframes during and around the activities that will take the longest time to complete, then selecting the best ways to expedite or work around the phases of activities for contingency planning. The underlying logic here is that contingency planning reduces risk. When this time-scale interlinking of production activities is combined with a software tracking system, the scheduler can then provide computerized audit trails and cost tracking reports, as well as trends analysis, which is next quarter's forecast of the current numbers logical outcome. These are crucial functions for protecting your client's vested interests in the project and are major selling points of your services as a professional project scheduler.

CPM can be thought of as the path of least float, based on the relationship between sequential activities and completion duration of the activities.

Think of float as scheduling time leeway, or slack. In developing a CPM schedule, the critical path is first determined by identifying all activities with zero float time. Any activity is considered critical if its completion delay will cause total project completion delay. Critical path activities with zero float time must begin when scheduled, or the total project completion date will be pushed back. The arrow diagramming method (ADM) and the precedence diagramming method (PDM) are the two basic zero-float-time scheduling systems from which CPM has evolved.

One of the cost-effective benefits achieved by using CPM scheduling is the analytical consideration of activities duration and job logic sequencing of each activity in the initial stages of the project as the CPM schedule is being developed. An arrow diagram can describe an example of such a CPM network diagram. The tail end of the arrow indicates the start of an activity, and the head end represents the completion of that activity. Using a graphic arrow to indicate paths on a flowchart, each activity (or arrow) will have a start, stop, and duration. When two or more arrows or activities meet, the intersection is called an *event*. Activities are begun and completed at events, and succeeding activities in their production phases move forward from one event to another event. The events are assigned numbers, which the computer uses to change event sequences or durations as the CPM program is monitored and recycled during the production period. The various activities and events in the CPM schedule, making up the network diagram, are interlinked by interdependence and the project's timeline.

A CPM schedule shows the interdependence of one activity on a preceding or succeeding activity, much like a shadow. For instance, if the excavation for the building's footings is scheduled to commence 10 days before forming activity commences and 16 days before placing of the concrete event commences, any delays due to late delivery of materials or inclement weather will cause subsequent activities to be delayed, pushing back the contractual completion date. Typically, in modern commercial projects, a structural-steel framing system will be erected on the building's foundation. So if, in our example, the earthwork excavation delayed the forming and pouring of the footings, the delay would also push back the entire phase of activities involving placement of the steel and iron workers. The CPM schedule will also show what effect inclement weather delays will have on foundation work, completion leading to the structural-steel starting events and finishing events, and the relations of these changes to all other construction phases. If there is zero float time on the critical path, the project scheduler using CPM can decide whether the concrete foundation work is to be accelerated or the steel erection can be delayed.

Showing interdependence of one task, or work item, on another is the major difference between bar charts and CPM scheduling methods. Whereas the standard bar chart may show a continuous line of activity for a particular trade, which starts at one point and continues uninterrupted to another point, the CPM chart draws attention to the specific starting and ending dates (events) for each major portion of a construction component. Critical path management will also show the interdependence of each activity and the effect of one event finishing late or early on the starting event of the succeeding construction activity.

CPM scheduling has its disadvantages also. It will increase the total contract price. Such schedules are expensive to create and maintain. In addition, a professional CPM scheduler usually must be hired to develop and manage the schedule. The project team, or at least those who are responsible for production, must be trained in CPM. Finally, small- to medium-sized contracting companies typically believe such a sophisticated schedule is unnecessary and a hindrance to work. In such a case, the subcontractors developing and maintaining a CPM schedule may be haphazard at best. However, requiring the contractors to construct and maintain a CPM schedule has at least three advantages. First, it requires the contractors to work more efficiently. Second, it gives the owner an instantaneous summary of the actual progress to date of the project. Third, from a litigation standpoint, requiring the contractors to maintain a CPM schedule helps prove or disprove financial claims and change orders.

CPM project scheduling starts with the preparation of a network diagram displaying all project planning and construction activities required for the project's completion. The primary work items needed to complete each activity must be identified, located, and lined up. The scheduler then determines which tasks must be completed before each following work item can be started. Once the overall length of time is determined by adding all the phases that will take the longest, the job logic order in which these activities must be completed is established. Finally a network diagram, which is an activities flowchart, is worked out.

Some project activities precede others on a straight-line basis and cannot start until a prior activity has been completed. Other activities can start prior to the completion of a preceding activity, while other activities are performed simultaneously or concurrently with others. Those activities whose durations are crucial to the overall project completion date are considered to be on the critical path. These are the basic factors necessary to construct a CPM network.

Next comes the scheduling phase, in which an estimate of the time required to accomplish each of the activities is developed. This is really an educated "guesstimate," so we have ways of dealing with inside and outside figures for factoring a time cushion, which we call *float*. The third stage involves installing these estimates into the activities network diagram and, finally, in the fourth stage, computations are made of data and critical paths

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of activities to provide the time-scaled network of the project. CPM is traditionally explained as this sequential order for illustration. However, in real-world usage this is rarely the standard procedure. And that's the crux of the matter right there. *There is no standard procedure*. Because each project is unique, no single formula can factor in all the intangibles. The computers can do instantaneous, error-free computations, but it will always take an analytical mind using experienced critical thinking to program and run those numbers profitably.

For example, in the time-compressed business world of today, these four basic planning steps often are completed simultaneously. Those trained in CPM use programs that "wash through" this data instantly to each stage, and change datum in all related stages if one factor is changed, using "what-if?" scenarios. For the sake of instruction, though, we will use the assumption that they are each treated separately and in the order listed above.

Timeline computations are just simple addition and subtraction. The task of time-scaled computation is usually just as simple and easy. However, managing the timelines of the many tasks and activities involved in a modern project quickly becomes an enormous challenge. You will see, as your career progresses, that there are days when your CPM network timeline feels like a nervous mustang ready to leap out of control. Accordingly, most schedulers use computers to manage their CPM timelines. And with the use of dedicated software programs, the timeline can be updated regularly without redoing the entire network diagram. Complex time variables can be "best line linked." Forecasting by use of trends analysis shows the probability of various outcomes. Each activity can be updated regularly for accurate data factoring.

Typically, this is done in daily updates. This frequency serves two purposes. First, it guarantees timely accuracy in your data and pries open the largest window of opportunity necessary to make changes and workarounds before problems start costing money. Second, it produces a superior kind of detail orientation, combined with fast results, that tend to prevent budget cost overruns and give the astute project scheduler a definite advantage over the competition. This is the type of professionalism that produces profit and builds the reputation that you are worth a larger paycheck. Your competition consists of scheduling management companies that specialize in all levels of network scheduling, for contractors, production factories, architects, and owners.

The complex scheduling problems that occur in commercial CPM can be worked out rapidly by using program logic in a dedicated software network system, and time management becomes a viable tool for working out options, workarounds, and solutions. A programming task that normally takes hours to complete, if done by hand, can be accomplished in seconds by computer programs incorporating program logic. This rapid access to data is one of the

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key reasons for the successes of CPM. This speed of program logic allows variables to be worked out or planned around before they cost money.

TERMINOLOGY

To better understand critical path management, you first must know the lingo of CPM, along with the terms' meanings in network diagram scheduling. Here are the principal terms and definitions of procedures of network scheduling, in order of their precedence:

Task. A task is an individual unit of work that may combine with other tasks to complete an activity or be independent work items. Tasks can be thought of as the separate work unit items that collectively need to be done to finish each activity sufficiently enough to start the next activity.

Activity. Activities are any single identifiable work step in the total project's production. Groups of tasks, combined to finish a job item, are activities. Once the activities have been identified, their sequential task logic is established. Then begins outlining the project graphically into a network diagram. In a velocity diagram, the symbol for an activity is an arrow. The arrow connotes linear timeline movement from left to right, start to finish. The continuity indicator is the arrow from one activity to another.

Activity number. Number assigned to each activity. These numbers should be sequential. The computer will not be able to establish job logic if activity numbers are nonsequential.

Activity list. List of work items for a project; also the work breakdown structure.

Activity duration. Elapsed time to perform an activity, start to finish.

Arrow diagram. CPM network diagramming method using arrows to show activities interrelationship and the flow of job logic.

Event. An event is the exact day at which an activity is just starting or finishing. Network program logic applying to all events is that all activities leading into an event can be started at that time. An activity is always preceded by an event and followed by a sequential event. Thus, an activity always has both a starting event and a finishing event. Theoretically, that finishing event is the starting event of the next activity. However, one must always account for the natural constraints of the real world and provide a timing leeway cushion allowance as problems in actual production will require the ability of contingency planning for tasks and/or activities that may get bottlenecked along the way. Proper use of float is the method of contingency planning here, which is known by the term *workaround.*

Event diagram. The most common event system uses circles at the ends of each activity arrow. These circles are placed at the junction of the arrows and they represent the event, or the moment of time at which an activity is just starting or finishing. Important events that mark the completion of a phase, such as a foundation final, are called milestone events for they serve as benchmarks to your schedule's progress versus run time.

Milestone. Date on the schedule predetermined for a phase or important occurrence is scheduled to take place.

Early start date. Earliest date an activity can start.

Late start date. Latest date an activity can start.

Early finish date. Earliest date an activity will be completed without float.

Late finish date. Latest date an activity will be completed without negative float.

***I–J* number.** The letter *i* designated symbol for the tail of an arrow (start of an activity), and the letter *j* designated symbol of the head of an arrow (finish of the activity).

Float. Measure of available scheduling leeway time on any activity's completion.

Free float. Time that activity finish can delay event without affecting the succeeding activity's start event.

Total float. Measure of available spare time or scheduling leeway available on all activities' completion. Total sum of all free float.

Negative float. Time a critical activity is late meeting its finish event.

Phases. Phases are groups of activities that will happen in a logical order, precede or succeed one another or happen simultaneously. As tasks are the micro-units, phases are the project's macro-units. Phases are arranged in divisions with sequential velocity management. Phases are supposed to flow into each other smoothly, on time, with no problems. If problems are anticipated, contingency planning in the form of workarounds needs to be established ahead of time.

Constraint. A constraint is a potential real-world limitation, or a tactic of the scheduler in creating a float window during monthly recycling of the schedule, that can delay the starts of activities or tasks. Constraints, known as a dummy activity on network schedules, are shown as dashed lines with zero elapsed time. Constraints are negative factors that balance the calculations of job logic.

Job logic. This is the sequential relationship between activities, identified and defined during preschedule planning. These relationships consist of the necessary time and sequential order of construction operations throughout the project.

Logic diagram. Arrow diagram of complete project network schedule, or a cross section of an area of production.

Time-scaled chart. Logic diagram with a time scale.

Velocity diagram. Velocity diagram means a straight-line, time-scheduled flowchart. The purpose of the velocity diagram is to determine the most efficient paths to joining the activities in total operational network scope. Traditionally, the arrows in a velocity network diagram represent the activity itself, not the direction of movement. The angle of slope and arrow's length are not factors in the scheduling, simply the designer's choice. Each arrow in the velocity network diagram represents an activity, identified by its activity number.

Velocity network schedule. This is the culmination stage of CPM. All the preceding scheduling elements are computed into a master network plan for the entire project's scheduling, including postproject closeout. Here each activity is now also assigned its relative *i–j* number.

PERT. Program evaluation research technique. Mainly used by the military and defense industry contractors. Optimistic time = earliest completion, shortest time. Pessimistic time = latest completion, longest time. Realistic time = normal completion, average time.

CPM schedule. A production schedule using the critical path method of activities management.

PDM schedule. A schedule using the precedence (or node) diagramming method.

DEVELOPING YOUR CPM SCHEDULE

The first step in developing your schedule is to establish the "levels of specificity." It is important that you decide at the outset where you will put your planning energy. Consider which parts of the schedule and which aspects of the project are most important to your planning objectives. Set some general time expectations for each part of planning the schedule and try to keep them. This is a critical stage of the planning process, as you must answer each level of specificity question to avoid getting bogged down in the process or devoting an unreasonable amount of time to less important parts of the schedule. Consider the following in creating a level of specificity in developing your CPM schedule:

Sufficiency of past performance data. How good is your company's historical information? Have the numbers shown a consistent pattern? If so, you can rely on them more. If not, find a better predictive source or database.

Study vulnerabilities. Are there predictable risks? Do certain types of activities show poor event estimates in the past? How about the subcontractors? Are other construction projects similar to yours experiencing problems in areas of production?

Seek opportunities. Are there particular areas of the project, such as atypical activities, that would benefit from special attention or critical inspection before scheduling? Find the greatest opportunity areas and devote extra time to them. These are areas in which you can save the owner money and thereby improve your professional reputation (and price).

How much can you gain? What is the potential for increasing production in each activity? If the potential is small, do not spend much time on it, even though solving the problem might give you some personal satisfaction as a tactician.

Time management. How much time can you devote to planning and developing the schedule? What resources can be economically devoted to developing the schedule? This is often a tough balance. The answer here lies in what kind of businessperson you are. If you spend much of your business time in fighting business fires between contractors' work schedules in developing the schedule, planning is most important but least convenient. Consider your personal business tendencies: Are you generally obsessed with detail? Better then, in the interests of time management, to be a little more general to ensure getting the job done.

In summary, levels of specificity generally establish how much detail you will gather. You would be well advised to do a detailed activity survey as part of your planning. You might also choose to research your competition via other projects that have finished lately. Are they doing financially well now? Did they come in on time and on budget? What did the project managers do wrong?

At this point, the development of the schedule depends on the project team's talking the project through. This is a critical part of the project schedule's development. The project's management is now subject to careful scrutiny by all those who will have a hand in building it. Detailed examination of the project scheduling network logic comes next, by not only the owner and project team but by the prime and subcontractors who will be doing the work. The network diagram is then broken up into its timeline, and the sequential order of the construction phases plus the timetables for those phases are agreed upon or negotiated.

By the time a project owner or developer puts the project out to bid, a viable CPM network schedule needs to be in place. Production scheduling usually starts right after the project's contract is awarded. At the precon, the prime contractor provides his overall timing schedule for the project and the activities subcontractors provide their scheduling within the parameters set by the prime contractor. Typically, if the owner has any experience in construction development, the owner (or his agent, usually the project manager) will provide a contractual CPM schedule to which all three parties agree (or negotiate their positions)—which means your project schedule now becomes a legal contract document.

In a CPM schedule, arrow diagramming is most frequently used. The logic of an arrow diagram is graphically apparent to any reader. Obviously, the total project cannot be completed earlier than those portions of the work that require the *most* time to complete. This point of logic is what CPM is based upon. On complex schedules it is impossible to determine by examination of the network diagram which paths represent the critical path; thus computers have come into the picture. By using their speed and accuracy in computations, all possible combinations of tasks and activities times, the early and late starts and finish dates, and the float times can be analyzed until all the key times can be determined from the computer printout. In addition, the computer determines the critical path, or paths, and shows any overruns in time along the critical path that will result in a total schedule overrun. This same program function can be set up for the schedule budget.

If performed manually, CPM does not offer the benefit of tabular printouts, which give key time data; thus the user must rely upon observation of the diagram itself. Although on very simple arrow diagrams, it may be possible to determine the critical path, it is normally necessary to construct a time-scaled network from the arrow diagram before any true scheduling can be determined. There are four basic steps in setting up a manual CPM network:

1. Establish the critical activities and their durations.
2. Determine the project's job logic and construct a dependency network.
3. Initially prepare a time-scaled diagram of the dependency network and determine the critical path and activities float times.
4. The project scheduler needs to obtain copies from all subcontractors of purchase orders of long-lead items to verify that the items have indeed been ordered and will be delivered on or before starting event deadlines.

There are also four important production timing facts that are determined from a CPM network:

1. Earliest time an activity can start and finish.
2. Latest time an activity can start and finish without completion delay.
3. The amount of float time available in that activity's scheduling.
4. How much of the project is now actually completed versus what is scheduled for completion

These constraints are tools of time manipulation in CPM project scheduling. For example, usually site development includes earthwork and underground excavation work that must be completed before foundation work can be begun. Conversely, the roughing-in of systems, such as fire protection and

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plumbing, can be performed at the same time, because they are similar in job logic but neither is dependent on the other. Activities subcontractors in these groups can finish work of simultaneous duration. Finally, the prime contractor estimates how long it will take the subcontractors to complete their activities. This estimate is made after the prime contractor consults with its subcontractors and reviews their schedules.

Total critical path management can be seen as a structure made up of arrow diagrams reflecting constraints, precedence diagrams reflecting activity interdependence with predecessor and successor, and activities-on-nodes, which show where the activities' events and durations fall. The CPM project scheduler begins by dividing the total project into different activities in different phases. Float time is used to act as an activity-linkage cushion for the network schedule, to handle the unforeseen variables and long-lead item delivery uncertainties that exist in construction projects. Next, the scheduler identifies the activities that must be completed before the other activities can be started and which will take the longest to complete, and a critical path

Activity	Duration	Constraints
Excavation	10 days	None
Formwork	7 days	Excavation
Concrete pour	4 days	Formwork/plumbing
Plumbing	5 days	Concrete pour
Electrical	4 days	Concrete pour
Roof	6 days	All

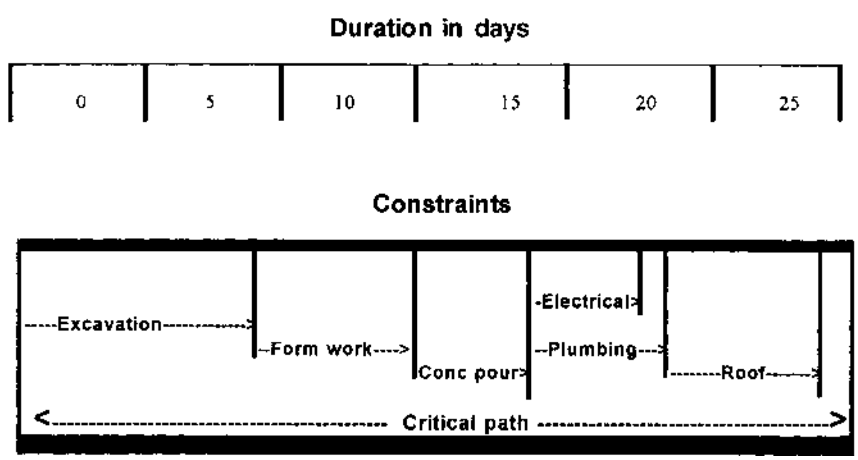

FIGURE 4.1 Activities, durations, and constraints.

for these activities. A commercial or industrial project may have thousands of activities, with just as many subcontractors, on multiple critical paths. Figure 4.1 shows the production activities for a small job (garage), and their respective durations and constraints.

Now let's look at a larger residential project. The CPM schedule for this project appears in Fig. 4.2. The total project under this schedule should be completed in 90 working days. The critical path is shown as the longest path on this schedule, consisting of those critical activities that will cause a delay to the total project if they are delayed. In this example, all critical activities are on the critical path. A delay to any of these activities will delay the entire project. In contrast, lot grading and heating activities are not on the critical path. Their delay, up to a point, will not delay the total project. If the heating work is delayed five days, the total project will not be delayed. There is allowance

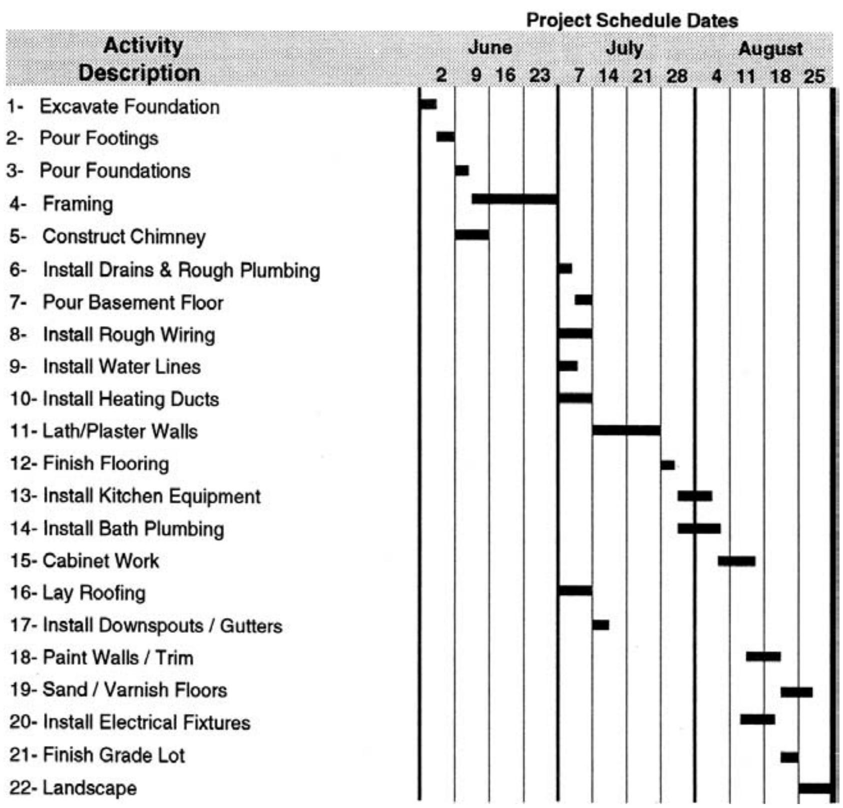

Figure 4.2 CPM bar chart.

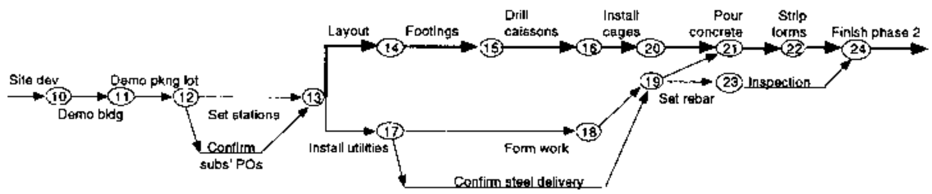

FIGURE 4.3 Network schedule.

for float in our example. The number of days each noncritical path activity can be delayed (free float) is

Roofing	53 days
Downspouts and gutters	55 days
Grade lot	54 days
Landscape	55 days
Chimney	55 days
Heating	57 days

If any of the activities on the noncritical path (16–22) or (5–11) are delayed beyond their float period, they become part of the critical path. After the activity (3–4) Frame, five noncritical paths running in parallel join the critical path. Some activities that were previously on the critical path will no longer be there. Suppose there is a three-day delay to (17–21) Grade lot. Originally, (17–21) Grade lot had four days of free float. Now the CPM must be adjusted, because (17–21) Grade lot now has only one day of free float. The total project has now been delayed one day of total float. (4–21) Heating has now become part of the critical path, and (16–17) Downspouts and gutters has moved off the critical path. Critical path activities, such as (2) Pour footings, (4) Framing, and (11) Lath/plaster walls are not affected by changes in the deduction in free float of (17–21) Grade lot.

Figure 4.3 shows the relative S-chart with a timeline for those activities.

SCHEDULE PLAN EVALUATION

The last major step in the development stage of a CPM network schedule is evaluation. The evaluation process begins the final design of the schedule. Consider each activity and phase of the schedule. Also consider how you can begin gathering data and information now that will make future evaluations more effective. The first level of testing is achievable milestones matching projected budget costs. If the costs and milestones are right on target, is there any point in studying the schedule plan further and not just submitting it for approval and implementation? You bet there is! Here are some good questions that need to be answered:

Are the project milestones attainable because of your CPM scheduling effort or in spite of it?
Could you achieve the same milestone completion dates with fewer dollars spent? (This one question, addressed to the project team by the project scheduler, will endear the scheduler to the owner forever. Don't fail to ask it.)
Will future budget expenditures be likely to have the same effect?
Could we repeat this cost-effectiveness with similar activities in other project schedules?

If the opposite is true (that is, the milestones and budget breakouts are not matching up), the reverse perspective needs to be applied. In such a case, these questions need to be faced:

Have we failed to implement our CPM successfully?
Were our time management tactics and activities objectives sufficient to attain scheduled milestones?
Were our milestones unrealistic?
Were there changes in our schedule assumptions during the plan period that affected its outcome?

To test the effectiveness of your CPM schedule during schedule recycling, it is essential to begin gathering data throughout the planning period. This may be as simple as asking subcontractors their opinions of previous jobs they've done, similar to their respective activity, keeping a record of their comments, and averaging the information received. Or it could be as complex as a major push to obtain data from every database that has any conceivable bearing on similar activities production. Your database information networking efforts here will provide the basis for success in your schedule plan evaluation.

PERFORMANCE TARGETS

Performance expectations are at the root of a successful CPM project schedule. In the first instance, this is the process of setting production objectives: the percentage of activities completion per day and the relative cost-effectiveness projected versus actual cost. In each phase of production the prime contractor and activities subcontractors need to know exactly what is contractually expected of them.

In the second instance, performance targets are set to establish milestones for each phase's completion. Modern CPM management theory is evolving toward the position that contractors who will be affected by critical path milestone events should participate in creating those milestones during the schedule planning period. Accordingly, as part of the planning process, current CPM standards and methodology should be reviewed periodically before the schedule is implemented. Performance targets should be concentrated around areas of progress development or production constraint, which should then be critically examined and options or workarounds considered.

CPM PROJECT PLANNING

Advance planning of job logic prior to developing the phases of scheduling is a crucial CPM primary step. The importance of planning is often overlooked in the anticipation and excitement of doing the deed. I could go into all the reasons I've encountered over the years about the importance of advance planning, but an author who lived long before my time put it much better:

> He who every morning plans the transaction of the day and follows out that plan, carries a thread that will guide him through the maze of the most busy life.
>
> —Victor Hugo

I doubt if Victor ever did construction scheduling, but his words ring just as true today just as they did 120 years ago. Chaos is the anchor that must be cut loose for a project schedule to perform properly. Prior planning prevents chaos and the variables that cause chaos, thereby reducing risk. The planning of any network schedule must start from a work breakdown structure (which is the detailed activities list) showing each activity to be scheduled. Sometimes it looks like an activity tree, as one major item is subdivided into its major parts.

For example, we might have an activity called "install foundation," which could be further subdivided into "excavation," "forming," "setting rebar," and "pouring concrete." The foundation activity could be further subdivided into "buildings" (affecting structural steel erection) and "equipment" (affecting equipment delivery and erection). The decisions affecting the degree of work activity breakdown will determine the length of the activity list and the complexity of the overall construction schedule. As everything in CPM is series-strung, one thing leads to another. All decisions affect the whole. Conversely, the greater the detail, the greater the control.

Accordingly, the first step in CPM scheduling is the planning stage. The project must first be broken down into its activities and related tasks. Activities and tasks are the two basic components of CPM. The extent to which the project is subdivided into tasks and activities depends on the size of the project; however, the project's sequential planning steps are always the same:

1. **Create milestones.** Planning establishes expectations and goals for your project schedule. It requires project-wide coordination and project team commitment to common goals of achievements in critical activities.

2. **Establish priorities.** Planning requires you to consider basic goals, policies, plans, and resources, and their relative importance. By establishing priorities, you also establish a relative scale of importance to assess your resources allotments.

3. **Predict problems.** Planning predicts problems and production bottlenecks in activities and operations. It invites the creation of controls and evaluation procedures.

4. **Solve problems.** Contingency planning allows you to evaluate what doesn't work and then to consider what might be done to fix the situation. With a plan detailing your assumptions and expectations, it is much easier to identify what went wrong when problems arise in the project schedule. Even guessing will allow you to check and improve areas of concern within the schedule.

5. **Go for profitability.** Planning forces consideration of the financial issues and owner's cost before resources are committed. It imposes a test on intuitive choices, points out options, and allows for you to consider alternatives.

6. **Establish motivation.** Planning also encourages full participation from the project team and motivates everyone concerned, including you, to put forth his or her best efforts.

7. **Create cost control.** Planning controls costs by creating a demand for periodic reporting, audit tracking, similar comparisons, and cost-effectiveness evaluation. This is a big area of concern to all owners and is one of the major advantages in having a professional project scheduler on the project team, as architects and design professionals traditionally have shown a casual attitude towards owners' cost control.

8. **Encourage development.** Planning is the only way to put milestones into the operational phases of the schedule accurately. It requires considered decisions, rather than default outcomes, balancing needs and demands for resources.

If we boiled all this down into short title tags to aid in memorizing, the list of item nametags would look like this:

Establish objectives.
Organize.
Develop project team.
Motivate.

Hire contractors.
Communicate.
Measure.
Record.
Analyze.

If these steps are considered activities, some of the relative tasks within each activity would be steps like these:

Designate different areas of activity completion responsibility, such as subcontracted work, that are separate from the work being done directly by the prime contractor.
Prepare a spreadsheet list of different categories of work as distinguished by trade.
Prepare a spreadsheet list of different categories of work as distinguished by equipment.
Prepare a spreadsheet list of different categories of work as distinguished by materials.
Break out distinct and identifiable subdivisions of structural work.
Locate all work within the project that necessitates different timing.
Identify all long-lead items that will be special-ordered.
Use owner's breakdown for bidding or payment purposes.
Use contractor's breakdown for estimating or cost accounting purposes.
Use weekly summary reports to track progress.

The activities chosen may represent relatively large segments of the project or may be limited to small steps only. For example, a concrete slab may be a single activity or it may be broken into separate steps necessary to construct it, such as erection of forms, placing of steel, placing of concrete, finishing, curing, and stripping of forms or headers. As the separate activities are identified and defined, the sequential relationships between them must be determined. These relationships are referred to as job logic and consist of the necessary time and order of construction operations. To develop a project schedule, one applies these crucial questions to the preceding steps:

What is the estimated time duration of this project? Exact start date? Finish date?
How detailed a schedule is appropriate? How many reports or sorts do I need?
How often will I update this schedule?
Who needs to receive information about specific areas of progress? When?
What kinds of field reports will I need? From whom and when?

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What computer resources will help me schedule tasks best?
How much time can I afford to spend on this specific project schedule?

Now "flesh out" the schedule by adding these details:

Determine in your mind how to effectively build the project.
Identify each task necessary to complete the job; make a detailed list.
Determine how these tasks will group together to form activities, and make a detailed list.
Estimate how much time will be needed for each activity.
Define how the activities relate to each other. Build a network task flow diagram that clearly shows relationships between activities.
Assign a responsible subcontractor to each activity so that, when you update the schedule, you'll know who's responsible for each phase.
Create an interactive activity flow diagram with the contractors and subcontractors who will do the work.
Modify the task flow diagram until activities seem to flow correctly.
Identify the critical path of production. Remember CPM in its simplest form means establishing the chain of activities that will require the most time to complete.
Seek ways to simplify the project. Explore any options to compress the schedule by performing activities in parallel.
Consider whether you will have sufficient resources to accomplish several tasks at once.
Eliminate negative float by modifying the network. (We further define float in Chapter 5.)
Identify all long-lead items. Long-lead items are those materials and items that are not readily available on the local market and must be ordered, fabricated, or manufactured.
When satisfied with this basic schedule, apply the resources to the activities to build a complete schedule. Although the schedule indicates required actions and when they must be done, resources such as people, equipment, material, and money actually do the work.
Double-check to make sure you will have the required resources when you need them. Failure to do this step always results in cost overruns.
Juggle the schedule to resolve conflicts with other activities that use the same resources, and reallocate resources if necessary. Use constraints in reallocating resources, because all activities are interdependent and any juggling on your part will have long-reaching effects.
Check that your schedule doesn't call for more than the normal availability of resources. This is one of the pitfalls the inexperienced project scheduler often encounters.

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Graph out and level your resource plan. Examine the resource-use profiles to determine whether the schedule contains hard-to-manage peaks and valleys.

Consider the combination of time and money your schedule represents. Could you deliver the finished product sooner if you had more money or resources? Are these factors worth thinking about before you seek approval of the schedule? Compare costs, list requirements, check assumptions with the project owner(s), and refine the plan.

Organize your project's schedule information by categorizing activities by phase, responsibility, department, and location.

Set priorities and progress milestones along the schedule.

Make your computer summary reports easy to retrieve, and interlink the files to automatically analyze field progress reports. Summarize all details.

Be sure to regularly record the status of every activity. Keep track of who did what and how close each came to the projected scheduling so that you can improve future schedules. Gather progress reports regularly, preferably daily. Record how long it takes to perform each activity, what percentage of the activity is actually accomplished, and how much more time is required to finish the activity. Make sure the data you use for your analysis are accurate. Any data processing system, such as a CPM network schedule, is only as good as the data and information entered into the system for computation.

When the time sequence of activities is being considered, constraints must also be considered. Constraints are the practical limitations that can influence the start of certain activities, and they are shown on CPM schedules as dummy arrows. For example, an activity that involves the placing of reinforcing steel obviously cannot start until the steel is on the site. Therefore, the start of the activity of placing reinforcing steel is constrained by the time required to prepare and approve the necessary shop drawings, fabricate the steel, and deliver it to the job site. A CPM project schedules timeline constraints just the same as activities and will display them as dummy arrows with durations on the network diagram.

A comparison of the amount of detail covered in a CPM work breakdown structure and in a comparable bar chart clearly shows the difference in the amount of detail the two systems cover. Bar charts cannot even approach CPM schedules in activity numbers without becoming completely unworkable. Another outstanding advantage of CPM is the intangible benefit of forcing the project team during the planning stage to dissect the project into all of its working parts. This forces the early critical analysis of each work activity. The project team will then run the first pass of the schedule several times, to test and debug the logic diagram before the final version is ready for review and approval. So your initial CPM logic diagram equates to a practice run on the computer for the full-blown project schedule.

Experienced owners and developers are aware that the actual scheduling phase, such as calculating the early and late start dates with interlinked free float, is best left to the professional project schedulers who can cook the schedule into that final, debugged, logic diagram. They will want to see a smoothly flowing job logic within the network schedule that they can relate to as being realistic and achievable. The owner and project team look favorably on contingency planning here by the scheduler, that provides alternate critical paths.

SCHEDULING BUDGETS

A scheduling budget allows you to keep control over cost expenses. It shows you what you need to do to make the schedule operate successfully. It indicates where resource allocations have priorities, and in this sense a scheduling budget is used to project goals to work toward. Meeting these goals means expenses should match projections by the end of each month. And if they do not, you should immediately adjust the scheduling budget, based on the newly revised anticipated cost expenses.

Budget costs in construction projects are divided into two major categories: direct costs and indirect costs. Direct costs are those expenses that are specifically by the project, such as labor and materials. Indirect costs are those expenses that are the costs of doing business not directly related to any one job, such as operating expenses and overhead. If the indirect cost budget does not allow for the expense of a sophisticated scheduling method, and the cost of training personnel required to use it, the project is going to come up short of money. Most computerized CPM scheduling costs have a tendency to grow and overrun their budgets because of just such an oversight.

A common problem is job stretch-out, which increases the schedule cycles, which in turn runs up the scheduling personnel hours and computer time. A factual estimate of the total cost of the proposed scheduling system is needed if an effective system for the project is to be selected. A second common problem is mixing cost control and schedule control. This, in my experience, has never been very successful on larger projects. The problem here lies in the fact that the budget numbers are broken down into different categories than the schedule activities, and cost-tracking systems need the numbers of both the budget and the schedule to be separated for cost accounting accuracy in the audit trail.

Combined schedule and cost-reporting systems have not yet become sophisticated to the point of overcoming intermittent data entry such as this, and accordingly they cannot generate audit-trail accuracy. Although these scheduling systems are cheaper to purchase and operate, it is best to use caution when employing a system that ties those two key areas of project control together and thereby runs the risk of losing control of two very critical areas of project management. This is especially true of larger projects with multiple critical paths. Schedule control and cost control need separation for individual control.

In order to make the most efficient use of remaining resources in the scheduling budget, the project scheduler must look carefully for cost overruns. Checking for cost overruns means determining where cost exceeded expenses. This is money that could have been applied in the project in a more efficient manner, is now lost, and must be made up by shaving money from succeeding activities or from the owner's profit.

HUMAN RESOURCES LEVELING

Another major advantage of the computerized CPM system is the ability to level out labor resources peaks during the project schedule, in workforce labor and administrative personnel requirements. These peaks happen intermittently throughout the project's design and construction phases. By taking advantage of the available float and rescheduling the start of noncritical activities, it is possible to shave some labor force and personnel peaks. Leveling the personnel requirements leads to more cost-effective use of the project's human resources by adjusting the costs to phases, and deleting duplication of effort. This option is invaluable for smoothing out the different work trades manpower peaks in key areas of the work. Judicious use of the early and late start dates can also keep subcontractors from getting in each other's way, which results in delay for those interrelated activities.

Selecting specific areas of human resources leveling allows the project scheduler to level only a select area, or range, of the network schedule. This select critical analysis cuts down the time needed for leveling operations. It also improves the computer's variables needed by the program to calculate "what-if" analyses. As critical activities are completed, the network's human resources leveling decreases as activities are omitted. And as the human resources needs will vary from project to project, the scheduler needs to utilize the select areas of leveling that are applicable to the specific circumstances.

An important aspect of human resources leveling is that key project team personnel should be thoroughly trained in CPM. That includes all levels of personnel, from the design architects through the construction management team, and should also apply to field operations supervisory personnel. It is not recommended that a newly trained crew be controlling a large project, or using a new software system without running the old scheduling system in parallel, at least until the new system has proven itself to work and the personnel running the system have become familiar with it. If the new system breaks down for any reason, and you don't have a back-up system that's been running in parallel, you will be without any way to control the completion event on the project, and on a critical path to litigation.

MATRIX NETWORKING

The most sophisticated CPM project scheduling systems incorporate "matrix networking," in which specialized subcontractors and activities are utilized in a variety of project-oriented configurations. The project manager works with small teams from the various areas of specialization in the project, toward common ends of interlinking completion events.

This is a highly responsive and event-oriented operations system, producing a matrix network that will suffice as divisional factors in the CPM schedule, thereby reducing the time required to manage multiple schedules. This is one of the basic elements in fast-tracking. However, matrix networking requires sophisticated subcontractors and project team members with good communication skills and a commitment to the project's schedule.

Matrix networking is a process of determining:

The tasks and activities to be performed
The time, in events, to be devoted to each
The job logic sequence of each activity
An optimistic and pessimistic completion timeframe

By combining these four tasks into a timeline matrix, we cut down on some of the data processing time on most of the schedules if we are running multiple projects and multiple schedules—and if those schedules are similar. Controlling the CPM network schedule by matrix networking is a combination of planning and presetting policies for operations that include activity milestone summary sorts. The advantage to using matrix networking is that if you do so, the summary sorts become evaluation mechanisms *before the fact*. This gives the owner an edge just as fast-tracking does.

This type of controlling is an area of opportunity for most small- and medium-sized projects running budgets of $10 to $25 million (that's a medium-sized construction project in California, according to SBA statistics). The development of cost-efficient processes for assessing performance expectations, measured by milestone indications of success, coupled with remote (field) data collection systems linked to a host processing computer back at the office, is fast becoming the difference between success and failure in CPM scheduling.

As the schedule grows in complexity, the functions of controlling CPM through matrix networking also become increasingly complicated. At this point, it is critical to keep in mind that it is not necessary for you to be a statistician to begin analyses of these time manipulation factors. Remember, that's what the computer is for. Set up the spreadsheet formulas to do the range statistics calculations for you. Spread your databases over many ranges, and remember to leave a blank row or column between each database for additional safety in data retrieval. The big picture is what's important, and where you need to stay focused. So the more you understand about the limits of your schedule and the elements that define as well as constrain the project's production events, the better you will be able to manage time manipulation of those events.

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5

Network Scheduling

ACTIVITY ARROWS

In network diagramming, the symbol for an activity is an arrow. The arrow represents linear timeline movement from left to right, start to finish. The production continuity is the arrow moving from a preceding activity to a succeeding activity. Arrows in a velocity network diagram represent the activity itself, not the direction of movement. Neither the angle of slope nor the arrow's length is a factor in the scheduling, simply the designer's choice. Each arrow in the velocity network diagram represents either an independent activity or an interdependent activity. Its respective activity numbers identifies each arrow.

In the example diagram in Fig. 5.1, the activity arrow designated (3–7) is "Install caissons." The according tasks that will fulfill that activity, in their order of precedence, are as follows:

1. Accept winning bid and award contract.
2. Schedule municipal inspection.
3. Order and deliver reinforcing steel cages.
4. Lay out the exact location of the hole.
5. Excavate caisson.
6. Install rebar cages.
7. Connect cages to foundation continuous rebar.
8. Place concrete.
9. Strip forms.
10. Clean up site.

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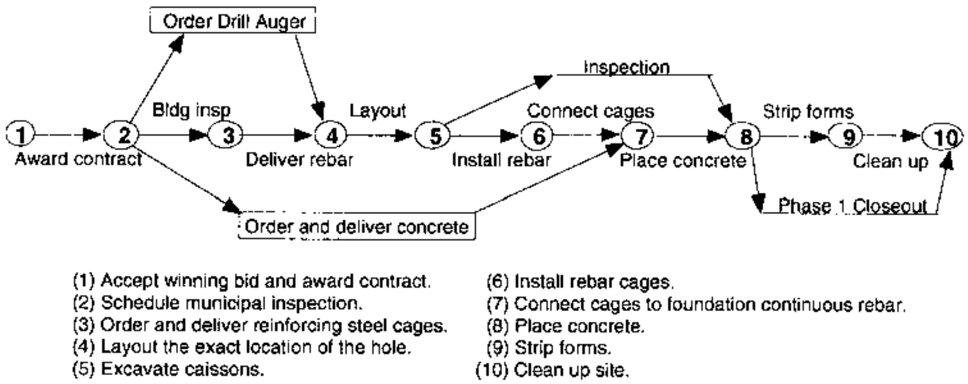

FIGURE 5.1 Job logic.

In Fig. 5.1 we see the sequential path that represents the job logic of the production. Although the activity (3–7) "Install caissons" is in actuality the task of pouring concrete into the predrilled holes over the preinstalled rebar, the task is dependent on activities 1 through 7 having been completed before the concrete truck shows up on the job site. If any of those activities are incomplete or delayed, there will be a direct effect on activity 8. Thus we have established the critical path for this part of the network schedule.

DUMMY ARROWS

Dashed-line arrows in CPM diagramming are the symbols for dummy arrows, which are diagramming symbolism showing the constraint dependency between activities. Any dummy activity acting as a constraint is shown as a dashed line with zero elapsed time. The direction of the arrow shows the production order of activities, and a dummy arrow shows what activities constrain the start of another activity or activities.

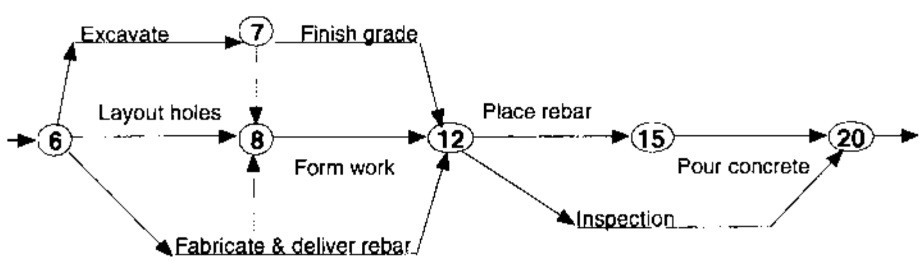

FIGURE 5.2 Dummy arrows.

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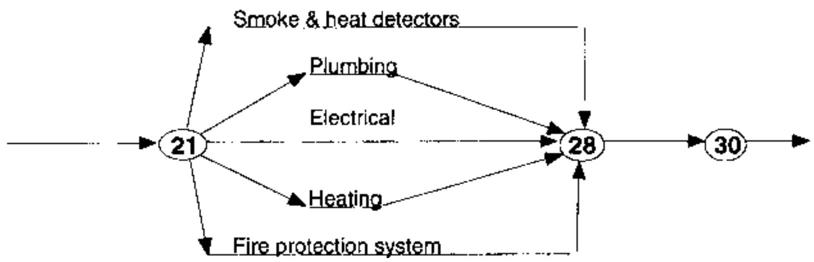

FIGURE 5.3 Parallel activities.

In Fig. 5.2, the dashed arrow (7–8) is a dummy arrow showing the constraint of (8–12), starting until both (6–7) and (6–8) have finished. There is no similar constraint upon activity (7–12), so it can start when (6–7) finishes. It is not dependent (constrained) on the completion of (6–8). It also shows that the CPM job logic must move forward from this activity. If two or more activities begin to run simultaneously, the computer reads only the same *i–j* number of both activities. So the project scheduler gives each activity its own *i–j* number for the computer to use as a relative cell address for that specific data, showing it on the network diagram as a dummy arrow.

In Fig. 5.3, five activities in this network diagram can start and finish at the same time and be completed in timelines parallel to one another. However, the computer reads only the same *i–j* number of (21–28) for all five activities, thereby making it impossible to separate the activities in the computer program. To overcome this lack of separation and control, the project scheduler uses dummy arrows to assign *i–j* numbers to each activity, thereby giving each activity its own computer cell address. The project scheduler who assigns different *i–j* numbers to any activities that are running in parallel also uses dummy arrows.

Fig. 5.3 shows how these five parallel activities can be run simultaneously and can be further utilized in time management as parallel activities

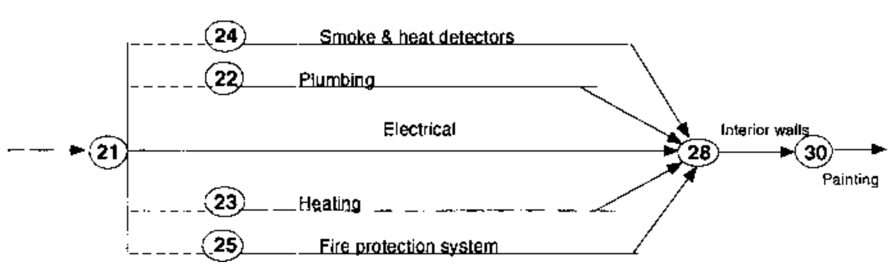

FIGURE 5.4 Parallel activities constrained by dummy arrows.

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adding to total float. By the use of distinct *i–j* numbers assigned to each of the five activities, dummy arrows are used as shown in Fig. 5.4 to show the interdependent relationships. Now the five parallel activities shown in Fig. 5.3 retain the interdependency relationship of each activity to the other and are further identified by distinct *i–j* numbers. The computer program now identities them as activities (21–24), (21–22), (21–23), and (21–25), as seen in Fig. 5.4.

I–J NUMBERS

In CPM, events are the exact day an activity starts or finishes. They are also dates of milestone completions. Events are assigned identification numbers for computer processing. The starting event number is the *i* number, and the completion event is the *j* number. The *i–j* number is used as a relative cell address for recording the activity's data. If CPM diagrams were to be prepared using random activity numbering, all activity numbers in the entire network would have to be renumbered to allow any new or changed activity to fit in a sequence with the other activities.

Therefore, it is a basic CPM requirement that, when event numbers are assigned, the finishing event number at the head of the arrow must be greater that the starting event number at the tail of the arrow, and the *j*-value of each activity must be greater than its *i*-value. A typical CPM network can involve hundreds of separate activities that must remain flexible in scheduling, so the experienced project scheduler assigns the activities *i–j* numbers only *after* the entire network has been completed and is ready for its first cooking or trial-run computation.

Using the vertical and horizontal axes of graph coordinates, *i–j* events can be displayed in either plane. The vertical numbering method is more widely used, which numbers all events in a vertical column in sequence from top to bottom that equates to a parallel timeline those groups of activities then moving from left to right. There is no significance to the event numbers themselves except as means of identifying activities, so if the CPM format of keeping the *j*-value of each activity greater than its *i*-value is used, blank cells can be left in the numbering system so that spare numbers are available for changes or additional work that may come up. Sequential *i–j* numbering provides this flexibility in scheduling, while also providing the computer with program logic data for events and activities locations on the network diagram.

MILESTONES

Milestones are benchmarks of long-term and short-term progress events that require some reasonable progress in activities or tasks toward a desirable

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outcome. Milestones are specific, time-limited objectives that, in combination, are sufficient to achieve those progress goals. Milestones are placed in the schedule to produce

Motivation for project team and contractors
Utilization of competitive advantages
Repair schedule of competitive disadvantages
Acceptable progress to the owner and project team if those milestones are met on time and within budget
Measurement of actual progress versus scheduled progress

At this stage of the process in installing milestones, the scheduler should be thinking in broad terms. As one studies particular areas of the schedule, one develops progress objectives that can be related as milestones. Milestones should reflect both strategic planning as well as current period objectives. They should also represent success, not the absence of failure or the remediation of existing problems. This is an important concept for the professional project scheduler to grasp and use in developing the schedule. Unscrewing a problem isn't progress if the problem should not have happened, so milestones should mark progress only. Positive benchmarking is important; milestones should be specific and measurable objectives. They should also appear as projections of progress evaluations at the end of each construction phase. Interim milestones should measure phases of progress that are critical to meeting long-term project timing. They should "back down" from the specified completion date to the present in sequential order.

Once you have identified milestone phase areas, schedule dates for those events and the completion objectives that go with them. If you are scheduling with a group, such as the project team, it is important to agree upon the goals and objectives of each phase, leading to the establishment of milestones as benchmarks to evaluate the progress toward those goals and objectives. It is necessary to agree upon milestones prior to establishing phases, because milestones should lead the completion of each phase.

To reach CPM milestone events on time, it is necessary to back down to the present. If you are to reach the critical completion date, where must the project be in one month? In two months? Next quarter? To actually achieve your CPM milestones, it will be necessary to periodically re-evaluate start and finish events and use float to close gaps in timing. In planning the schedule, don't spend unreasonable amounts of time on making "perfect phases," but instead create obtainable and realistic milestones by which you can measure the project's progress.

The best planning process is to estimate durations based on what you know and on your company's historical data. Include in the schedule periodic sorts, or summary reports, that will test the milestones objectives for the coming quarter. This tactic will improve future milestone projections. Remember that the purpose of planning is to reduce risk. The best schedule plan is one that allows you to test your estimates before they cost lots of money. This is always your client's perspective and should be yours as well. We schedulers do this by running "what-if?" scenarios with varying activity early and late starts, and varying the activity early and late finishes. A test of the schedule's quality is the extent to which completion events are balanced against float. Every project schedule needs to be built upon these basic criteria:

1. Each macroactivity step, defined into phases. This should be detailed enough to be measurable and give guidance to those who are responsible for managing that area of work.
2. The person responsible for seeing that the activity is completed. This is usually the prime contractor, the site supervisor, a project team member, or an activity subcontractor.
3. Activity cost in relationship to total budget. This should include time estimates and indirect, and direct costs. In the budget sort, a calculation needs to appear with this data to build a cost-tracking analysis.
4. Project phases deadlines. These should include the actual time available by the subcontractor responsible for the activity, including its assigned early and late start and finish events.

All four steps should be closely monitored up to and including project closeout. In larger and more sophisticated projects, this basic outline of plan elements will be more complex but will still follow these basics in a larger configuration. Time and cost estimates are made in greater detail for each activity. "Event dependencies" are established, which must be accomplished before others can be begun. Resources that must be devoted to each are listed, then broken out from the total budget. Resources are then allocated with priority weighing, to ensure critical path activities are resource-covered first. Progress-checking milestones and specific sorts are built in to the procedure to ensure project schedule compliance.

JOB LOGIC

The logical sequence of the project's construction activities, factored by local practical limitations, is referred to as job logic. The activities chosen may represent relatively large segments of the project or may be limited to only small steps. To use a previous example, a concrete slab may be a single activity on a small job, but on a larger job it will be broken into the separate steps necessary to construct it, such as excavation, sub-ex preparation, erection of forms, placing of steel, placing of concrete, finishing, curing, and stripping of

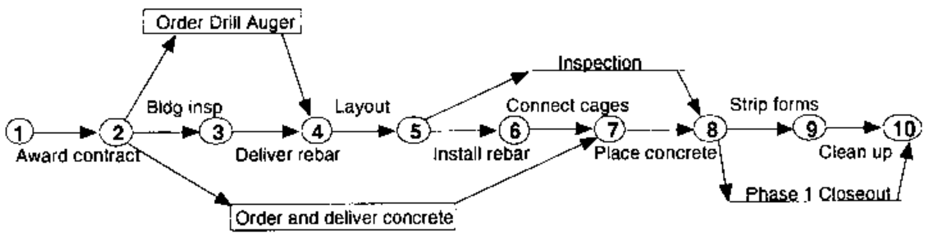

FIGURE 5.5 Job logic factoring program logic.

forms. As the separate activities are identified and defined, the sequence relationships between them must be determined (See Fig. 5.5). These relationships are referred to as job logic and consist of the necessary time durations and sequential order of typical local construction operations that are unique to your geographic area.

It is a basic fundamental in CPM that each activity must have a determined starting event, which may be either its own start or the finish of the preceding activity. Activity durations cannot overlap their finish events. Therefore, job logic is established to provide operations sequences within practical constraints. Established job logic is then used to build program logic within the computerized CPM program. By determining the job logic, activities can have their interdependencies critically examined during all phases of the schedule, before errors occur costing delays and money.

LOGIC LOOPS

The logic loop is a paradox in network planning. It indicates that a critical activity must be followed by another critical activity that has already been completed. Even as I read that last sentence I realize it doesn't make any sense, but bear with me and I'll try to explain. The term "logic loop" is really an oxymoron, since a logic loop is anything but logical. Logic loops should be called illogic loops, but again, we professionals like to keep our industry jargon as confusing as possible. If, in our network schedule, one arrow was inadvertently connected to the wrong node, its path might well be shown to the computer to run backward. Although this seems obvious in a simple, single-path CPM schedule, if we multiplied the paths by hundreds of activities such as in large commercial or industrial network diagrams, logic loops can be easily overlooked in the planning stage.

In the vertical method of notating event nodes, which is more widely used, numbers of all events are in a vertical column in sequence from top to bottom, which equates to a parallel timeline. Because of the vertical config-

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uration, activity job logic can have logic loops in those vertical groups of activities without the scheduler realizing that they are there, the error then moving from left to right on the timeline with the activity group.

I advise you to study the network diagram carefully at the beginning of the development of the schedule to confirm the job logic of the structure and to search carefully for logic loops. The best method to safeguard against them is to use sequential *i–j* numbering. The computer sort printout cannot indicate any clues to the presence of logic loops under the use of a random *i–j* numbering system, so random numbering guarantees a greater likelihood of error by allowing logical loops to remain undiscovered. Accordingly, to make ultimate use of computer program logic—the database—which in this case is the *i–j* numbers, we must number the activities sequentially.

PROGRAM LOGIC

Program logic can best be described as the way the computer puts together the time sequence for the activities involved in the project. The program logic for the sequence of operations in our example of Fig. 5.5, would be based on the following job logic:

Activity	Sequence	Symbol	*I–J* #
Accept winning bid and award contract	1	BC	1
Schedule municipal inspection	2	MI	2
Order and deliver reinforcing steel cages	2	OD	3
Layout the exact location of the hole	2	LC	4
Excavate caisson	3	EC	5
Install rebar cages	4	IR	6
Connect cages to foundation rebar	4	CR	7
Place concrete	5	PC	8
Strip forms	6	SF	9
Clean up site	7	CU	10

This is the type of data strategy that the project scheduler decides initially, and then the project team approves in the planning stage. For the purposes of CPM, job logic requires that each of the activities in the network a definite event to mark its starting point, and another to mark its completion point. This event may be either the start of the project or the completion of preceding activities.

It is a basic tenet of CPM that the finish of one critical activity cannot overlap the start of a succeeding critical activity. When this happens, the work must be further subdivided into more detail. It is a fundamental rule of CPM that a critical activity cannot start until all those critical activities preceding it have been completed.

LOGIC-BASED SCHEDULING

Now we'll take all of the previous elements and combine them into an example that will illustrate logic-based scheduling. Examine the basic layout of a small commercial project's logic-based schedule, as shown in Fig. 5.6. Because all phases have similar traits but different activities, we will examine only one phase of the schedule. The foundation's phase activities, in their job logic, include all subactivities up to and including installing the building's foundation (see Figure for numbers 11–22).

11. Demolish existing structure
12. Remove existing parking lot
13. Survey and set engineering stations
14. Lay out footings, caissons, building envelope
15. Dig footings
16. Drill caissons
17. Install utilities
18. Form work
19. Set rebar
20. Install cages
23. Pour concrete
22. Strip forms

The foundation phase begins as soon as the site development phase finishes with the demolition activity, which can be done as the last part of the site development or the first part of the foundation clearing, thereby having

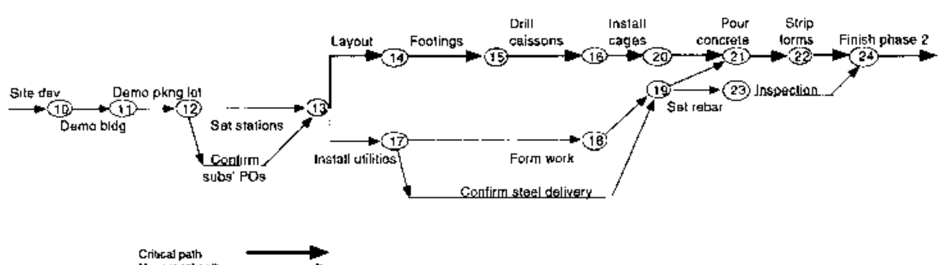

FIGURE 5.6 Logic-based scheduling.

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free float that the scheduler can use to either constrain or accelerate the activity event. The phase begins with demolition of the existing building and removal of the old parking lot. These events run in series because the same subcontractor can do them simultaneously. Activities (17) and (14) can run in parallel, as layout can be done right behind the surveyors. Activities (15) and (18) run in parallel, because the same subcontractor can do them at the same time. However, activities (14) through (21) are in series because each requires the completion of the preceding activity.

Each activity has subtasks within it that require sequential completion. Subtasks within (19) Set rebar, for example, include order and fabrication of the specified reinforcement steel, delivery, and placement of that steel. (20) Install cages would also have a final subtask of pre-pour rebar placement inspection by the municipal inspector before (21) Pour concrete could be done (usually the next day). Each activity's duration is given in events and time-scaled in working days.

The noncritical path for the foundation phase lies through activities 13, 17, 18, and 19. The critical path lies through activities 10–16, 20, 21, and 22. To decrease total phase duration in our network scheduling, we seek ways to shorten the critical path activities' durations. If we could shorten the path through the Footings activity by more than seven days, the critical path would shift to the Form work path. If we could shorten the path through the Form work by 3 days, we would have two critical paths of (15) Footings and (18) Form work running in parallel duration of 10 days.

In network scheduling, when activities are combined in a network in which one activity shares a dependency on a processor activity with another activity, a parallel arrow is introduced into the network, as illustrated in Fig. 5.6, to show the interdependency relationship, as in the case of activities (17–19) and (19–24) to the critical path activities (13–21) and (21–24). A dummy arrow along either path, or subpaths, would indicate a constraint on that activity by a predecessor on that path. A dummy arrow representing a constraint differs from an activity arrow in that it does not represent time, only activity event dependency. All other arrows represent both time and dependency.

To illustrate the timescale difference between paths 1, 2, and 3, activity (17–19) can start up seven days later than activity (14–16) and still finish without extending the critical path of (15–21). Path 1 has 5 days of total float, path 2 has 7 days of free float, and path 3 has 10 days of free float. The free floats of (17–19) and (14–16) can be used to add to the total float of all the activities on the critical path.

By adjusting the activities start and finish events to match the logic-based schedule in Fig. 5.6, we begin to interlock the necessary components. In Fig. 5.7, the numbers in the circles represent the *i–j* numbers for the activities, based on early start and late finish. The numbers under the lines represent the amount of time required in days to complete the activity.

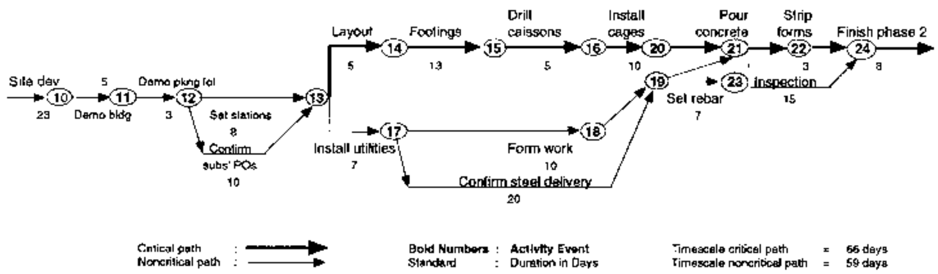

FIGURE 5.7 Logic-based duration scheduling.

By adding the final ingredient of timescale linkage, our network schedule now has controlling CPM. The numbers below or across from a circled *i–j* number represent days' duration, with no float factoring. The time to reach starting event 17 from starting event 13 is seven days, and it is not on the critical path. This allows it to contribute its free float (if any) to the project's total float as needed for the critical path through events 14 to 24. By inspection of the timescaled network, we see that activity (17–19) has 10 days of free float compared to activity (17–18), although both must be accomplished by starting event of activity 19. These types of parallel activities are also used as workarounds in the event of a bottleneck on the critical path.

Examining the arrow diagram and the timescaled chart in Fig. 5.7 shows that the path through activities 17 through 21 cannot proceed past event 21 until the completion of activity 15. Event 21 must be delayed until the completion of event 19. Event 23 and event 21 are to be completed on the same day, so they are shown as happening in parallel. The path from event 16 to event 20 is a total of 10 days, as they are in series, in contrast to the 10 days' total duration for both paths from activity (16–20) and from (18–19). Both paths converge again at event 24, which is constrained by activity 23.

Early and late start dates for each activity represent the earliest that activity can start. Those events, combined with early and late finish dates for that activity (which represent the latest that activity can finish), are the durations that will change the critical path of the production. Events are further assigned a computer identification number, with the starting event number being the *i* number and the completion event being the *j* number. The *i–j* number then links the event to the network timeline as the relative cell address for the activity's data sort.

When event numbers are assigned, the finishing event number at the head of the arrow must be greater that the starting event number at the tail of the arrow, such as event 19 leading to event 21. The computer reads the network schedule timeline as a mathematical sequence, and the *j*-value of each activity must be greater than its *i*-value for computations of program logic.

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Without the use of float, any change in the start day of any event on the critical path will result in changing the completion date of the project. If activity (19) Set rebar is delayed, its delay would push back activity (21) Pour concrete, whereas activity (19) Set rebar and activity (20) Install cages are running in parallel. A typical CPM network involves hundreds of separate activities running in series or in parallel, all of which must have timeline flexibility in the network scheduling. Working back from event 24 on the network schedule in Fig. 5.7, it can be seen that activities (13–22), running in series, must be completed first, plus all activities (17–23), running in parallel, must precede activity 24.

Now we will take all the examples so far of CPM network scheduling and add the ingredient of time manipulation. As we said, without the use of float, any change in the start day of any event on the critical path will change the completion date of the project. Now, by adding the element of float and the flexibility of workarounds, we begin to gain control over the network timeline.

TYPES AND USES OF FLOAT

Float can best be described as scheduling leeway or slack time between production activities. In CPM, float is the number of days a noncritical path activity can be delayed before it becomes part of the critical path. All float types that we look at in this chapter are in increments of working days. It is in the best interest of the prime contractor, the subcontractors, the project management team, and the owner that the project has float periods. These float periods ensure that every activity has some time flexibility. This window of cushioning can be opened or closed (accelerated or constrained) at a critical point to provide a cost-effective production timeframe. Properly used in CPM scheduling, float is a major tool of time manipulation.

Float periods show that every project schedule, even fast-track, has some timeline flexibility. A noncritical path activity can be started a few days after it was scheduled to begin without delaying the critical completion date, whereas a critical path activity must be started immediately once the preceding critical path activity has been completed. Additionally, a noncritical path activity can finish later than the date it was scheduled for completion. However, if a critical path activity's completion is delayed, the total project will be delayed. In terms of constraint on a noncritical path activity, it cannot be delayed longer than its float period without moving to and becoming part of the critical path. By using float in CPM project scheduling, time manipulation of noncritical path activities means accelerating or constraining their starting events a few days after they were originally scheduled, without delaying the total project's completion date.

When an activity has float time available, these extra days may be used to serve a variety of scheduling purposes. When float is available, the earliest starting event of an activity can be delayed, its finishing event can be extended, or a combination of both can occur. We do this through constraints and acceleration. Constraints are explained later in this chapter; acceleration speaks for itself. If we can string activities tightly together, obviously we'll save the most money. To successfully manage the schedules of noncritical activities and work items within the critical activities on the critical path, the project scheduler must understand the interdependent workings of these types of float times and constraints:

Free Float

There are three basic types of float time and other subfactoring types of float within those basic three. The major three are free float, total float, and negative float. Free float is the exact amount of days that any specified activity can be delayed without delaying the early start of the succeeding activity. As we learned earlier, events mark these days and therein the days of free float available on that activity. In schedule computations, free float is the least difference in days between the early finish event of an activity and the early start event of all following activities.

Total Float

Total float is the amount of time that an activity can be delayed without delaying the late finish event for the project's completion. Total float is shared with all activities. When an activity has a certain amount of total float, it can be used without tighter scheduling constraints affecting all the other critical path activities.

Free float, however, is not shared with other activities as is total float, and accordingly free float provides the only true measure of how many days an activity can be delayed or extended without delaying any of the other activities. It must also be added as part of the total float of preceding activities. In Fig. 5.6, the network schedule arrow diagram is used to show a CPM network with *i–j* numbers shown in the circles and the numbers beneath or across from the arrows representing time duration required in days.

Free float would be a portion of each activity's noncritical duration. Total float would be the sum of each activity's remaining free float that could be committed to the critical path. Total float is shown on the CPM summary report "Sort by Total Float/Late Start." It is computed twice by the computer: once plotted on the spreadsheet for early start and finish events, then again plotted for late start and finish events.

Line Float

Line float is the amount of time slack available per line item on a computer spreadsheet. The line float time is easy to compute, because it is simply the difference between the early and late dates for an activity. It represents the available time between the earliest time in which an activity can be accomplished (based on the status of the project to date) and the latest time by which it must finish for the project to finish by its event deadline.

Negative Float

When the critical path has been delayed and production is now behind schedule, the earliest starting event when an activity can begin is now past the latest time in which it can be completed to stay on schedule. This is known as negative float. As the activity has no float, its completion time is reduced to critical duration, and if it is behind, the difference between the early and late dates is less than zero. Negative float shows how far behind schedule the activity is, and if it is a critical path activity, it shows how late the project completion will be.

Distributed Float

Float is sometimes used as a legal weapon by owners and contractors to approve or deny claims for liquidated damages in CPM contracts. Distributed float calculations are used in network scheduling to prevent float being used up by either party in a premature or unjustifiable manner, thereby deleting float from the total project. Distributed float allocates float to each individual activity by using PERT system duration averaging.

Low Float

The most critical work activities within the critical path(s) are assigned low float timing. Leeway is crucial to contractual completion date. Low float activities are listed first on the Total Float Sort, for primary attention.

High Float

Less critical work activities within the critical path(s) can be scheduled with more events timing leeway. High float appearing in later project activities is listed on the Total Float Sort for schedule recycling analysis.

CONSTRAINTS

Constraints are delays placed on an activity's starting event by practical limitations, preceding activity delay, or the project scheduler's time manip-

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ulation of that event. They are used as factoring tools in timescale computations of the network schedule. The only CPM fundamental in constraint on a noncritical path activity is that it cannot be delayed longer than its free float available.

If a noncritical path activity is constrained beyond its float period, in CPM it therefore reaches negative float and automatically becomes part of the critical path. As the project proceeds, some of the activities that were previously on the critical path will no longer be there. Suppose there is a three-day delay to framing. Originally, framing had one day of float. Now the critical path must be readjusted, because the total project has now been delayed two days. Framing has now become a critical path activity, and concrete has moved off the path.

Remember that constraints are those practical limitations that can influence the start of certain activities. The activity that involves the placing of reinforcing steel obviously cannot start until the steel is on the site. Therefore, the start of the activity of placing reinforcing steel is constrained by the time required to prepare and approve the necessary shop drawings, fabricate the steel, and deliver it to the job site. In CPM, you treat constraints the same as activities and represent them as event durations on the network diagram.

These types of constraints prevent activities from starting until other preceding activities are sufficiently complete. Policy constraints are those methods the project team uses in the project's production to consume total float. Constraints are shown as dummy arrows on CPM network scheduling and as dashed lines with zero elapsed time.

FLOAT EXAMPLE

The float of an activity represents the scheduling timing leeway available to be committed for total project critical path duration. When total float is available, the earliest start of an activity can be delayed, its duration can be extended, or a combination of both can occur as long as the late finish time is not exceeded. It is the window of timing available for that activity if the activities preceding it are started as early as possible and the ones following it as late as possible. When an activity has free float time available, this extra time may be utilized to accelerate or constrain succeeding activities. Critical path management uses float as a time manipulation tool, and the nomenclature and workings of float comprise essential knowledge of the project scheduler.

In summary, we have seen that the total float of an activity is the maximum time that its actual completion can go beyond its earliest finish time and not delay the entire project. If the entire total float is used on one activity, a new critical path is created. The free float of an activity is the maximum time allotted by which its actual completion date can exceed its latest finish event without affecting either the overall project completion or the times of any subsequent activities. If a work item within an activity is delayed enough to consume an activity's free float, if it still completes on time, the activities following it are not affected and they can still start at their earliest start times.

If we took our example of the CPM network schedule in Fig. 5.6, and doubled the phase in size to two quarters from January to July as in Fig. 5.7, the network schedule easily shows how days of scheduling leeway between activities could be used along the critical path to shorten activities' duration if needed. Float is computed by certain factors determined by the network time, as in Fig. 5.8, as well as the unit factors of the Sort by Total Float/Late Start.

To illustrate those factoring units of float, we need to identify them each as in Fig. 5.9, our Sort by Total Float/Late Start summary report. The sort shows data columns for each factor of float, which are as follows:

The activity's description
The activity's *i–j* number for computer identification
The activity's estimated duration versus remaining duration

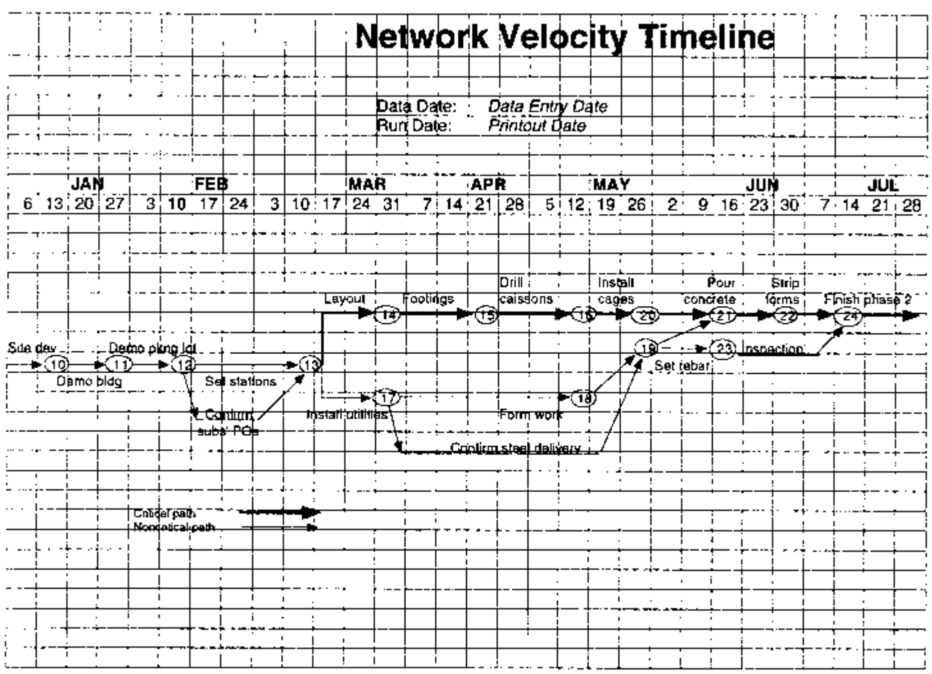

FIGURE 5.8 Durations timeline.

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Your Company Name Here **Sort By Total Float/Late Start**

Prepared For: *Your Client's Name Here*
Project: ***Project's Name Here*** **Page: 1 of 3**
File Name: *Your Computer File Name Here* Data Date: *Data Entry Date*
Description: *Project Description Here* Run Date: *Printout Date*
Our Invoice: ***Your Company's Job Number***
Client Invoice: ***Owner's Job Invoice Number***

I Node	J Node	Activity Description	Duration Est	% Comp	Actual Start	Actual Finish	Free Float	Total Float
Phase 1								
		Subsurface Investigation						
		Instructions To Bidders						
		Information Available To Bidders						
		Bid Forms						
		Supplements To Bid Forms						
		Agreement Forms						
		Bonds And Certificates						
		General Conditions						
		Supplementary Conditions						
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Phase 2:		**Specifications**						
		Subsurface Investigation						
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		Coordination						
		Field Engineering						
		Regulatory Requirements						
		Abbreviations & Symbols						
		Identification Systems						
		Recordation Systems						
		Reference Standards						
		Special Project Procedures						
		Project Meetings						
		Submittals						
		Quality Control						
		Construction Facilities & Temp Controls						
		Material & Equipment						
		Starting Of Systems/Commissioning						
		Contract Closeout						
		Maintenance						
Phase 3:		**Commencement: Site Work**						
		Subsurface Investigation						
		Demolition						
		Site Preparation						
		Dewatering						
		Shoring & Underpinning						
		Excavation Support Systems						
		Cofferdams						
		Earthwork						
		Tunneling						
		Piles & Caissons						
		Railroad Work						
		Marine Work						
		Paving & Surfacing						
		Piped Utility Materials						
		Water Distribution						
		Fuel Distribution						
		Sewer & Drainage						
		Restoration Of Underground Pipelines						
		Ponds & Reservoirs						

Figure 5.9 Sort by total float/late start.

The percentage of activity completion
The activity's actual start and finish
The activity's early and late start
The activity's early and late finish
The activity's remaining free float
The activity's available total float

The computer determines each activity's float by computations between *i–j* numbers of events and corresponding timelines. In addition, we can determine the critical path in this phase runs from event 10 to event 24, the completion time for critical activities, early start and finish dates for each activity, free float, and total float available.

If we use the job logic of two sequential activities, such as placing reinforcement steel for a concrete slab and the succeeding activity of pouring the concrete, we can examine them using the factors in Fig. 5.9 to calculate float. If these activities are not on the critical path and the difference between the early and the late start dates is a total of five days, how much total float does the rebar activity have? (Assume no other activities have constraints on these activities.)

The answer is five days: the difference between the early and late start, or the early and late finish. Now, how much total float does the pour activity have? The answer is five days also, calculated from that activity's duration. Then together, how much total float does the entire sequence of activities have? Ten days? No, because total float cannot be added; the sequence of activities still has only five days. What if the rebar installer is two days late in starting? As of the time started, the activity subcontractor has only three days of total float. The prime contractor has also been reduced to three days of total float. If the placement of rebar finishes three days late, the prime contractor has no float left in the schedule, and the project is on critical path.

In float computations within CPM scheduling, each activity does not have total float individually, but all the activities in all of the phases share the same total float time made from their individual free float. Phases of activities have total float, and if it is consumed by one activity, float no longer exists in that phase for any activities—not a good situation for any project scheduler, and one that the pros avoid like the plague.

6

Network Diagramming

PHASE SCHEDULING

Phase scheduling refers to combining all the divisions of activities (designated as phases) into a multiple critical path network diagram. This type of network scheduling is complex, but it can be made much more accurate by using computer systems. On commercial projects with 10,000 or more activities, CPM computer programs begin using 10 multiple critical paths. Multiple critical path project scheduling software uses dedicated program logic in phase scheduling of multiple critical path management. In phase scheduling, precedence diagrams use float to act as an activity linkage cushion in the network schedule. Normally, the prime contractor divides the total project into different activities in a schedule parallel to the owner's. An industrial project typically will have thousands of activities, with each subcontractor performing a different activity, each of these having subactivities and tasks within them. Then the owner's project scheduler determines the critical activities that must be completed before the other activities can be started.

These types of job logic constraints are a function of phase scheduling CPM management. For example, usually site work must be completed before concrete work can begin, these activities running in series. Conversely, plumbing and electrical activities can be performed simultaneously, these activities running in parallel, as neither is typically dependent on the other. These activities can be in the same phase scheduling, because the subcontractors can work on them at the same time. By grouping activities with similar job logic, we develop macroactivities that can be scheduled in phases.

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By stepping up to management at the macroactivity level, the sorts make large units of data manageable.

Remember that job logic constraints always dictate the path(s) of the CPM network schedule. Because excavation has no prior constraints, it can be performed first. Once it is completed, the form work, plumbing, and electrical, which were constrained by the need to complete excavation first, can now start. The critical path, the longest path on a network diagram, consists of those activities that will cause a delay to the total project if they are delayed. In most projects the primary activities, such as excavation, form work, concrete pour, and roof work, are on the critical path. A delay to any of these activities will delay the entire project. In contrast, plumbing and electrical activities are usually not on the critical path. Their delay, up to a point, will not delay phase scheduling within the total project.

MULTIPLE CRITICAL PATHS

A network with phase scheduling of 10 critical paths of equal duration and event length would have varying levels of activities running in series, and others running in parallel. In such a network, the project team would first develop a primary critical path through the 10 paths. Then they would adjust the durations of the other activities to create secondary paths that, together, would make the 10-critical-path condition. Normally, about 20% of project activities will continually fall on the critical path, so multiple critical path management is a management-by-exception technique. When more than 20% of the activities fall on the critical path, multiple critical paths need to be established or the schedule will no longer be achievable in its present form. Very little float is available in a multiple critical path network, and the owner is subject to claims any time it delays the prime contractor on any primary or secondary critical paths.

The prime contractor, in this situation, is in an adversarial position through clauses in the schedule specifications that direct the contractor to redraw the network any time it is behind schedule on the primary critical path. So it is in the contractor's best interest to eliminate float and back-charge the owner through claims for delay. Often this will last for the duration of the project.

This tactic in multiple critical path schedules, of eliminating as much float as possible from the network, puts the owner at a disadvantage by not having cushions for delays. The project moves faster but at a higher cost, due to claims made by the prime contractor at project closeout. Now that you see both perspectives, you can understand how a project scheduler using different types of float in the phase scheduling can either benefit the owner (if that is your client) or the contractor (if that is your client). It's another profit tool for the professional project scheduler.

In network diagram sorts, as with all summary report printouts factored by the computer on a sorting by *i–j* node numbers, the order in which the activities appear on the list has no relationship to the job logic sequence. This is the computer linkage between the activity on the diagram and the computer data on that activity. Velocity indicates the amount of forward momentum in the timeline, and time manipulation is the tool we use to either accelerate or retard that forward progress in collective or individual activities. This tool is applied through the proper use of free float and total float. Adding these controls to phase scheduling in our network diagram gives us the foundation of network velocity diagramming. Adding event velocity to CPM network diagramming gives us the foundation of fast-tracking, which is today's production scheduler's "jump start" option, which we examine later in this chapter.

BAR CHARTS

The bar chart was invented in the late 1950s by Henry Gantt. He was working as an engineer on a capital works job and developed the bar chart as a graphic representation of the project schedule he proposed. It was so successful that soon everybody was using bar charts for tracking vertical components through a horizontal timeline, which was applicable to every business in existence. Bar charts are now used in all industries for easy and quick visual representation of data. As construction scheduling became more sophisticated, the bar chart was used in combination with hand spreadsheets, to schedule and track construction projects.

Computerized CPM scheduling also produces a bar chart printout sort, which is sorted from the activities' early starts. Bar charts are included in the weekly meetings, as progress reports of scheduled progress versus actual progress. These bar chart sorts are an essential tool for presentation of network scheduling details in the CPM project schedule to the owner and the project team.

Bar charts are effective at activity scheduling and tracking as a job logic diagram. They are cost-effective scheduling tools for smaller projects and on residential work. In commercial and industrial work, schedulers and site supervisors normally have bar charts covering one wall of the job trailer with lots of different colors of highlighter going everywhere on the diagram. No one but a project scheduler has the time or the desire to compute the variables.

Bar charts, however, do not show all the interdependencies between activities, whereas network diagrams show the dependence (constraint) of one starting activity and the finish of the activity preceding it. Further, bar charts do not allow for variable float control at those activities' events. There are also limits to the number of activities, usually around 50, that can be tracked on a bar chart before the chart becomes overloaded and the milestones within the bar chart schedule miss their marks.

S-CURVE CHARTS

S-curve charts, known in the industry as S-charts, add timeline momentum to bar charts and can be thought of as flowcharts. These are the types of graphs that use coordinates to plot flowlines, as in the example in Fig. 6.1. These are scaled in a tighter timeline than the bar chart, to provide more scheduling control over subtasks within activities. Bar charts are typically structured with a one-month timeline, whereas S-charts are structured with a one-week timeline that opens up the activity and its subtasks to greater detail and control. The project scheduler now obtains the margins between work items necessary to establish workable free float.

S-charts show the interrelationships of sequential and parallel activities more clearly than do bar charts. The manipulation of the starting and finishing events is critical to effective CPM. Even work items within subtasks

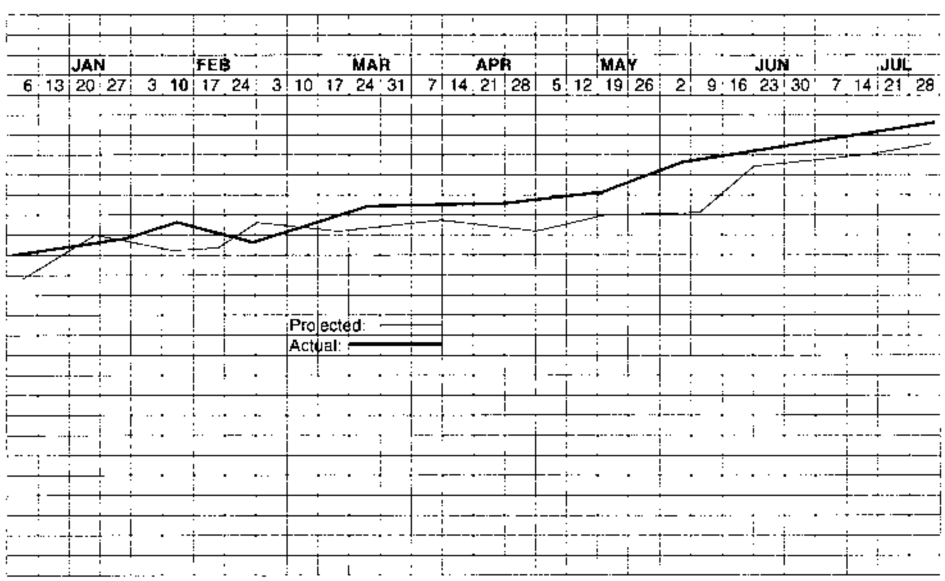

FIGURE 6.1 Flowline by plotted coordinates.

within activities should be broken out, with individual computer numbers for dedicated cell address data storage. All activities are made up of smaller activities that need attention and control. For example, if we have an activity "Obtain building permits," it is entered and computed as one activity, whereas anyone experienced in pulling permits will tell you that obtaining building permits is far from a one-step operation. Many activities are involved in the permit process alone. Each of the activities has subactivities involved, which are not shown here for clarity of concept.

Once the scheduler has identified these work items at the microcosm level, the activities listed on the primary report file (Sort by Activities) are then broken out from the Sort by Activities timeline and transposed onto the accelerated S-chart timeline. This, in effect, shifts the production network into double-time. Professional ball players have reported that when they are really in the groove and doing well, things seem to slow down a notch and they can really control their timing. I once heard baseball great Barry Bonds remark that he started his home run streak when "time seemed to go into slow motion and I could see every stitch lace on the baseball clearly as it was coming at me." So he focused better and connected. This is exactly what happens at this transposition point of superimposing the Network Timeline S-chart on the Sort by Activities bar chart. Here is where *you* focus and connect. This is the point in your development of the schedule where the double-timing opens up details on subtasks and work items within the activities and, thus, windows of float. Superimposed events and milestones begin to interweave, and the job logic of the network velocity diagram becomes workable.

CPM VERSUS BAR CHART METHODS

Bar charts, as we have seen, have only a limited ability to show a large project's many detailed work activities and, even more importantly, their time-scaled interdependence. The advantage of using CPM scheduling systems versus bar charts on capital projects is in the increased control over event interrelationships and higher accuracy of detailed summary reports (sorts). The instantaneous critical data regarding actual progress versus schedule, readily available at any given time on the computer monitor screen, are essential for any modern production under a deadline. The CPM system has a far greater ability to handle with ease the hundreds of work activities on large commercial and industrial projects.

On smaller projects, however, it is important not to add more activities or detail than is necessary to a CPM schedule. The amount of data flow and the time it takes to deal with that data may not be cost-effective to generate on a smaller project. Too much unnecessary detail in any type of schedule makes it harder to use and costs more money to operate. Costwise, the scheduling system should be appropriate to the size of project. If you have a $50,000, state-of-the-art, computerized CPM scheduling system in the office that's already paid for, great! Go out and schedule every monster project your estimators can get contracts on. If, on the other hand, you're concerned with the initial cost of new hardware, software, and user training (which would be a direct cost to the project), then don't buy what you don't really need. This tendency to overload a nominal schedule with too much detail is a common problem encountered by schedulers trying to use a system with too much power on a small project. The trick is to break out some of the less complicated scheduling areas and use bar charts for them. A blend of the two systems often results in a simpler and more effective schedule for smaller projects.

A CPM network schedule has disadvantages also. First, it will increase the total contract price. Such schedules are expensive to create and maintain. Second, the contractor may consider it an unnecessary intrusion into its work. In such a case, the contractor's creation and maintenance of the schedule during construction may be haphazard. The cost of running a CPM network schedule is likely to be higher than that of using bar charts, particularly on smaller projects. That was especially true of running the CPM schedule on a mainframe computer. In recent years, the relatively modest cost of PC hardware, software, and training has enabled us to expense-off the cost for computerized CPM network scheduling on a medium-to-large project. It might take several small-sized projects to cover the writing off of a PC CPM scheduling system.

ARROW DIAGRAMMING (ADM)

Once the scheduler has identified the job logic, the schedule is plotted in a flowchart by using the arrow diagramming method (ADM). In arrow diagramming, the basic unit is a work activity that occurs between two events. The events in arrow diagramming are known as *nodes*. The events, or nodes, are numbered sequentially, and the beginning and ending event numbers identify the activity. Those numbers are also designated as the *i–j* number, as shown on the computer summary report Sort by *I–J* Numbers.

Each activity has a projected duration necessary to complete the activity. Each activity's estimated duration is determined by the parameters of the work items involved. The best source of data for factoring here is your company's historical data, available from previous similar projects. If there are no historical data on the activity, the project scheduler uses cost estimate publications, such as Lee Saylor or Means Cost Index, and uses area adjustments for geographical cost factoring. Experienced project schedulers will also seek a best estimate of the activity's duration from input from the subcontractors most experienced in performing that activity. The function of the arrow diagram is to determine the longest time path through the diagram, which is the critical path.

In Fig. 6.2, the critical path for project completion passes through activities 1–2, 2–3, 3–4, 4–6, 6–7, 7–10, 10–11, 11–12, 12–13, 13–15, 15–18, 18–19, and 19–23, for a total of 190 working days. Path two (4–21, 21–22, 22–23) and path three (4–16, 16–17, 17–21) are the same duration of 120 working days. The fourth path (4–9, 9–11) lasts only 35 days, and then rejoins the critical path, having float of 5 days. Path five (4–8, 8–20, 22–23) lasts for half the duration of path three and shows float of 10 days. Keep in mind, however, that this arrow diagramming shows constraints but not accelerators. To accelerate activities' durations, we manipulate the early and late start events and the early and late finish events. These have yet to be added to the CPM arrow diagram in Fig. 6.2.

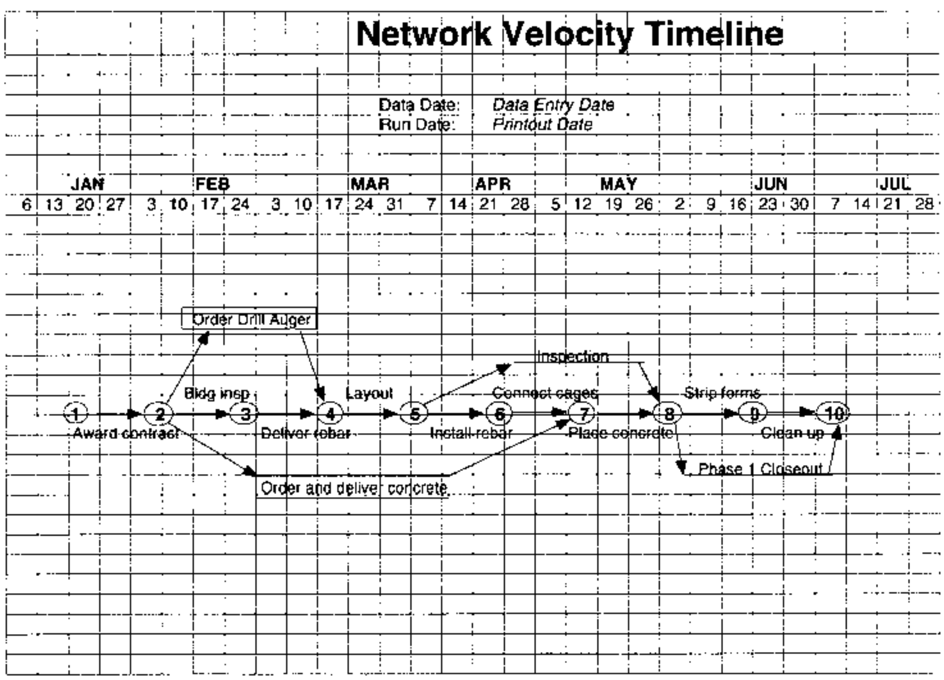

Figure 6.2 Arrow diagramming.

PRECEDENCE DIAGRAMMING (PDM)

The next level of network diagramming is called the precedence diagramming method, or PDM. In this method, the activities are represented on the network as boxes instead of arrows. We call these boxes *nodes*, and in PDM the arrows between the nodes only indicate the established job logic interdependencies among the activities. Nodes may be represented on the network diagram as either boxes or circles.

PDM diagramming shows the activity number in a block and not on the arrow line, as shown in the arrow diagram in Fig. 6.2. The larger rectangles are better suited for detailed activity descriptions and duration events than are circles with numbers in the vicinity, as in an arrow diagram. Instead of a single *i–j* number appearing in the circle, in PDM the activity number also appears in the block as further identification and data detail. The nomenclature of an arrow diagram and a node diagram is the same, as are calculating float times and the early and late start dates for all activities in the logic diagram.

A PDM diagram is easier to read than an arrow diagram, because the connecting line is shortened between nodes. The main advantage of PDM is its ability to show the constraints an activity has on its succeeding activity. CPM programs that run on Activity-on-Node formats are combinations of both ADM and PDM systems. Scheduling personnel typically like to have both ADM and PDM diagrams displayed, so they can visually check the logic of the diagram in detail as the project proceeds. The project managers need to refer to it to resolve production bottlenecks. Usually, however, project managers work from the early and late start dates, increasing float sort and milestone sorts. Site supervisors typically use the bar chart sorts for day-to-day supervision of the construction work.

In PDM diagramming, the length and direction of the arrows show only the flowline of interrelationship. Often arrows are deleted altogether, and only lines connect the nodes. The line between two nodes indicates the relationship between them; these lines are connectors only and do not represent timescale, because they are all of zero time duration. PDM diagramming thus eliminates the need for dummy arrows. Different notations can be made in the node, as the project scheduler needs to show a wider range of events' interdependencies or more detailed data. This gives more flexibility to event scheduling when building the job logic diagram.

As mentioned previously, typically about 20% of project activities will continually fall on the critical path, so CPM network project scheduling is a management-by-exception technique. When more than 20% of the activities on a PDM or Activity-on-Node diagram fall on the critical path, it is a sign that the network schedule is falling behind in its timing and needs to be

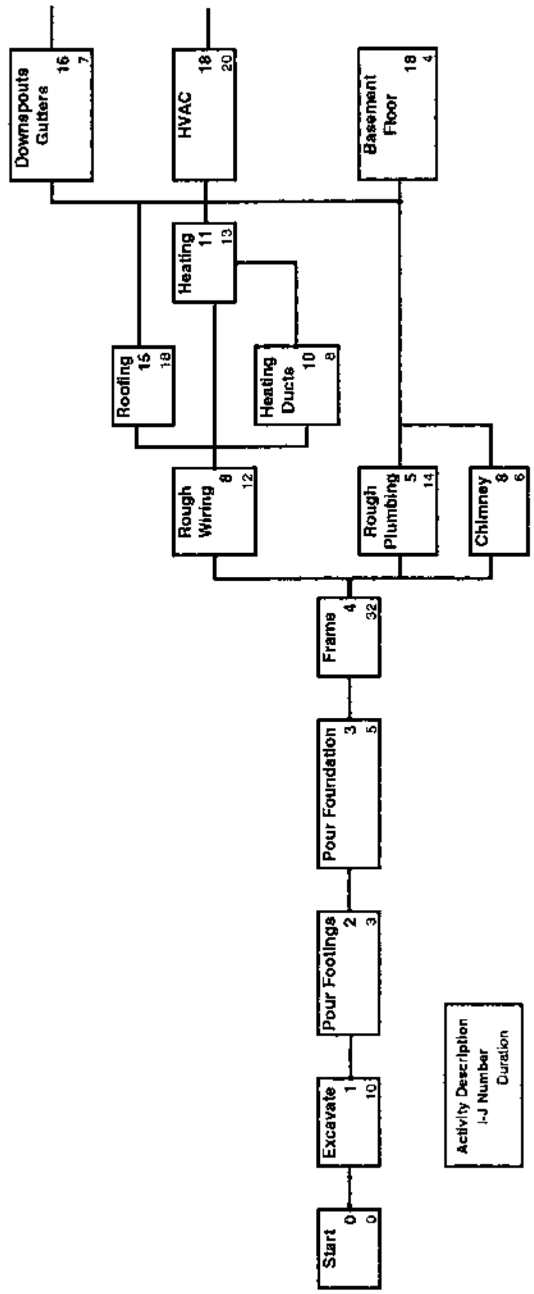

FIGURE 6.3 PDM job logic.

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recycled immediately. Recycling the schedule is normally done at the end of the month, but needs to be done immediately if your short-term milestones are not being met.

Figure 6.3 shows typical PDM job logic on a residential project. Although the two methods of producing ADM and PDM diagrams produce different appearing networks, the production job logic remains the same. In a precedence diagram, the rectangular activity box (node) now shows the activity that would be represented as an arrow in ADM diagramming.

In ADM, a dummy arrow differs from an activity arrow in that it represents a constraint, while all other arrows represent both time and dependency. When four or more activities converge in one intersection event, a dummy arrow is introduced into the diagram network to indicate where an activity has a starting event constraint dependency on a preceding activity. In PDM diagramming, however, the four or more activities would be best time linked in a series according to established job logic.

ADM VERSUS PDM

ADM scheduling requires knowing the timing significance and proper usage of dummy arrows, and mistakes using constraints or accelerators in the wrong place are disastrous in a CPM network schedule. Therefore, the standard in the industry is for the site supervisor and field personnel to use a PDM network rather than arrow diagramming. The nodes' ability to expand to include any pertinent data also makes it easier to modify the network diagram with PDM.

PDM is popular in the business for these reasons and is in wide use through the modern construction industry, especially in its CPM version Activity-on-Node format, which we look at next. However, ADM also has a distinct advantage over PDM. The major difference between the two, and where ADM has the time manipulation edge, is that there are no events in PDM box node diagrams, which makes it impossible to use early and late start and finish events to interrelate events between activities networks.

ACTIVITY-ON-NODE FORMAT

Activity-on-node diagramming is a combination of both ADM and PDM that produces a superior precedence diagram format for scheduling. This format is a variation of PDM diagramming that uses dependency arrows with no constraints (dummy arrows). In activity-on-node diagramming, the activities are shown as horizontal bars, their lengths relative to their duration. Activity nodes run from event to event, and a single, narrower line following

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each activity node represents float. When run on the computer network timeline, the resulting diagram becomes a time-scaled network.

Activity-on-node uses a format wherein the horizontal activities bars contain the activities' respective *i–j* numbers, which the computer uses to best-time sequence the *j* node (finishing event) of the preceding activity with the *i* node (starting event) of the succeeding activity, and thus establish the dependency lines that determine job logic. Sometimes, if constraint must be shown, a dummy activity is used to show the activity event dependency. Conventional CPM network scheduling programs, by far, use Activity-on-Node formats for network velocity timeline computations. Some programs offer what they term "dependency bar chart scheduling," which is a similar Activity-on-Node format.

Figure 6.4 is an example of activity-on-node diagramming, showing activities interrelationships, dependencies, job logic, activity durations, and available float, with constraints noted as dummy arrows. Note the similarities to PDM, with the added benefit of trackable float.

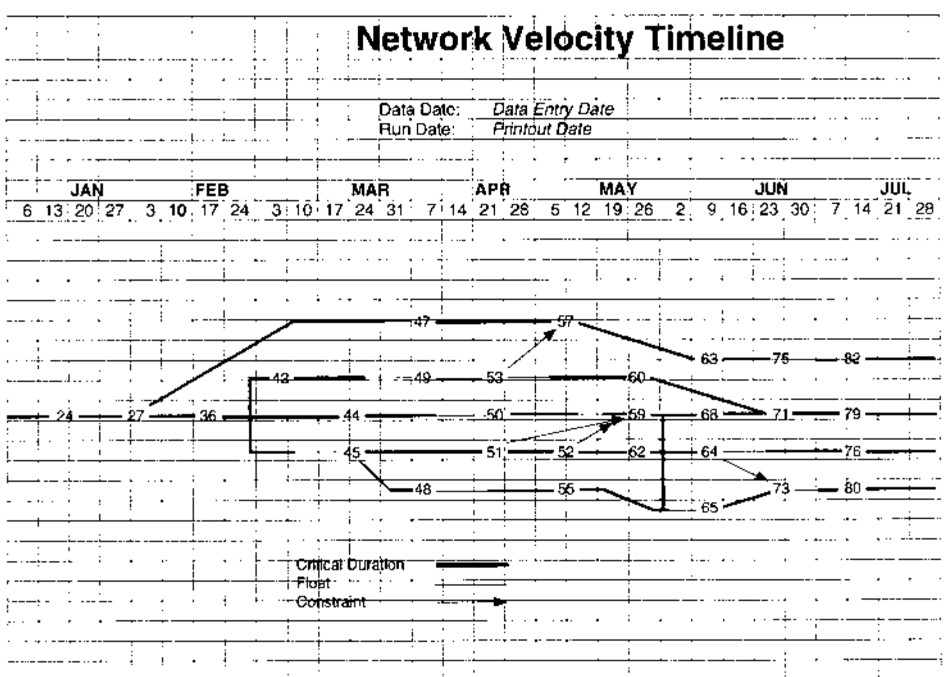

FIGURE 6.4 Activity-on-node diagramming.

FAST-TRACKING

Phased construction, or fast-tracking, is a modern variation of the previously examined CPM techniques. In fast-track projects, prearranged phases of the project are started prior to main project commencement. The big advantage to the owner in fast-tracking is that production can begin before the total project design is completed, thereby incurring less interest cost on the construction loan by completing the project sooner. An owner who is not yet due for the first draw payment from the bank does not yet have use of bank construction loan funds and will have to draw on personal credit lines to cover initial costs of commencing the project. This additional debt load taps many owners thin for project commencement cost contingencies and further reduces the owner's credit line to cover those contingencies.

Through fast-tracking, however, construction can begin with certain activities completed and ready for initial draw progress payment from the bank's construction loan funds. The project is completed sooner, the owner has income from the capital project sooner, and the construction loan is paid off sooner at a lower cost—same project, but more income and less cost. This type of project execution equates to sizable profit to the owner, but it must be remembered that the economic viability of fast-track project execution depends on the amount of the design completion available when the project schedule is being developed.

Fast-tracking has proven itself to be a viable project execution option in commercial construction and is being touted as the next wave of the future. I have my doubts about that point, but fast-tracking does work extremely well in certain types of similar multilevel types of construction projects. The primary advantage in the fast-track method is that construction can begin while design is still being worked out. This should mean that the project would be completed sooner. Obviously, owners like fast-tracking. It makes them money and cuts their debts sooner. It will no doubt continue to be a real contender in the field of future professional project scheduling executions.

In fast-tracking, preconstruction input by the subcontractors and project team begins while the architect is still in the design phase, to prevent design changes later in the schedule. Prime contractors then compensate for not having a detailed finished set of plans and specifications to make their bids with cost-plus contracts tied to whatever actual costs are incurred. Activity subcontractors' bids are usually figured by square footage takeoffs, tied to whatever finished design costs are incurred regardless of projected costs. The main fast-track advantage in project execution is speed of project completion. This contracting environment requires early, close, and formal coordination by the owner between the contractors, project team, and architect.

Phased construction has become so popular in current project scheduling that CMI and similar corporations are now offering full-program courses in fast-track CPM. These types of nontraditional project production execution methods are indications of the changes yet to come for the professional CPM project scheduler. Modern fast-track project scheduling has evolved as an efficient scheduling system for obtaining equal or higher-quality construction at the lowest possible price and in the quickest turnaround timeframe.

But, as with all things, there is a downside to fast-tracking that owners are frequently unaware of. A study by the U.S. General Accounting Office of the use of CPM construction management by federal agencies noted cost overruns with fast-track project execution in some projects, due to contractor delay claims. The study further found that if fast-tracking is used in a single contracting system, phased construction leads to cost-plus contracts by prime contractors, which means that the contract price will be tied to costs incurred no matter what numbers the design finishes with, since there are too many unknown variables to lock in a final price when the contracts are signed.

It also noted the difficulty of using CPM concepts with untrained users in federal construction and reports that those projects experienced time delays, some exceeding six months. Conversely, however, the study also found that those projects using CPM fast-tracking with personnel trained in CPM techniques had cost decreases that averaged 15%. Obviously, then, CPM fast-tracking will achieve its objective advantages only when applied by those who know how to operate the system. Intuitively, one can grasp here that the reciprocal then must also be true: A CPM fast-tracking system is not cost-effective when used by personnel untrained in its use.

DESIGN/BUILD

Often a fast-track project schedule is used in combination with a design/build system. This means that the designer and builder are the same entity. It also means that the prospective bidders cannot be given a detailed set of plans and specifications on which to make their bids, as design is not yet complete. So contractors bid by square footage costs added to a profit margin percentage, and contract by cost-plus contracts tied to whatever actual costs are incurred, regardless of projected costs. The advantage to the design/build system, from a project scheduling standpoint, is its speed of project completion, because the design/build system uses phased construction already in progress as its scheduling basis. By having materials or inventory in advance, contractors can start the project with modular sections of their activities already completed.

Adding precommencement activity completions and events timing controls to our network diagram gives us the factors of modern fast-tracking project scheduling. Design/build systems use events' time manipulation to either accelerate or retard forward progress in collective or individual activities, producing forward momentum in production scheduling. This tool is applied through the proper use of free float and total float, in parallel activities as well as in series activities. Adding these events' time manipulation controls to our network velocity diagram gives us the working foundation of fast-tracking. This is a modern scheduling technique of today's professional project scheduler. Let's look at the basic elements of a fast-track design/build system. Figure 6.5 represents the first element, showing a bar chart schedule of a typical home-building project, scheduling the phases of that project.

I have made this example bare-bones and overly simplistic for the purpose of illustration. The project's phases are as follows:

1. Bid out design and plans.
2. Approve design and plans contract.
3. Obtain building permits.
4. Bid out construction.
5. Negotiate contractors' bids.
6. Complete any required geotechnical site surveys and soils testing.
7. Negotiate project schedule with best bidder.
8. Approve and award winning general contractor's bid.
9. Obtain contractors bonds, workers comp, and liability insurance.
10. Begin site work.
11. Finalize inspection site work.
12. Make first progress payment.
13. Begin foundation work.
14. Finalize inspection foundation work.
15. Make second progress payment.
16. Begin framing work.
17. Do prefinal inspection of framing work.
18. Make third progress payment.
19. Begin electrical, plumbing, and HVAC rough out work.
20. Finalize inspection framing work.
21. Make fourth progress payment.
22. Do prefinal inspection of electrical, plumbing, and HVAC rough out work.
23. Make fifth progress payment.
24. Begin interior work.
25. Do prefinal inspection interior work.

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CERTIFIED CONSULTANTS

Sort By Activities

Prepared For:	Power Engineering Corporation
Project:	Stanford University
File Name:	cc/pe/stndford/activties
Description:	Cancer Research Building
Our Invoice:	95-097-PEC
Client Invoice:	CRB-102

Data Date: 22 Dec 93
Run Date: 14 Jan 94

Activity Number	Activity Description	Original Duration	Remaining Duration	% Comp	Early Start	Late Start	Early Finish	Late Finish
General Conditions								
00010	Subsurface Investigation	30	0	100	20 Nov 92	24 Nov 92	10 Dec 92	12 Dec 92
00100	Instructions To Bidders	12	0	100	13 Nov 92	18 Nov 92	26 Nov 92	28 Nov 92
00200	Information Available To Bidders	2	0	100	28 Nov 92	02 Dec 92	04 Dec 92	08 Dec 92
00300	Bid Forms	1	0	100	10 Dec 92	12 Dec 92	11 Dec 92	15 Dec 92
00400	Supplements To Bid Forms	3	0	100	18 Dec 92	20 Dec 92	20 Dec 92	24 Dec 92
00500	Agreement Forms	0.5	0	100	10 Dec 92	12 Dec 92	11 Dec 92	15 Dec 92
00600	Bonds And Certificates	2	0	100	12 Dec 92	14 Dec 92	14 Dec 92	18 Dec 92
00700	General Conditions	0.5	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
00800	Supplementary Conditions	0.5	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
00850	Drawings & Schedules	1	0	100	18 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
00900	Addenda & Modifications	1	0	100	19 Dec 92	21 Dec 92	20 Dec 92	25 Dec 92
Subtotal:		**53.5**	**0**	**100%**	**29**	**30**	**10**	**17**
Phase 1:	**Specifications**							
01010	Soils: Reports & Remediations	10	0	100	20 Nov 92	24 Dec 92	10 Jan 93	15 Jan 93
01020	Allowances	1	0	100	10 Dec 92	12 Dec 92	11 Dec 92	15 Dec 92
01025	Measurement & Payment	1	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
01030	Alternates/Alternatives	0	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
01040	Coordination	0.5	0	100	17 Dec 92	19 Dec 92	18 Dec 92	20 Dec 92
01050	Field Engineering	3	0	100	19 Dec 92	20 Dec 92	20 Dec 92	24 Dec 92
01060	Regulatory Requirements	1	0	100	26 Dec 92	30 Dec 92	28 Dec 92	30 Dec 92
01070	Abbreviations & Symbols	0.5	0	100	17 Dec 92	19 Dec 92	18 Dec 92	20 Dec 92
01080	Identification Systems	1	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
01090	Reference Standards	1	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
01100	Special Project Procedures	1	0	100	10 Dec 92	12 Dec 92	11 Dec 92	15 Dec 92
01200	Project Meetings	1	0	100	10 Dec 92	12 Dec 92	11 Dec 92	15 Dec 92
01300	Submittals	1	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
01400	Quality Control	1	0	100	10 Dec 92	12 Dec 92	11 Dec 92	15 Dec 92
01500	Construction Facilities & Temp Controls	1	0	100	17 Dec 92	19 Dec 92	17 Dec 92	20 Dec 92
01600	Material & Equipment	30	0	100	20 Dec 92	04 Jan 93	22 Jan 93	25 Jan 93
01650	Starting Of Systems/Commissioning	1	0	100	22 Jan 93	25 Jan 93	26 Jan 93	27 Jan 93
01700	Contract Closeout	1	0	100	28 Jan 93	29 Jan 93	29 Jan 93	30 Jan 93
01800	Maintenance	10	0	100	30 Jan 93	31 Jan 93	10 Feb 93	15 Feb 93
Subtotal:		**66**	**0**	**100%**	**70**	**78**	**30**	**35**
Phase 3:	**Site Work**							
02010	Subsurface Investigation	10	0	100	31 Jan 93	31 Jan 93	11 Feb 93	16 Feb 93
02050	Demolition	3	0	100	16 Feb 93	18 Feb 93	19 Feb 93	21 Feb 93
02100	Site Preparation	30	0	100	16 Feb 93	18 Feb 93	19 Feb 93	21 Feb 93
02140	Dewatering	6	2	80	20 Feb 93	22 Feb 93	25 Feb 93	27 Feb 93
02150	Shoring & Underpinning	3	0	100	25 Feb 93	27 Feb 93	27 Feb 93	30 Feb 93
02160	Excavation Support Systems	3	0	100	25 Feb 93	27 Feb 93	27 Feb 93	30 Feb 93
02170	Cofferdams							
02200	Earthwork	7	0	100	28 Feb 93	30 Feb 93	04 Mar 93	07 Mar 93
02300	Tunnaling							
02350	Piles & Caissons	5	0	100	10 Mar 93	12 Mar 93	09 Mar 93	17 Mar 93
02450	Railroad Work							
02480	Marine Work							
02500	Paving & Surfacing	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02600	Piped Utility Materials	2	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02660	Water Distribution	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02680	Fuel Distribution	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02700	Sewer & Drainage	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02760	Restoration Of Underground Pipelines	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02770	Ponds & Reservoirs	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02780	Power & Communications	3	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93
02800	Site Improvements							
02900	Landscaping	20	0	100	17 Mar 93	19 Mar 93	21 Mar 93	23 Mar 93

FIGURE 6.5 Durations factoring fast-track.

26. Make sixth progress payment.
27. Do final inspection of electrical, plumbing and HVAC work.
28. Make seventh progress payment.
29. Do final inspection of exterior and roof.
30. Make eighth progress payment.
31. Finish out punch list.
32. Finish out changes and claims.
33. Do final total building project inspection.
34. Do project closeout.
35. Do contract closeout.
36. Make final payment and release of retention.
37. Obtain release of liens and file Notice of Completion.

These 37 activities are easily shown on the bar chart in Fig. 6.5, sequenced and computed for duration of activity originally estimated and actual duration remaining. Remember, this breakout of durations completion percentage represents only the first stage of a fast-track network. The second step is to put the phases of activities, along with the early and late start and finish events, into the formula.

The 37 activities can easily be scheduled with a manual bar chart or a time-scaled logic diagram, produced on a PC with CPM software. With a preselected contracting plan developed by the project team to start preliminary activities prior to commencement, we get the combined elements of fast-tracking. Our CPM time-scaled network schedule now has the advantage of a head start prior to project commencement. The disadvantage is that the owner assumes most of the cost-performance risk of a cost-plus contract with the prime contractor. But that risk management can be handled with a preselected contracting plan of a guaranteed cost and profit maximum plus incentive contract.

Once the durations percentages in Fig. 6.5 reach the 34 to 45% completed design point, the contract could be let out to bid in a fast-track project execution. Now our schedule contains job logic, time manipulation tools of early and finish events, all the necessary elements of a velocity network diagram with activity interdependence linked by a time scale, plus the head start of contracted phased construction activities.

While the design/build fast-track project execution will be in wide use throughout the construction industry for this century, new variations of phased construction project scheduling are already becoming alternative construction management options. These include "just-in-time," process-oriented projects, and "bridging" project scheduling methods, which are variations of phased construction fast-track being pursued by developers, owners, architects, and engineers at an increasing rate.

FAST-TRACK CPM

The economic advantage of fast-track CPM is the cost control over the selected paths of critical activities running in series and the many paths of activities running in parallel on the schedule. In addition, the early precommencement starts of the phased construction provide financial advantages to a project owner on a fast-track CPM project schedule, ideally reaching the earliest possible strategic project completion date. In fast-track CPM, the overall responsibility for controlling project execution remains not with a prime contractor, but with the owner. Typically, responsibilities for completion of the project design and specification are delegated to the project engineer, long-lead item procurement and construction activities to the project manager, supervision of field personnel to the site supervisor, and CPM schedule development and tracking to the project scheduler.

Mutual cooperation between design professionals and the project team is essential throughout the project in this type of project execution. The project scheduler and prime contractor make their field schedules in close cooperation with each other. This early contractor cooperation with the project team produces a smooth and effective design–construction interface and further ensures a viable and cost-effective CPM network schedule, thereby maximizing the potential for fast-track project profit. Phased construction projects create a combined-resource approach of an integrated owner/designer/construction team, which is why fast-tracking is becoming a major CPM project scheduling productivity enhancer.

One of the main differences in fast-track CPM, as opposed to standard CPM, is the handling of long-lead items. In fast-track CPM, the project scheduler accelerates the delivery of all long-lead items to the project site. These are now scheduled to intersect early construction phases at key activity starting events, thus accelerating the required long-lead items field delivery dates along with the activity's early starting event. Early quantitative survey material takeoffs also permit construction procurement personnel to order critical bulk materials in advance, such as lumber, pipe, and fixtures. Those activities are especially important in fast-track CPM construction project execution.

For a fast-track CPM schedule to be viable and operational, the plans and specifications need to be 30 to 45% completed before the CPM project schedule is developed and executed. Because the project schedule must interlink with other major project considerations, such as design and long-lead items procurement, getting a fast-track's jump start without adequate finished design can incur costly errors. In fabrications with long-lead delivery times, error is obviously probable if the groundwork has not been done previously to provide accurate activities duration.

COST-LOADED CPM

Cost-loaded CPM comes into use with unit-price contracts. These contracts use prices based on an itemized breakout of all work activities involved in the contract. Each is assigned a unit price. The final line-item price on each activity item is then computed by factoring the unit price times the item quantities. The unit price is then used as the controlling price for each item. Cost-loaded CPM is built from the unit-price bid sheets supplied in the original contract by the activities subcontractors.

Cost-loaded CPM is used by the project scheduler as a schedule of values and must not be confused with the lump-sum method. In a lump-sum project, the contractors contract to do all the work defined in the plans and specifications for a fixed price stated in the contract. Any quantity variations that are not added by the project team as change orders are not factored in. To cover these possible variations, a schedule of values is also requested from the contractors in their bids. A schedule of values is basically a unit-price bid with some notable differences. For example, item prices are shown for ease in making monthly progress payments only; they cannot be used for price change orders and imply no contractual obligations. Cost-loaded CPM is used to advance phased scheduling on progressive milestones.

A common problem that occurs from owners requesting cost-loaded CPM is their assumption that cost-loaded CPM will always result in easier progress payments management. This is true of lump-sum projects, but the situation is reversed in unit-price contract projects, because a cost-loaded network does not synchronize with the payline items on unit-price contracts. Therefore, in a lump-sum contract with cost-loaded CPM, the unit-price breakout should be submitted after the contract approval but before the first progress payment. In a lump-sum contract without cost-loaded CPM, a schedule of values should be submitted after the contract approval but before the commencement of work.

Typically, all engineering projects are based on a quantitative survey unit-price contract, in which the actual unit prices stated in the original bid would be held as the factor for all progress payment disbursement amounts. Because a unit-price contract does not have a fixed ceiling price, the final cost to the owner will be determined by the quantities actually completed. For the project scheduler to adequately protect the financial investment of the owner, the scheduler must be careful to determine if the field quantities are precise. Conversely, in a lump-sum contract project, if an error is made within the first month of work, it can be compensated for in a later progress payment. The contractor cannot bill for more than the stated fixed price, even if some of the final quantities varied from the anticipated amounts. In a lump-sum contract, contractors agree to complete the project as per plans and specifications.

Anything else necessary to complete the project must be considered as part of the contract, even if not specifically stated in the plans and specifications.

Conversely, in a unit-price contract, the contractor may still be required to construct a complete functional project. But if any variation occurs in the quantities of any of the separate bid items listed, the contractor is entitled to an amount of money equal to the unit price of the bid item multiplied by the actual quantity of the item supplied or installed.

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7

Project Operations

SCHEDULING CONTINGENCIES

Scheduling controversies often arise in the construction process, not only from disagreement over poor planning in the primary stages but also from operations among construction methods or sequences of activities and the project team and activity subcontractors in the secondary production stages. Often these disputes occur where a project is constructed under multiple prime contracts such as those commonly experienced in fast-tracking, in phased construction, or in a professional construction management contract. The absence of any contractual relationship between the individual prime contractors and the architect has been the main cause of numerous court litigations.

A cursory routine approval of contractor-prepared schedules can be the most costly mistake an owner can make. In the absence of a thorough review by an experienced CPM project scheduler, contractually required schedules can become the primary source of documentation from successful contractor claims. The contractor can simply provide as evidence in court its prebid, preconstruction, and progress schedules and then compares them with the as-built or adjusted schedules. The comparison can be very graphic, especially to those who have not had the training, as you have, to know how CPM works and how it can be subverted. If the owner approved the contractor's schedule, the owner can be left in an extremely weak legal position. This kind of comparison, to laypeople, is simple and straightforward. It appears to be the truth, pure, and simple and will have a significant impact on a panel of arbitrators or a jury.

But as we've already learned, the truth is rarely pure and never simple. CPM network schedules reflect those who produce them. Project schedulers who understand the nomenclature and advantageous uses of CPM also realize how it can be abused. The only thing between the owner and bankruptcy in scenarios like this are adequate records and a bulletproof CPM project schedule. So the professional project scheduler knows about the following scheduling contingencies and how to plan for them in the best interests of the client.

OUTSIDE DELAYS

Referring to the software program, you will find that the field daily reports have columns for weather delays. An inclement weather system passing through your area that turns out to be a toad floater will also delay outside activities, such as excavation, grading, paving, and placement of concrete. These are considered constraints of practical limitations and must be factored as such in the CPM schedule. The reasons are twofold. First, time cushions must be installed within total float, to provide allowances in practical production parameters. And second, AIA Doc A201, Section 4.3.8.2 (which is the section dealing with claims), requires the contractor to document "by data substantiating that weather conditions were abnormal for the period of time and could not be reasonably anticipated" before the contractor can receive a time extension for weather conditions. Section 4.3.8.2 further requires that the contractor document that the weather conditions "had an adverse effect on the scheduled construction."

The overall precedence concerning CPM schedule delay is found in AIA Doc A201, Section 8.3.1, which states

> If the Contractor is delayed at any time in the progress of the Work by any act or neglect of the Owner or the Architect, of an employee of either, or of a separate contractor employed by the Owner, or by changes ordered in the work, or by labor disputes, fire, unusual delay in deliveries, unavoidable casualties, or any causes beyond the Contractor's control, or by delay authorized by the Owner pending arbitration, or by other causes which the Architect determines may justify delay, then the Contract Time shall be extended by Change Order for such reasonable time as the Architect may determine.

This section delineates the parameters of acceptable and enforceable delay claims submitted by the contractor. These requirements can make it difficult for a contractor who does not keep detailed weather records to claim a time extension for adverse weather conditions. They reflect a belief by the AIA that weather generally is a risk assumed by the contractor and that only in extraordinary circumstances should weather be the basis for a time extension. The legal documents used by the courts to determine judgments in weather-related claims are a Daily Inspection Report (DIR) and a Quality Assurance Report (QAR). If the contractor or owner is unaware of these documents, then certainly you, the professional project scheduler, should be. And you should implement them on your client's behalf to protect your schedule.

Another reason for not granting a time extension is the single contract system's primary objective of centralizing administration and responsibility in the prime contractor. Only if subcontractor-caused delay is specifically included should it excuse the prime contractor. This needs to be stated within the contract specifications to protect your client from the schedule's default through circumstances beyond your control. The independent contractor rule, though subject to many exceptions, relieves the employer of an independent contractor for the losses wrongfully caused by the latter.

As noted previously, prime contractors assert that subcontractors are independent contractors because the subcontractor is usually an independent business entity and can control the details of how that activity is performed. Even so, the independent contractor rule does not relieve the employer of an independent contractor when the independent contractor has been hired to perform a contract obligation and, under that employer's direction, the party suffering the loss caused by the independent contractor is the party to whom the contract obligation was owed.

Another portion of contract law affects the CPM project schedule, and that is AIA Doc A201, Sections 4.3.3 and 4.3.8.1, which cover time extensions in construction contracts. These usually provide a mechanism under which the contractor will receive a time extension if the project is delayed by the owner or by designated events such as those described in the contract specifications. Increasingly, contractors make large claims for delay damages. As a result, it is becoming even more common for clauses in public works contracts to attempt to make the contractor assume the risk of owner-caused delay. Public entities are limited by appropriations and bond issues, so they must contract in advance for the full cost of the project. To do this, many public entities use the disclaimer system for unforeseen subsurface conditions. Similarly, they wish to avoid facing claims at the end of the project, based on allegations that they have delayed completion or required the contractor to perform its work out of sequence.

RECYCLING THE SCHEDULE

The CPM schedule should be recycled weekly. This means to put it to critical analysis and cook it. Float, elapsed-time estimates, summary sorts, and critical paths and trends analysis forecasting take first priority on the agenda. Critical path activities that met scheduled events need to be analyzed for the characteristics of success that can be incorporated into future project schedules. Critical path activities running in negative float need to be straightened out.

A computerized CPM system simplifies recycling the schedule. Besides the traditional weekly and monthly reworking of the schedule, recycling becomes necessary whenever schedule deviations accumulate to the point where some of the intermediate milestones are in jeopardy. Recycling involves revising any target dates that may have slipped beyond repair, perhaps because a significant change in scope has occurred. Exercising some "what-if" options allows the project scheduler to make the best revisions.

Having activities with negative float is a sign that the schedule no longer is achievable in its present form. Recycling the schedule should not be confused with the monthly progress evaluation. Recycling is necessary at the end of the quarter if your short-term milestones are not being met. The recycling procedure critically analyzes how to get the project back on track without extending the completion date.

When recycling the schedule, keep juggling and rechecking the resulting logic diagram for the best job logic. Because network project scheduling, especially one in crisis, is in motion and the variables are constantly changing, professional project schedulers are paid handsomely for saving a sinking project. Jumping into the fire to rescue a runaway CPM schedule pays well, but it is much akin to jumping into a mixer-blender and having someone hit the puree button.

But one must start somewhere, and I have found from experience that the best place to start recycling is with the project's job logic. Remember that the logic diagram is the central command center of the CPM schedule. If the program logic doesn't wash there, that's the beginning of the end. Nothing else, from the logic diagram outward in the network, will be running in sync. Fix this crucial component of the schedule first. Then move into the next stage of schedule recycling, which is operations analysis.

The simplest scheduling recycling is concerned with *time* use. Thus, you might allocate 10 hours each week in project cost tracking and audit trail, and 20 hours to sorts and their communication with appropriate project team members. You might dedicate the last day of the month to end-of-month sorts and the summary reports, and an hour every Monday to preweek schedule management planning.

A more complex scheduling recycling system compartmentalizes by *activity function*. Calculating the percentage of each activity's progress toward completion is the responsibility of that activity's subcontractor, but the summary report of that progress is the scheduler's responsibility. These more complex systems tend to be (or become) hierarchical. They simplify delegation of each activity's responsibility and according sorts but de-emphasize total project objectives and are slow to adapt to changes during schedule recycling.

In planning the schedule activities and operations analysis, it is important to reflect the objectives of the owner and the project team. The degree of project team control versus prime contractor and subcontractor empowerment, and the overall project matrix network, will determine in significant part whether you will reach the project's phases milestones on time. This is a trade-off or averaging tool the project scheduler uses between time-scaled activity events and activity control, to accelerate or constrain the activity.

COST MONITORING

Separate and distinct from the architect's design costs, the project scheduler must monitor project field service costs during the project. Field costs are a function of the size and classifications of the on-site field labor forces assigned to the project, field office overhead costs, materials and supplies, support services from the home office, vehicle leases and fuel charges, the field office's share of corporate general and administrative (G&A) costs, outside consultants or contract services, and job profit.

By tabulating the monthly accumulations of budget and actual field service costs and then plotting each amount on a time-versus-cost chart, similar in form to the traditional S-curve chart, you can make a visual comparison that clearly not only indicates the status of the contract at any given time, but also shows the project manager or owner any change in trend toward either a savings or a cost overrun. By also plotting a curve representing the amounts invoiced to the owner for such field services, you can provide an additional dimension of usable data to the owner.

To help prepare and maintain the chart, regular inputs are required from the site supervisor, on all field costs and hours of work in each classification at the project site. Arrangements should be made by the project scheduler to ensure that all such field data are received from the project manager on a regular, scheduled basis at the end of each week.

Typically, the monthly pay estimates of the project's contractors' work, for progress payments, are submitted by the 25th of the month, and all submittals are in office for payment before the end of the month. Billings from the architect to the owner, however, usually are based on the closing date of the end of the month. Therefore, tabulation of these data should not interfere with the project manager's review of the contractors' pay requests.

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SCHEDULE OPERATIONS ANALYSIS

Interlinked operations of activities and time-scale systems are the basic structures of your CPM network schedule. They include everything from materials delivery scheduling to the entire scheduling process itself. The operations analysis is unique to each schedule and each project. You should review each element of your schedule in planning but shouldn't, in the interests of time management, revise or develop a full plan for each activity and interlinked operations in every planning cycle. Look for the critical path activities and interlinked operations that are most in need of attention or offer the greatest opportunity for development of shorter events through fast-tracking. All schedules have the following operating systems:

1. **Planning.** This is the process that you initially begin when you first start building the project schedule.
2. **Organizing.** In complex projects, this is reflected in network scheduling diagrams, work flowcharts, and sorts.
3. **Controlling.** This is the process of creating expectations and evaluating progress effectiveness. This involves the time analyzing of sorts and making appropriate changes in the schedule's recycling phase.

Another important area of schedule operations analysis is the determination of your network schedule's capacity and efficiency. To make cost and performance evaluations, it is necessary to know your project schedule's current performance limits. Capacity study is based on an understanding of the tasks devoted to the activity. Good project schedulers continuously monitor and improve their capacity assessments. The initial assessment can be done through hypothesis or best "guess-estimate," but it is far more accurate if based on the company's historical data from similar projects. As an example, consider this simple illustration. For a single subcontractor providing services for one activity, the elements of capacity determination are

1. The number of hours in a desirable work week . . . 40
2. The average number of hours of reporting effort to produce field reports on that activity . . . 0.5
3. The hours per week of administrative time for the scheduler to produce the summary sort for that activity . . . 4

Weekly productive capacity for that activity is 36 hours (40 less administrative hours) divided by 1.5 (1 hour of computer processing plus 0.5 hour of field reporting). Net capacity = 24 hours per week. This is the basis of the schedule's capacity and efficiency. The trick to matrix networking productivity improvement is to follow up with the following questions.

Answering yes to any of these questions brings more critical path management to the project.

1. How can I check the accuracy of my timeframe assumptions? Perhaps a daily time allocation study?
2. Can I improve my matrix network efficiency?
3. Can I reduce my schedule's administrative hours in controlling?

DAILY FIELD REPORTS

Daily field reports are the fundamental documents that record actual job progress, together with all conditions that affect the work. They provide the progress-reporting basis for the actual results of the schedule as compared to projected progress. They begin an organization's standardization of reporting at the source of causes and effects—the point of production. If actually prepared daily, they are generally considered to be the best sources of job information. This is because they are supposed to be prepared immediately as the information is being generated, with no appreciable time lapses. The inclusions and descriptions are fresh in everyone's mind. This facilitates complete details of the work. In addition, daily field reports are prepared by those with authority and responsibility for the work. They have an interest in the accuracy of the information and have a significant incentive to maintain the report's accuracy and completeness. These are the people who actually witnessed the work and are recognized to be the most qualified to describe the reported facts. Because they will be the most detailed, accurate, and complete records of all job site events, the daily field reports will be used to resolve any dispute about what actually happened on the job. They are so valuable because of the wealth of information recorded in summary form. These data include

Work and activity descriptions, separated into physical location and extent
Labor force, broken down by subcontractor, locations, and major activities
Equipment used and stored by the various activity subcontractors
Site administrative staff and facilities
Weather conditions and temperatures at key times of each work day
Change order work accomplished, with relevant details
Photographs taken during the day
Visitors to the job site along with meetings, discussions, and commitments

You will note that the daily field report in the accompanying software is two pages in length. Never use the back of a field report to continue information, because it will be overlooked when faxing, during a review, or when photocopying. Because it is impossible to tell in advance what will become the most important information, all categories must be accurately maintained. It is up to the central office project administration, whatever the exact authority structure within your organization, to regularly police the reports. They must be checked often enough to ensure that all required information is being properly recorded.

The requirement that the reports be completed *daily* cannot be stressed enough. If they're allowed to be lumped together for completion at the end of the week, the accuracy of the information quickly degenerates. The completeness of the data also is dramatically reduced. When on site, you should visibly refer to the reports often, during conversations, issue research, and so on. Let your field personnel know that the information is depended on and used and that their input is extremely important. Even if you don't really need to at the moment, come up with an excuse for looking at the reports. The minute that the field personnel begin to get the feeling that no one's looking at the information, the data will become very thin indeed.

Have the reports printed on two-page carbon or NCR paper. The original is to be sent to the central office, with the copy retained in the field office. Originals should be faxed over at regular daily times, with the original sent or picked up for recordation. Requiring daily deliveries or mailings of field reports further ensures they will be done daily, in a timely manner. The daily field report is typically filled out by the site superintendent and signed by the project manager if that is an on-site position. In the absence of a site superintendent on smaller projects, the responsible project manager on a daily basis must fill out the report. Field reports need to include information listed in these pertinent areas:

Title Box. Indicate project name, company job number, project location, and the name of the individual completing the report.

Date/Page. Account for each page of the total report. Use as many report forms as necessary for a complete record of the day's events.

Weather. Include a short comment on the typical condition of the day (rainy, cloudy, sunny, etc.). Record the temperature at the beginning and the end of each day.

Visitors. List all visitors to the job site that day who are not part of the regular workforce. Include a brief remark as to the reason for the visit. Note any special situations deserving immediate attention. Include references to appropriate documentation.

Work Force. Indicate the number of each type of employment classification for each type of labor involved.

Activity Performed. Directly adjacent to the respective labor force information, include a short description of the type of work performed.
Equipment. List all major pieces of equipment on the site, whether or not they arrived on that day. Include brief descriptions of equipment work performed.
Items Received/Sent. List all materials and equipment received or sent that day only.
Location. Provide sufficient references to allow accurate location of the work. For example, "Continue foundation wall forming along column line A, between lines 4 and 6."
C.O. No. If the work described under "Location" applies to a change or a proposed change, insert the number of the change order or change estimate number in the column provided.
Problems/Comments. Self-explanatory.

CPM SORTS

Sorts are the summary reports of all estimated, projected, and actual information current in the project as of each report's run date. They must be organized and distributed during project operations. The computerized network schedule has sorts that are interlinked with one another and provide summary reports that must be "sorted" out to the appropriate project team members, owner, and responsible activity and procurement personnel by the type of information the reader needs.

The large menu of output sorts is another big advantage of a computerized CPM project schedule. Sorts allow the various members of the project team to receive summary reports of progress, pending construction, or future scheduling in the output sort best suited for their needs. Most CPM programs will yield a sort menu as follows:

1. Sort by activities
2. Sort by *i–j* numbers
3. Sort by early starts
4. Sort by job logic
5. Sort by project milestone
6. Bar chart printout
7. Human resource leveling
8. Key-milestone-date sort
9. Critical item sort
10. Sort by events
11. Free float per activity with total float summary
12. Critical path sort

13. Critical equipment sort
14. Sort by total float/late start
15. Limited periodic look-ahead sorts
16. Schedule of anticipated earnings
17. Cost by activity number

Most project managers and site supervisors find the sorts by total float and by milestone are the most valuable for their project management needs. The total float sort starts with the low-float (most critical) work activities listed first for immediate attention. The less critical high-float items show up later on the list. By using the periodic look-ahead sorts, one can also home in on specific time periods. A 30-, 60-, or 90-day look-ahead sort will list only those critical items that will occur in the next 30, 60, or 90 days. These sorts are extremely useful for the field superintendent, area supervisors, and field schedulers.

Other members of the project team need other types of data sorts to make their work more productive. For example, materials-control people find the critical item sort more convenient in tracking their required delivery dates than extracting those dates from a milestone chart. As the revised delivery data and actual progress are fed into the computer, revised printouts quickly reflect the delivery changes and their effect on the field schedule. Field people usually find that the key-milestone-date sort better suits their needs. That section of the CPM schedule is the basic document that the field scheduler uses to make the detailed weekly work schedules in the field.

The rapid turnaround of data sorts by the computer also allows the project team to perform "what-if" exercises with the logic diagram. When scheduling problems arise, the project team can try alternative solutions by reworking elapsed times for problem activities. This generates new early and late start dates that can be shifted to improve the critical path. The computer calculates a new critical path in a matter of seconds, with immediate access to the new output data sorts on the computer monitor.

If it is desired to determine all items that can be started as of any given date, reference to this sort will show under the column headed "Event Start," subhead "Early," the earliest date that any activity can be begun. On the schedule, the sort report shows that the effect of using total float for a given activity can be isolated and analyzed. Activities that are in series are consecutive operations, a fact that can be noted on both the project operations printouts and the detailed CPM network plan. By altering the events of other activities in the network, days of slack can be realized for the activities not on the critical path schedule. Zero free float in activities red-flags the scheduler that this activity is heading into negative float, which in turn robs total float from the entire project.

The summary report sorts include these following standard sorts:

Sort by Activities

This is the main sort of the program and the heart of a CPM network schedule. We begin the network programming by entering data into this sort. This summary report breaks out each phase and the activities within each phase, assigns each activity an identifying number for program computations, the activity's duration when started and how much duration remains, percentage of activity completed to date, early and late start dates, early and late finish dates, the amount of free float assigned to the activity as well as the amount of total float that can be dedicated to or appropriated by the total project, the responsible activity subcontractor, and the activity's budgeted cost. This is the originating data generator and needs to be filled out in detail.

The activities sort sets the precedence for the network diagram format. Under this precedence diagramming format, each activity is represented by its respective activity number. You may assign any number to any activity you wish, but they must be sequential, relative to production, for the program to have job logic (see Fig. 7.1).

Sort by Events

In the Sort by Events, we see the different structuring of the program computation factors by event dates. The columns next to the activity's description are relative to the activity. This is further connected to the computer cell address, which is represented by the activity's number. The next event columns are sequence finish events connected to the *i–j* numbers in the preceding column. The sort further shows the percentage of the activity that is complete and the activity's free and total float. The sort is then linked to the cost-tracking sort by its projected cost and actual cost for the summary audit trail.

The Sort by Events represents the computer's registering of an event as the exact day at which an activity is just starting or finishing. Network program logic applying to all events is that all activities leading into an event can be started at that time. An activity is always preceded by an event and followed by a sequential event. Thus, an activity always has both a starting event and a finishing event. In CPM, that finishing event is the starting event of the next activity.

To build the events sort database, you start by designing a data range. This range must include all events (early start, late start, early finish, and late finish) to be sorted and wide enough to include all the info in all the fields in each record. If you do not include all field ranges when sorting, you destroy the integrity of the database because parts of one record end up with parts of

Your Company Name Here

Sort by Activities

Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date:	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***		**Page: 1 of**
Client Invoice:	***Owner's Job Invoice Number***		

Activity Number	Activity Description	Original Duration	Remaining Duration	% Comp	Early Start	Late Start	Early Finish	Late Finish
Phase 0:	**General Conditions**							
# 00010	Subsurface Investigation	30	0	100	20-Nov	24-Nov	10-Dec	12-Dec
# 00100	Instructions to Bidders	12	0	100	13-Nov	18-Nov	26-Nov	28-Nov
# 00200	Information Available to Bidders	2	0	100	28-Nov	2-Dec	4-Dec	8-Dec
# 00300	Bid Forms	1	0	100	10-Dec	12-Dec	11-Dec	15-Dec
# 00400	Supplements to Bid Forms	3	0	100	18-Dec	20-Dec	20-Dec	24-Dec
# 00500	Agreement Forms	0.5	0	100	10-Dec	12-Dec	11-Dec	15-Dec
# 00600	Bonds and Certificates	2	0	100	12-Dec	14-Dec	14-Dec	18-Dec
# 00700	General Conditions	0.5	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 00800	Supplementary Conditions	0.5	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 00850	Drawings and Schedules	1	0	100	18-Dec	19-Dec	17-Dec	20-Dec
# 00900	Addenda and Modifications	1	0	100	19-Dec	21-Dec	20-Dec	25-Dec
	Subtotal:	**53.5**	**0**	**100%**	**29**	**30**	**10**	**17**
Phase 1:	**Specifications**							
# 01010	Soils: Reports & Remediations	10	0	100	20-Nov	24-Dec	10-Jan	15-Jan
# 01020	Allowances	1	0	100	10-Dec	12-Dec	11-Dec	15-Dec
# 01025	Measurement & Payment	1	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 01030	Alternates / Alternatives	0	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 01040	Coordination	0.5	0	100	17-Dec	19-Dec	18-Dec	20-Dec
# 10150	Field Engineering	3	0	100	19-Dec	20-Dec	20-Dec	24-Dec
# 01060	Regulatory Requirements	1	0	100	26-Dec	30-Dec	28-Dec	30-Dec
# 01070	Abbreviations & Symbols	0.5	0	100	17-Dec	19-Dec	18-Dec	20-Dec
# 01080	Identification Systems	1	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 01090	Reference Standards	1	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 01100	Special Project Procedures	1	0	100	10-Dec	12-Dec	11-Dec	15-Dec
# 01200	Project Meetings	1	0	100	10-Dec	12-Dec	11-Dec	15-Dec
# 01300	Submittals	1	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 01400	Quality Control	1	0	100	10-Dec	12-Dec	11-Dec	15-Dec
# 01500	Const Facilities & Temp Control	1	0	100	17-Dec	19-Dec	17-Dec	20-Dec
# 01600	Material & Equipment	30	0	100	20-Dec	4-Jan	22-Jan	25-Jan
# 01650	Commissioning of Equipment	1	0	100	22-Dec	25-Jan	26-Jan	27-Jan
# 01700	Contract Closeout	1	0	100	28-Dec	29-Jan	29-Jan	30-Jan
# 01800	Maintenance	10	0	100	30-Dec	31-Jan	10-Feb	15-Feb
	Subtotal:	**66**	**0**	**100%**	**70**	**78**	**30**	**35**
Phase 2:	**Site Work**							
# 02010	Subsurface Investigation	10	0	100	31-Jan	31-Jan	11-Feb	16-Feb
# 02050	Demolition	3	0	100	16-Feb	18-Feb	19-Feb	21-Feb

FIGURE 7.1 Sort by activities.

# 02100	Site Preparation	30	0	100	16-Feb	18-Feb	19-Feb	21-Feb
# 02140	Dewatering	6	2	80	20-Feb	22-Feb	25-Feb	27-Feb
# 02150	Shoring & Underpinning	3	0	100	25-Feb	26-Feb	27-Feb	28-Feb
# 02160	Excavation Support Systems	3	0	100	25-Feb	26-Feb	27-Feb	28-Feb
# 02170	Cofferdams							
# 02200	Earthwork	7	0	100	28-Feb	30 Feb	4-Mar	7-Mar
# 02300	Tunneling							
# 02350	Piles & Caissons	5	0	100	10-Mar	12-Mar	19-Mar	22-Mar
# 02450	Railroad Work							
# 02480	Marine Work							
# 02500	Paving & Surfacing	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02600	Piped Utility Materials	2	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02660	Water Distribution	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02680	Fuel Distribution	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02700	Sewer & Drainage	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02760	Restoration of Pipelines	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02770	Ponds & Reservoirs	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02780	Power & Communications	3	0	100	17-Mar	19-Mar	21-Mar	23-Mar
# 02800	Site Improvements							
# 02900	Landscaping	20	0	100	17-Mar	19-Mar	21-Mar	23-Mar
	Subtotal:	**43**	**0**	**100%**	**27**	**33**	**11**	**19**
Phase 3:	**Concrete**							
# 03100	Concrete Formwork	11	0	100	23-Mar	25-Mar	4-Apr	6-Apr
# 03200	Concrete Reinforcement	3	0	100	6-Apr	8-Apr	9-Apr	11-Apr
# 03250	Concrete Accessories							
# 03300	Cast-in-Place Concrete	1	0	100	11-Apr	12-Apr	13-Apr	15-Apr
# 03370	Concrete Curing	15	0	100	15-Apr	18-Apr	3-Mar	5-Mar
# 03400	Precast Concrete							
# 03500	Cementious Decks							
# 03600	Grout	3	0	100	5-Mar	8-Mar	9-Mar	11-Mar
# 03700	Concrete Restoration & Cleaning							
# 03800	Mass Concrete							
# 03850	Site Clean-up	3	0	100	5-Mar	9-Mar	11-Mar	15-Mar
	Subtotal:	**36**	**0**	**100%**	**45**	**49**	**35**	**39**
	Phases Totals:	**268.5**	**2**	**98%**	**105**	**78**	**78**	**82**
Phase 4:	**Masonry**							
# 04100	Mortar	*(Enter your data here, chain-link macro spreadsheet formulas)*						
# 04150	Masonry Accessories							
# 04200	Unit Masonry							
# 04400	Stone							
# 04500	Masonry Restoration & Cleaning							
# 045500	Refactories							
# 04600	Corrision Resistant Masonry							
	Subtotal:							
Phase 5:	**Metals**							
# 05010	Metal Materials	*(Enter your data here, chain-link macro spreadsheet formulas)*						
# 05030	Metal Finishes							
# 05050	Metal Fastening							

# 05100	Structural Metal Framing	
# 05200	Metal Joists	
# 05300	Metal Decking	
# 05400	Cold-Formed Metal Framing	
# 05500	Metal Fabrications	
# 05580	Sheet Metal Fabrications	
# 05700	Ornamental Metal	
# 05800	Expansion Control	
# 05900	Hydraulic Structures	
	Subtotal:	
Phase 6:	**Wood & Plastics**	
# 06050	Fasteners & Adhesives	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	
	Subtotal:	
Phase 7:	**Thermal & Moisture**	
# 07100	Waterproofing	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	
	Subtotal:	
	Phases Totals:	
Phase 8:	**Doors & Windows**	
# 08100	Metal Doors & Frames	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	

FIGURE 7.1 Continued.

# 08800	Glazing	
# 08900	Glazed Curtain Walls	
	Subtotal:	
Phase 9:	**Finishes**	
# 09100	Metal Support Systems	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	
# 09500	Acoustical Treatment	
# 09540	Special Surfaces	
# 09550	Wood Flooring	
# 09600	Stone Flooring	
# 09630	Unit Masonry Flooring	
# 09650	Resilient Flooring	
# 09680	Carpet	
# 09700	Special Flooring	
# 09780	Floor Treatment	
# 09800	Special Coatings	
# 09900	Painting	
# 09950	Wall Coverings	
	Subtotal:	
Phase 10:	**Specialities**	
# 10100	Chalkboards & Tackboards	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	

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270 Madison Avenue, New York, New York 10016

# 10900	Wardrobe & Closet Specialties	
	Subtotal:	
Phase 11:	**Equipment**	
# 11010	Maintenance Equipment	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 11020	Security & Vault Equipment	
# 11030	Teller & Service Equipment	
# 11040	Ecclesiastical Equipment	
# 11050	Library Equipment	
# 11060	Theater & Stage Equipment	
# 11070	Instrumental Equipment	
# 11080	Registration Equipment	
# 11090	Checkroom Equipment	
# 11100	Mercantile Equipment	
# 11110	Laundry Equipment	
# 11120	Vending Equipment	
# 11130	Audio-Visual Equipment	
# 11140	Service Station Equipment	
# 11150	Parking Control Equipment	
# 11160	Loading Dock Equipment	
# 11170	Solid Waste Equipment	
# 11190	Detention Equipment	
# 11200	Water Supply / Treatment	
# 11280	Hydraulic Gate Valves	
# 11300	Fluid Waste Equipment	
# 11400	Food Service Equipment	
# 11450	Residential Equipment	
# 11460	Unit Kitchens	
# 11470	Darkroom Equipment	
# 11480	Recreational Equipment	
# 11500	Industrial Process Equipment	
# 11600	Laboratory Equipment	
# 11650	Planetarium Equipment	
# 11660	Observatory Equipment	
# 11700	Medical Equipment	
# 11780	Mortuary Equipment	
# 11850	Navigation Equipment	
	Subtotal:	
	Phases Totals:	
Phase 12:	**Furnishings**	
# 12050	Fabrics	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 12100	Artwork	
# 12300	Manufactured Casework	
# 12500	Window Treatment	
# 12600	Furniture & Accessories	
# 12670	Rugs & Mats	
# 12700	Multiples Seating	
# 12800	Interior Plants & Planters	
	Subtotal:	

FIGURE 7.1 Continued.

Phase 13:	Special Construction	
# 13010	Air Supported Structures	(Enter your data here, chain-link macro spreadsheet formulas)
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	
# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
	Subtotal:	

Phase 14:	Conveying Systems	
# 14100	Dumbwaiters	(Enter your data here, chain-link macro spreadsheet formulas)
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
	Subtotal:	

Phase 15:	Mechanical	
# 15100	Basic Materials & Methods	(Enter your data here, chain-link macro spreadsheet formulas)
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	

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270 Madison Avenue, New York, New York 10016

# 15850	Testing	
	Subtotal:	
Phase 16:	**Electrical**	
# 16100	Basic Materials & Methods	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	
	Subtotal:	
	Phases Totals:	

FIGURE 7.1 Continued.

other records. Be sure that the data range does not include the field name row. If this error is committed, the field name row is considered one of the records to be sorted and the database may be destroyed. The data range does not necessarily have to include the entire database. If part of the sort by events database already has the database organization you want, or if you do not want to sort all the records, you can selectively sort only a portion of the database (see Fig. 7.2).

Sort by *I–J* Numbers

In the Sort by *I–J* Numbers report, events are logged as the exact day an activity starts or finishes. They are also dates of milestone completions. Events are assigned an identification number for computer processing. The starting event number is the *i* number and the completion event number is the *j* number; each is shown in italic typeset to stand out from standard block printing. The *i–j* number is used as a relative cell address for the activity's data recordation.

Therefore, it is a basic CPM requirement that, when event numbers are assigned, the finishing event number at the head of the arrow must be greater that the starting event number at the tail of the arrow, and the *j*-value of each activity must be greater than its *i*-value. A typical CPM network can involve hundreds of separate activities that must have flexibilities in scheduling, so the experienced project scheduler assigns the activities *i–j* numbers only *after* the entire network has been completed and is ready for its first cooking or trial-run computation.

Using the vertical and horizontal axes of graph coordinates, *i–j* events can be displayed in either plane. The vertical numbering method is more

Your Company Name Here

Sort by Events

Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date:	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***	**Page: 1 of**	
Client Invoice:	***Owner's Job Invoice Number***		

Activity Number	Early Event	Late Event	Activity Description	I - J Number	Early Finish	Late Finish	Free Float	Percent Complete
Phase 0:			**General Conditions**					
# 00010	0	0	Subsurface Investigation	1	20-Nov	24-Nov	0	100
# 00100	0	0	Instructions to Bidders	1	13-Nov	18-Nov	0	100
# 00200	0	0	Information Available to Bidders	1	28-Nov	2-Dec	0	100
# 00300	0	0	Bid Forms	1	10-Dec	12-Dec	0	100
# 00400	0	0	Supplements to Bid Forms	2	18-Dec	20-Dec	0	100
# 00500	0	0	Agreement Forms	2	10-Dec	12-Dec	0	100
# 00600	0	0	Bonds and Certificates	2	12-Dec	14-Dec	0	100
# 00700	0	0	General Conditions	2	17-Dec	19-Dec	0	100
# 00800	0	0	Supplementary Conditions	3	17-Dec	19-Dec	0	100
# 00850	0	0	Drawings and Schedules	3	18-Dec	19-Dec	0	100
# 00900	0	0	Addenda and Modifications	3	19-Dec	21-Dec	0	100
			Subtotal:					**100%**
Phase 1:			**Specifications**					
# 01010	0	0	Soils: Reports & Remediations	4	20-Nov	15-Jan	0	100
# 01020	0	0	Allowances	4	10-Dec	15-Dec	0	100
# 01025	0	0	Measurement & Payment	4	17-Dec	20-Dec	0	100
# 01030	0	0	Alternates / Alternatives	4	17-Dec	20-Dec	0	100
# 01040	0	0	Coordination	4	17-Dec	20-Dec	0	100
# 10150	0	0	Field Engineering	4	19-Dec	24-Dec	0	100
# 01060	0	0	Regulatory Requirements	4	26-Dec	30-Dec	0	100
# 01070	0	0	Abbreviations & Symbols	4	17-Dec	20-Dec	0	100
# 01080	0	0	Identification Systems	4	17-Dec	20-Dec	0	100
# 01090	0	0	Reference Standards	4	17-Dec	20-Dec	0	100
# 01100	0	0	Special Project Procedures	5	10-Dec	15-Dec	0	100
# 01200	0	0	Project Meetings	5	10-Dec	15-Dec	0	100
# 01300	0	0	Submittals	5	17-Dec	20-Dec	0	100
# 01400	0	0	Quality Control	5	10-Dec	15-Dec	0	100
# 01500	0	0	Const Facilities & Temp Control	5	17-Dec	20-Dec	0	100
# 01600	0	0	Material & Equipment	5	20-Dec	25-Jan	0	100
# 01650	0	0	Commissioning of Equipment	6	22-Dec	27-Jan	0	100
# 01700	0	0	Contract Closeout	6	28-Dec	30-Jan	0	100
# 01800	0	0	Maintenance	6	30-Dec	15-Feb	0	100
			Subtotal:					**100%**
Phase 2:			**Site Work**					
# 02010	0	0	Subsurface Investigation	7	31-Jan	16-Feb	0	100
# 02050	0	0	Demolition	7	16-Feb	21-Feb	0	100
# 02100	0	0	Site Preparation	7	16-Feb	21-Feb	0	100

FIGURE 7.2 Sort by events.

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270 Madison Avenue, New York, New York 10016

# 02140	0	0	Dewatering	7	20-Feb	27-Feb	0	100
# 02150	0	0	Shoring & Underpinning	7	25-Feb	28-Feb	0	100
# 02160	0	0	Excavation Support Systems	7	25-Feb	28-Feb	0	100
# 02170	0	0	Cofferdams					
# 02200	0	0	Earthwork	7	28-Feb	7-Mar	0	100
# 02300	0	0	Tunneling					
# 02350	0	0	Piles & Caissons	8	10-Mar	22-Mar	0	100
# 02450	0	0	Railroad Work					
# 02480	0	0	Marine Work					
# 02500	0	0	Paving & Surfacing	8	17-Mar	23-Mar	0	100
# 02600	0	0	Piped Utility Materials	8	17-Mar	23-Mar	0	100
# 02660	0	0	Water Distribution	8	17-Mar	23-Mar	0	100
# 02680	0	0	Fuel Distribution	8	17-Mar	23-Mar	0	100
# 02700	0	0	Sewer & Drainage	8	17-Mar	23-Mar	0	100
# 02760	0	0	Restoration of Pipelines	8	17-Mar	23-Mar	0	100
# 02770	0	0	Ponds & Reservoirs	8	17-Mar	23-Mar	0	100
# 02780	0	0	Power & Communications	8	17-Mar	23-Mar	0	100
# 02800	0	0	Site Improvements					
# 02900	0	0	Landscaping	9	17-Mar	23-Mar	0	100
			Subtotal:				**0**	**100%**
Phase 3:			**Concrete**					
# 03100	0	0	Concrete Formwork	10	23-Mar	6-Apr	0	100
# 03200	0	0	Concrete Reinforcement	10	6-Apr	11-Apr	0	100
# 03250	0	0	Concrete Accessories					
# 03300	0	0	Cast-in-Place Concrete	10	11-Apr	15-Apr	0	100
# 03370	0	0	Concrete Curing	11	15-Apr	5-Mar	0	100
# 03400	0	0	Precast Concrete					
# 03500	0	0	Cementious Decks					
# 03600	0	0	Grout	11	5-Mar	11-Mar	0	100
# 03700	0	0	Concrete Restoration & Cleaning					
# 03800	0	0	Mass Concrete					
# 03850	0	0	Site Clean-up	12	5-Mar	15-Mar	0	100
			Subtotal:				**0**	**100%**
			Phases Totals:				**0**	**100%**
Phase 4:			**Masonry**					
# 04100	0	0	Mortar	*(Enter your data here, chain-link formulas)*				
# 04150	0	0	Masonry Accessories					
# 04200	0	0	Unit Masonry					
# 04400	0	0	Stone					
# 04500	0	0	Masonry Restoration & Cleaning					
# 045500	0	0	Refactories					
# 04600	0	0	Corrision Resistant Masonry					
			Subtotal:					
Phase 5:			**Metals**					
# 05010	0	0	Metal Materials	*(Enter your data here, chain-link formulas)*				
# 05030	0	0	Metal Finishes					
# 05050	0	0	Metal Fastening					
# 05100	0	0	Structural Metal Framing					

FIGURE 7.2 Continued.

# 05200	0	0	Metal Joists	
# 05300	0	0	Metal Decking	
# 05400	0	0	Cold-Formed Metal Framing	
# 05500	0	0	Metal Fabrications	
# 05580	0	0	Sheet Metal Fabrications	
# 05700	0	0	Ornamental Metal	
# 05800	0	0	Expansion Control	
# 05900	0	0	Hydraulic Structures	
			Subtotal:	
Phase 6:			Wood & Plastics	
# 06050	0	0	Fasteners & Adhesives	*(Enter your data here, chain-link formulas)*
# 06100	0	0	Rough Carpentry	
# 06130	0	0	Heavy Timber	
# 06150	0	0	Wood-Metal Systems	
# 06170	0	0	Engineered Structural Wood	
# 06200	0	0	Finish Carpentry	
# 06300	0	0	Wood Treatment	
# 06400	0	0	Architectural Woodwork	
# 06500	0	0	Prefabricated Structural Plastics	
# 06600	0	0	Plastic Fabrications	
			Subtotal:	
Phase 7:			Thermal & Moisture Protection	
# 07100	0	0	Waterproofing	*(Enter your data here, chain-link formulas)*
# 07150	0	0	Dampproofing	
# 07190	0	0	Vapor & Water Barriers	
# 07200	0	0	Insulation	
# 07250	0	0	Fireproofing	
# 07300	0	0	Roofing Tiles & Shingles	
# 07400	0	0	Preformed Roofing Siding	
# 07500	0	0	Membrane Roofing	
# 07570	0	0	Traffic Topping	
# 07600	0	0	Flashing & Sheetmetal	
# 07700	0	0	Roof Specialties	
# 07800	0	0	Skylights	
# 07900	0	0	Joint Sealers	
			Subtotal:	
			Phases Totals:	
Phase 8:			Doors & Windows	
# 08100	0	0	Metal Doors & Frames	*(Enter your data here, chain-link formulas)*
# 08200	0	0	Wood & Plastic Doors	
# 08250	0	0	Door Opening Assemblies	
# 08300	0	0	Special Doors	
# 08400	0	0	Entrances & Storefronts	
# 08500	0	0	Metal Windows	
# 08600	0	0	Wood & Plastic Windows	
# 08650	0	0	Special Windows	
# 08700	0	0	Hardware	
# 08800	0	0	Glazing	

# 08900	0	0	Glazed Curtain Walls

Subtotal:

Phase 9:			Finishes	
# 09100	0	0	Metal Support Systems	*(Enter your data here, chain-link formulas)*
# 09200	0	0	Lath and Plaster	
# 09230	0	0	Aggregate Coatings	
# 09250	0	0	Gypsum Board	
# 09300	0	0	Tile	
# 09400	0	0	Terrazzo	
# 09500	0	0	Acoustical Treatment	
# 09540	0	0	Special Surfaces	
# 09550	0	0	Wood Flooring	
# 09600	0	0	Stone Flooring	
# 09630	0	0	Unit Masonry Flooring	
# 09650	0	0	Resilient Flooring	
# 09680	0	0	Carpet	
# 09700	0	0	Special Flooring	
# 09780	0	0	Floor Treatment	
# 09800	0	0	Special Coatings	
# 09900	0	0	Painting	
# 09950	0	0	Wall Coverings	

Subtotal:

Phase 10:			Specialities	
# 10100	0	0	Chalkboards & Tackboards	*(Enter your data here, chain-link formulas)*
# 10150	0	0	Compartments & Cubicles	
# 10200	0	0	Louvers & Vents	
# 10240	0	0	Grilles & Screens	
# 10250	0	0	Service Wall Systems	
# 10260	0	0	Wall & Corner Guards	
# 10270	0	0	Access Flooring	
# 10280	0	0	Specialty Modules	
# 10290	0	0	Pest Control	
# 10300	0	0	Fireplaces & Stoves	
# 10340	0	0	Prefabricated Exterior Specialties	
# 10350	0	0	Flagpoles	
# 10400	0	0	Identifying Devices	
# 10450	0	0	Pedestrian Control Devices	
# 10500	0	0	Lockers	
# 10520	0	0	Fire Protection Specialties	
# 10530	0	0	Protective Covers	
# 10550	0	0	Postal Specialties	
# 10600	0	0	Partitions	
# 10650	0	0	Operable Partitions	
# 10670	0	0	Storage Shelving	
# 10700	0	0	Exterior Sun Control Devices	
# 10750	0	0	Telephone Specialties	
# 10800	0	0	Toilet & Bath Specialties	
# 10880	0	0	Scales	
# 10900	0	0	Wardrobe & Closet Specialties	

FIGURE 7.2 Continued.

Subtotal:

Phase 11:			Equipment	
# 11010	0	0	Maintenance Equipment	(Enter your data here, chain-link formulas)
# 11020	0	0	Security & Vault Equipment	
# 11030	0	0	Teller & Service Equipment	
# 11040	0	0	Ecclesiastical Equipment	
# 11050	0	0	Library Equipment	
# 11060	0	0	Theater & Stage Equipment	
# 11070	0	0	Instrumental Equipment	
# 11080	0	0	Registration Equipment	
# 11090	0	0	Checkroom Equipment	
# 11100	0	0	Mercantile Equipment	
# 11110	0	0	Laundry Equipment	
# 11120	0	0	Vending Equipment	
# 11130	0	0	Audio-Visual Equipment	
# 11140	0	0	Service Station Equipment	
# 11150	0	0	Parking Control Equipment	
# 11160	0	0	Loading Dock Equipment	
# 11170	0	0	Solid Waste Equipment	
# 11190	0	0	Detention Equipment	
# 11200	0	0	Water Supply / Treatment	
# 11280	0	0	Hydraulic Gate Valves	
# 11300	0	0	Fluid Waste Equipment	
# 11400	0	0	Food Service Equipment	
# 11450	0	0	Residential Equipment	
# 11460	0	0	Unit Kitchens	
# 11470	0	0	Darkroom Equipment	
# 11480	0	0	Recreational Equipment	
# 11500	0	0	Industrial Process Equipment	
# 11600	0	0	Laboratory Equipment	
# 11650	0	0	Planetarium Equipment	
# 11660	0	0	Observatory Equipment	
# 11700	0	0	Medical Equipment	
# 11780	0	0	Mortuary Equipment	
# 11850	0	0	Navigation Equipment	

Subtotal:
Phases Totals:

Phase 12:			Furnishings	
# 12050	0	0	Fabrics	(Enter your data here, chain-link formulas)
# 12100	0	0	Artwork	
# 12300	0	0	Manufactured Casework	
# 12500	0	0	Window Treatment	
# 12600	0	0	Furniture & Accessories	
# 12670	0	0	Rugs & Mats	
# 12700	0	0	Multiples Seating	
# 12800	0	0	Interior Plants & Planters	

Subtotal:

Phase 13:	Special Construction

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

# 13010	0	0	Air Supported Structures	*(Enter your data here, chain-link formulas)*
# 13020	0	0	Integrated Assemblies	
# 13030	0	0	Special Purpose Rooms	
# 13080	0	0	Sound, Vibration, Seismic	
# 13090	0	0	Radiation Protection	
# 13100	0	0	Nuclear Reactors	
# 13120	0	0	Pre-Engineered Structures	
# 13150	0	0	Pools	
# 13160	0	0	Ice Links	
# 13170	0	0	Kennels	
# 13180	0	0	Site Constructed Incinerators	
# 13200	0	0	Gas / Liquid Storage Tanks	
# 13220	0	0	Filter Underdrains & Media	
# 13230	0	0	Tank Covers	
# 13240	0	0	Oxygenation Systems	
# 13260	0	0	Sludge Conditioning Systems	
# 13300	0	0	Utility Control Systems	
# 13400	0	0	Industrial / Process Controls	
# 13500	0	0	Recording Instruments	
# 13550	0	0	Transportation Controls	
# 13600	0	0	Solar Energy Systems	
# 13700	0	0	Wind Energy Systems	
# 13800	0	0	Building Automation Systems	
# 13900	0	0	Fire Suppression Systems	
			Subtotal:	
Phase 14:			**Conveying Systems**	
# 14100	0	0	Dumbwaiters	*(Enter your data here, chain-link formulas)*
# 14200	0	0	Elevators	
# 14250	0	0	Moving Stairs & Walkways	
# 14300	0	0	Lifts	
# 14350	0	0	Material Handling Systems	
# 14400	0	0	Hoists & Cranes	
# 14500	0	0	Turntables	
# 14600	0	0	Scaffolding	
# 14700	0	0	Transportation Systems	
			Subtotal:	
Phase 15:			**Mechanical**	
# 15100	0	0	Basic Materials & Methods	*(Enter your data here, chain-link formulas)*
# 15200	0	0	Mechanical Insulation	
# 15300	0	0	Fire Protection	
# 15400	0	0	Plumbing	
# 15500	0	0	HVAC	
# 15550	0	0	Heat Generation	
# 15570	0	0	Heat Transfer	
# 15600	0	0	Refrigeration	
# 15700	0	0	Air Handling	
# 15750	0	0	Air Distribution	
# 15800	0	0	Controls	
# 15850	0	0	Testing	

FIGURE 7.2 Continued.

			Subtotal:	
Phase 15:			Electrical	
# 16100	0	0	Basic Materials & Methods	*(Enter your data here, chain-link formulas)*
# 16110	0	0	Power Generation	
# 16200	0	0	High Voltage Distribution >600v	
# 16250	0	0	Service Distribution <600v	
# 16300	0	0	Lighting	
# 16400	0	0	Special Systems	
# 16450	0	0	Communications	
# 16500	0	0	Electric Resistance Heating	
# 16600	0	0	Controls	
# 16700	0	0	Testing	
			Subtotal:	
			Phases Totals:	

widely used, which numbers all events in a vertical column in sequence from top to bottom that equates to a parallel timeline with those groups of activities moving from left to right. There is no significance to the event numbers themselves except as a means of identifying an activity, so if the CPM format of keeping the *j*-value of each activity greater than its *i*-value is used, blank cells can be left in the numbering system so that spare numbers are available for changes or additional work that may come up. Sequential *i–j* numbering provides this flexibility in scheduling while also providing the computer with program logic data for events and activities locations on the network diagram (see Fig. 7.3).

Sort by Job Logic

The logical sequence of the project's construction activities, adjusted by local limitations, is factored here in the job logic sort. The activities chosen may represent relatively large segments of the project or may be limited to small steps only. For example, a concrete slab may be a single activity on a small job, but on a larger job it will be broken into the separate steps necessary to construct it, such as excavation, sub-ex preparation, erection of forms, placing of steel, placing of concrete, finishing, curing, and stripping of forms. As the separate activities are identified and defined, the sequence relationships between them must be determined.

These relationships are referred to as job logic and consist of the necessary time durations and precedence, or sequential order, of typical local construction operations that are unique to your geographic area. It is a basic fundamental in CPM that each activity has a determined starting event, which may be either its own start or the finish of the preceding activity. Activity durations cannot overlap their finish events. Therefore, job logic is established to provide a sequence of operations within practical constraints.

Your Company Name Here		**Sort by I - J Numbers**					
Prepared For:	***Your Client's Name Here***						
Project:	***Project's Name Here***	Data Date:	*Data Entry Date*				
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*				
Description:	*Project Description Here*						
Our Invoice No:	***Your Company's Job Number***						
Client Invoice:	***Owner's Job Invoice Number***						

Activity Number	Activity Description	Original Duration	Remaining Duration	I Node	J Node	Previous I Number	Succeeding J Number
Phase 0:	**General Conditions**						
# 00010	Subsurface Investigation	30	0	1	3	0	4
# 00100	Instructions to Bidders	12	0	1	3	0	4
# 00200	Information Available to Bidders	2	0	1	3	0	4
# 00300	Bid Forms	1	0	1	3	0	4
# 00400	Supplements to Bid Forms	3	0	1	3	0	4
# 00500	Agreement Forms	0.5	0	1	3	0	4
# 00600	Bonds and Certificates	2	0	1	3	0	4
# 00700	General Conditions	0.5	0	2	4	1	5
# 00800	Supplementary Conditions	0.5	0	2	4	1	5
# 00850	Drawings and Schedules	1	0	2	4	1	5
# 00900	Addenda and Modifications	1	0	2	4	1	5
	Subtotal:	**53.5**	**0**				
Phase 1:	**Specifications**						
# 01010	Soils: Reports & Remediations	10	0	3	5	2	6
# 01020	Allowances	1	0	3	5	2	6
# 01025	Measurement & Payment	1	0	3	5	2	6
# 01030	Alternates / Alternatives	0	0	3	5	2	6
# 01040	Coordination	0.5	0	3	6	2	7
# 10150	Field Engineering	3	0	3	6	2	7
# 01060	Regulatory Requirements	1	0	3	6	2	7
# 01070	Abbreviations & Symbols	0.5	0	3	7	2	8
# 01080	Identification Systems	1	0	4	7	3	8
# 01090	Reference Standards	1	0	4	7	3	8
# 01100	Special Project Procedures	1	0	4	7	3	8
# 01200	Project Meetings	1	0	4	8	3	9
# 01300	Submittals	1	0	4	8	3	9
# 01400	Quality Control	1	0	4	8	3	9
# 01500	Const Facilities & Temp Control	1	0	4	8	3	9
# 01600	Material & Equipment	30	0	4	9	3	10
# 01650	Commissioning of Equipment	1	0	4	9	3	10
# 01700	Contract Closeout	1	0	4	9	3	10
# 01800	Maintenance	10	0	4	9	3	10
	Subtotal:	**66**	**0**				
Phase 2:	**Site Work**						
# 02010	Subsurface Investigation	10	0	5	10	4	11
# 02050	Demolition	3	0	6	15	5	16

FIGURE 7.3 Sort by *I–J* numbers.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

# 02100	Site Preparation	30	0	7	17	6	18
# 02140	Dewatering	6	2	8	18	7	19
# 02150	Shoring & Underpinning	3	0	10	20	9	21
# 02160	Excavation Support Systems	3	0	15	22	14	23
# 02170	Cofferdams						
# 02200	Earthwork	7	0	17	26	16	27
# 02300	Tunneling						
# 02350	Piles & Caissons	5	0	20	28	19	29
# 02450	Railroad Work						
# 02480	Marine Work						
# 02500	Paving & Surfacing	3	0	23	32	22	33
# 02600	Piped Utility Materials	2	0	25	38	24	39
# 02660	Water Distribution	3	0	30	45	29	46
# 02680	Fuel Distribution	3	0	35	48	34	49
# 02700	Sewer & Drainage	3	0	40	49	39	50
# 02760	Restoration of Pipelines	3	0	45	50	44	51
# 02770	Ponds & Reservoirs	3	0	50	60	49	61
# 02780	Power & Communications	3	0	53	68	52	69
# 02800	Site Improvements						
# 02900	Landscaping	20	0	55	73	54	74
	Subtotal:	**43**	**0**				
Phase 3:	**Concrete**						
# 03100	Concrete Formwork	11	0	90	110	89	111
# 03200	Concrete Reinforcement	3	0	92	117	91	118
# 03250	Concrete Accessories						
# 03300	Cast-in-Place Concrete	1	0	94	120	93	121
# 03370	Concrete Curing	15	0	95	125	94	126
# 03400	Precast Concrete						
# 03500	Cementious Decks						
# 03600	Grout	3	0	96	128	95	129
# 03700	Concrete Restoration & Cleaning						
# 03800	Mass Concrete						
# 03850	Site Clean-up	3	0	97	130	96	131
4	**Subtotal:**	**36**	**0**				
	Phases Totals:	**268.5**	**2**				
Phase 4:	**Masonry**						
# 04100	Mortar	*(Enter your data here, chain-link macro spreadsheet formulas)*					
# 04150	Masonry Accessories						
# 04200	Unit Masonry						
# 04400	Stone						
# 04500	Masonry Restoration & Cleaning						
# 045500	Refactories						
# 04600	Corrision Resistant Masonry						
	Subtotal:						
Phase 5:	**Metals**						
# 05010	Metal Materials	*(Enter your data here, chain-link macro spreadsheet formulas)*					
# 05030	Metal Finishes						
# 05050	Metal Fastening						

# 05100	Structural Metal Framing	
# 05200	Metal Joists	
# 05300	Metal Decking	
# 05400	Cold-Formed Metal Framing	
# 05500	Metal Fabrications	
# 05580	Sheet Metal Fabrications	
# 05700	Ornamental Metal	
# 05800	Expansion Control	
# 05900	Hydraulic Structures	
	Subtotal:	
Phase 6:	**Wood & Plastics**	
# 06050	Fasteners & Adhesives	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	
	Subtotal:	
Phase 7:	**Thermal & Moisture**	
# 07100	Waterproofing	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	
	Subtotal:	
	Phases Totals:	
Phase 8:	**Doors & Windows**	
# 08100	Metal Doors & Frames	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	

FIGURE 7.3 Continued.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

# 08800	Glazing	
# 08900	Glazed Curtain Walls	
	Subtotal:	

Phase 9:	**Finishes**	
# 09100	Metal Support Systems	*{ Enter your data here, chain-link macro spreadsheet formulas }*
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	
# 09500	Acoustical Treatment	
# 09540	Special Surfaces	
# 09550	Wood Flooring	
# 09600	Stone Flooring	
# 09630	Unit Masonry Flooring	
# 09650	Resilient Flooring	
# 09680	Carpet	
# 09700	Special Flooring	
# 09780	Floor Treatment	
# 09800	Special Coatings	
# 09900	Painting	
# 09950	Wall Coverings	
	Subtotal:	

Phase 10:	**Specialities**	
# 10100	Chalkboards & Tackboards	*{ Enter your data here, chain-link macro spreadsheet formulas }*
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

# 10900	Wardrobe & Closet Specialties	
	Subtotal:	
Phase 11:	**Equipment**	
# 11010	Maintenance Equipment	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 11020	Security & Vault Equipment	
# 11030	Teller & Service Equipment	
# 11040	Ecclesiastical Equipment	
# 11050	Library Equipment	
# 11060	Theater & Stage Equipment	
# 11070	Instrumental Equipment	
# 11080	Registration Equipment	
# 11090	Checkroom Equipment	
# 11100	Mercantile Equipment	
# 11110	Laundry Equipment	
# 11120	Vending Equipment	
# 11130	Audio-Visual Equipment	
# 11140	Service Station Equipment	
# 11150	Parking Control Equipment	
# 11160	Loading Dock Equipment	
# 11170	Solid Waste Equipment	
# 11190	Detention Equipment	
# 11200	Water Supply / Treatment	
# 11280	Hydraulic Gate Valves	
# 11300	Fluid Waste Equipment	
# 11400	Food Service Equipment	
# 11450	Residential Equipment	
# 11460	Unit Kitchens	
# 11470	Darkroom Equipment	
# 11480	Recreational Equipment	
# 11500	Industrial Process Equipment	
# 11600	Laboratory Equipment	
# 11650	Planetarium Equipment	
# 11660	Observatory Equipment	
# 11700	Medical Equipment	
# 11780	Mortuary Equipment	
# 11850	Navigation Equipment	
	Subtotal:	
	Phases Totals:	
Phase 12:	**Furnishings**	
# 12050	Fabrics	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 12100	Artwork	
# 12300	Manufactured Casework	
# 12500	Window Treatment	
# 12600	Furniture & Accessories	
# 12670	Rugs & Mats	
# 12700	Multiples Seating	
# 12800	Interior Plants & Planters	
	Subtotal:	

FIGURE 7.3 Continued.

Phase 13:	Special Construction	
# 13010	Air Supported Structures	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	
# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
	Subtotal:	

Phase 14:	Conveying Systems	
# 14100	Dumbwaiters	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
	Subtotal:	

Phase 15:	Mechanical	
# 15100	Basic Materials & Methods	*(Enter your data here, chain-link macro spreadsheet formulas)*
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	

# 15850	Testing	
	Subtotal:	
Phase 16:	**Electrical**	
# 16100	Basic Materials & Methods	{ Enter your data here, chain-link macro spreadsheet formulas }
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	
	Subtotal:	
	Phases Totals:	

FIGURE 7.3 Continued.

Established job logic in the job logic sort is then used to build program logic within the computerized CPM program. By determining the job logic, activities can have their interdependencies critically examined during all phases of the schedule, before errors costing delays and money begin. In the vertical method of event node, which is more widely used, numbers of all events are in a vertical column in a sequence from top to bottom that equates to a parallel timeline. Because of the vertical configuration, activity job logic can have logic loops in those vertical groups of activities without the scheduler realizing they are there, the error then moving from left to right on the timeline with the activity group.

Study the network diagram carefully at the beginning of the development of the schedule to confirm the job logic of the structure and to critically search for logic loops. The best method to safeguard against their inclusion in your schedule is the use of sequential *i–j* numbering. The computer sort printout cannot indicate any clues to the presence of logic loops under the use of a random *i–j* numbering system, so random numbering guarantees a greater likelihood of error by allowing logical loops to remain undiscovered. Accordingly, to make ultimate use of computer program logic, the database, which in this case is the *i–j* numbers, must be sequential (see Fig. 7.4).

Sort by Total Float/Late Start

Total float is shown on the Total Float/Late Start sort as the amount of time that an activity can be delayed without delaying the late finish event for the project completion. Total float is shared with all activities. When an activity has a certain amount of total float, it can be used without tighter scheduling constraints occurring to all of the other critical path activities. Late start of the

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270 Madison Avenue, New York, New York 10016

Your Company Name Here

Sort by Job Logic

Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***	**Page: 1 of**	
Client Invoice:	***Owner's Job Invoice Number***		

Activity Number	Activity Description	I - J Number	Critical Path	Early Start	Late Start	Total Float	Sequence Number
Phase 0:	**General Conditions**						
# 00010	Subsurface Investigation	1	A	20-Nov	24-Nov	1	1
# 00100	Instructions to Bidders	1	A	13-Nov	18-Nov	1	2
# 00200	Information Available to Bidders	1	A	28-Nov	2-Dec	1	3
# 00300	Bid Forms	1	A	10-Dec	12-Dec	1	4
# 00400	Supplements to Bid Forms	1	A	18-Dec	20-Dec	2	5
# 00500	Agreement Forms	1	A	10-Dec	12-Dec	1	6
# 00600	Bonds and Certificates	1	A	12-Dec	14-Dec	1	7
# 00700	General Conditions	1	A	17-Dec	19-Dec	1	8
# 00800	Supplementary Conditions	1	A	17-Dec	19-Dec	2	9
# 00850	Drawings and Schedules	1	A	18-Dec	19-Dec	2	10
# 00900	Addenda and Modifications	1	A	19-Dec	21-Dec	2	11
Phase 1:	**Specifications**						
# 01010	Soils: Reports & Remediations	2	A	20-Nov	24-Dec	10-Jan	12
# 01020	Allowances	2	A	10-Dec	12-Dec	11-Dec	13
# 01025	Measurement & Payment	2	A	17-Dec	19-Dec	17-Dec	14
# 01030	Alternates / Alternatives	2	A	17-Dec	19-Dec	17-Dec	15
# 01040	Coordination	2	A	17-Dec	19-Dec	18-Dec	16
# 10150	Field Engineering	2	A	19-Dec	20-Dec	20-Dec	17
# 01060	Regulatory Requirements	2	A	26-Dec	30-Dec	28-Dec	18
# 01070	Abbreviations & Symbols	2	A	17-Dec	19-Dec	18-Dec	19
# 01080	Identification Systems	2	A	17-Dec	19-Dec	17-Dec	20
# 01090	Reference Standards	2	A	17-Dec	19-Dec	17-Dec	21
# 01100	Special Project Procedures	2	B	10-Dec	12-Dec	11-Dec	22
# 01200	Project Meetings	2	A	10-Dec	12-Dec	11-Dec	23
# 01300	Submittals	2	A	17-Dec	19-Dec	17-Dec	24
# 01400	Quality Control	2	A	10-Dec	12-Dec	11-Dec	25
# 01500	Const Facilities & Temp Control	2	A	17-Dec	19-Dec	17-Dec	26
# 01600	Material & Equipment	2	A	20-Dec	4-Jan	22-Jan	27
# 01650	Commissioning of Equipment	2	A	22-Dec	25-Jan	26-Jan	28
# 01700	Contract Closeout	2	B	28-Dec	29-Jan	29-Jan	29
# 01800	Maintenance	2	A	30-Dec	31-Jan	10-Feb	30
Phase 2:	**Site Work**						
# 02010	Subsurface Investigation	3	A	31-Jan	31-Jan	11-Feb	31
# 02050	Demolition	3	A	16-Feb	18-Feb	19-Feb	32
# 02100	Site Preparation	3	A	16-Feb	18-Feb	19-Feb	33
# 02140	Dewatering	3	A	20-Feb	22-Feb	25-Feb	34

FIGURE 7.4 Sort by job logic.

# 02150	Shoring & Underpinning	3	A	25-Feb	26-Feb	27-Feb	35
# 02160	Excavation Support Systems	3	B	25-Feb	26-Feb	27-Feb	36
# 02170	Cofferdams						
# 02200	Earthwork	3	A	28-Feb	30 Feb	4-Mar	37
# 02300	Tunneling						
# 02350	Piles & Caissons	3	B	10-Mar	12-Mar	19-Mar	38
# 02450	Railroad Work						
# 02480	Marine Work						
# 02500	Paving & Surfacing	3	A	17-Mar	19-Mar	21-Mar	39
# 02600	Piped Utility Materials	3	A	17-Mar	19-Mar	21-Mar	40
# 02660	Water Distribution	3	A	17-Mar	19-Mar	21-Mar	41
# 02680	Fuel Distribution	3	A	17-Mar	19-Mar	21-Mar	42
# 02700	Sewer & Drainage	3	A	17-Mar	19-Mar	21-Mar	43
# 02760	Restoration of Pipelines	3	A	17-Mar	19-Mar	21-Mar	44
# 02770	Ponds & Reservoirs	3	A	17-Mar	19-Mar	21-Mar	45
# 02780	Power & Communications	3	A	17-Mar	19-Mar	21-Mar	46
# 02800	Site Improvements						
# 02900	Landscaping	3	B	17-Mar	19-Mar	21-Mar	47
Phase 3:	**Concrete**						
# 03100	Concrete Formwork	4	A	23-Mar	25-Mar	4-Apr	48
# 03200	Concrete Reinforcement	4	A	6-Apr	8-Apr	9-Apr	49
# 03250	Concrete Accessories						
# 03300	Cast-in-Place Concrete	4	A	11-Apr	12-Apr	13-Apr	50
# 03370	Concrete Curing	4	A	15-Apr	18-Apr	3-Mar	51
# 03400	Precast Concrete						
# 03500	Cementious Decks						
# 03600	Grout	4	A	5-Mar	8-Mar	9-Mar	52
# 03700	Concrete Restoration & Cleaning						
# 03800	Mass Concrete						
# 03850	Site Clean-up	4	B	5-Mar	9-Mar	11-Mar	53
Phase 4:	**Masonry**						
# 04100	Mortar	*(Enter your data here, chain-link spreadsheets)*					
# 04150	Masonry Accessories						
# 04200	Unit Masonry						
# 04400	Stone						
# 04500	Masonry Restoration & Cleaning						
# 045500	Refactories						
# 04600	Corrision Resistant Masonry						
Phase 5:	**Metals**						
# 05010	Metal Materials	*(Enter your data here, chain-link spreadsheets)*					
# 05030	Metal Finishes						
# 05050	Metal Fastening						
# 05100	Structural Metal Framing						
# 05200	Metal Joists						
# 05300	Metal Decking						
# 05400	Cold-Formed Metal Framing						
# 05500	Metal Fabrications						
# 05580	Sheet Metal Fabrications						

Figure 7.4 Continued.

05700 Ornamental Metal
05800 Expansion Control
05900 Hydraulic Structures

Phase 6:	Wood & Plastics	
# 06050	Fasteners & Adhesives	(Enter your data here, chain-link spreadsheets)
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	

Phase 7:	Thermal & Moisture	
# 07100	Waterproofing	(Enter your data here, chain-link spreadsheets)
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	

Phase 8:	Doors & Windows	
# 08100	Metal Doors & Frames	(Enter your data here, chain-link spreadsheets)
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	
# 08800	Glazing	
# 08900	Glazed Curtain Walls	

Phase 9:	Finishes	
# 09100	Metal Support Systems	(Enter your data here, chain-link spreadsheets)
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	

# 09500	Acoustical Treatment
# 09540	Special Surfaces
# 09550	Wood Flooring
# 09600	Stone Flooring
# 09630	Unit Masonry Flooring
# 09650	Resilient Flooring
# 09680	Carpet
# 09700	Special Flooring
# 09780	Floor Treatment
# 09800	Special Coatings
# 09900	Painting
# 09950	Wall Coverings

Phase 10:	**Specialities**	
# 10100	Chalkboards & Tackboards	*(Enter your data here, chain-link spreadsheets)*
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	
# 10900	Wardrobe & Closet Specialties	

Phase 11:	**Equipment**	
# 11010	Maintenance Equipment	*(Enter your data here, chain-link spreadsheets)*
# 11020	Security & Vault Equipment	
# 11030	Teller & Service Equipment	
# 11040	Ecclesiastical Equipment	
# 11050	Library Equipment	
# 11060	Theater & Stage Equipment	
# 11070	Instrumental Equipment	
# 11080	Registration Equipment	
# 11090	Checkroom Equipment	

Figure 7.4 Continued.

# 11100	Mercantile Equipment
# 11110	Laundry Equipment
# 11120	Vending Equipment
# 11130	Audio-Visual Equipment
# 11140	Service Station Equipment
# 11150	Parking Control Equipment
# 11160	Loading Dock Equipment
# 11170	Solid Waste Equipment
# 11190	Detention Equipment
# 11200	Water Supply / Treatment
# 11280	Hydraulic Gate Valves
# 11300	Fluid Waste Equipment
# 11400	Food Service Equipment
# 11450	Residential Equipment
# 11460	Unit Kitchens
# 11470	Darkroom Equipment
# 11480	Recreational Equipment
# 11500	Industrial Process Equipment
# 11600	Laboratory Equipment
# 11650	Planetarium Equipment
# 11660	Observatory Equipment
# 11700	Medical Equipment
# 11780	Mortuary Equipment
# 11850	Navigation Equipment

Phase 12:	**Furnishings**	
# 12050	Fabrics	*(Enter your data here, chain-link spreadsheets)*
# 12100	Artwork	
# 12300	Manufactured Casework	
# 12500	Window Treatment	
# 12600	Furniture & Accessories	
# 12670	Rugs & Mats	
# 12700	Multiples Seating	
# 12800	Interior Plants & Planters	

Phase 13:	**Special Construction**	
# 13010	Air Supported Structures	*(Enter your data here, chain-link spreadsheets)*
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	

# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
Phase 14:	**Conveying Systems**	
# 14100	Dumbwaiters	*(Enter your data here, chain-link spreadsheets)*
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
Phase 15:	**Mechanical**	
# 15100	Basic Materials & Methods	*(Enter your data here, chain-link spreadsheets)*
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	
# 15850	Testing	
Phase 16:	**Electrical**	
# 16100	Basic Materials & Methods	*(Enter your data here, chain-link spreadsheets)*
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	

FIGURE 7.4 Continued.

activity will reduce this availability and therefore must be computed against the total float to provide accurate computation.

Free float is not shared with other activities as is total float, so free float provides the only true measure of how many days an activity can be delayed or extended without delaying any of the other activities. It is added as part of the total float of preceding activities. In the sort by total float/late start, the network schedule is linked to show the CPM network with required activities

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270 Madison Avenue, New York, New York 10016

time durations in days. Free float would be a portion of each activity's noncritical duration. Total float would be the sum of each activity's remaining free float that could be committed to the critical path. Total float shown on the sort by total float/late start is computed twice by the computer, then plotted once on the spreadsheet for early start and finish events and plotted again for late start and finish events.

Line float is the amount of available slack time per line item on the computer network. In this software program, line float time is easy to compute because it is simply the difference between the early and late dates for an activity. It represents the available time between the earliest time in which an activity can be accomplished (based on the status of the project to date) and the latest time by which it must finish for the project to finish by its event deadline. When the critical path has been delayed and production is now behind schedule, the earliest starting event when an activity can begin is now past the latest time in which it can be completed to stay on schedule. This is known as negative float. Because the activity has no float, its completion time is reduced to critical duration and, if it is behind, the difference between the early and late dates on the sort by total float/late start is less than zero. Negative float shows how far behind schedule the activity is and, if it is a critical path activity, shows how late the project completion will be (see Fig. 7.5).

Cost by Activity Number

The crucial tasks of monitoring the project field service costs as separate and distinct from the architect's design costs are handled by the Cost by Activity Number sort. The amount of the field costs is a function of the size and classifications of the on-site field labor forces assigned to the project, field office overhead costs, materials and supplies, support services from the home office, vehicle leases and fuel charges, field office share of corporate general and administrative (G&A) costs, outside consultants or contract services, and job profit.

By tabulating the monthly accumulations of budget and actual field service costs, then graphically plotting each amount on this time-versus-cost chart (similar in form to the traditional construction S-curve chart), you can make a visual comparison that will not only clearly show the status of the contract at any given time but will also show the project manager or owner any change in trend toward either a savings or a cost overrun. By also plotting a curve representing the amounts invoiced to the owner for such field services, you can provide an additional dimension of usable data to the owner.

To prepare and maintain the cost-tracking chart on the computer program, enter the items into the cost by activity number program file. This

Your Company Name Here

Sort by Total Float / Late Start

Prepared For: ***Your Client's Name Here***
Project: ***Project's Name Here***
File Name: *Your Computer File Name Here* Data Date: *Data Entry Date*
Description: *Project Description Here* Run Date: *Printout Date*
Our Invoice No: ***Your Company's Job Number***
Client Invoice: ***Owner's Job Invoice Number***

Activity Number	Activity Description	Duration Estimate	% Comp	I Node	J Node	Free Float	Total Float
Phase 0:	**General Conditions**						
# 00010	Subsurface Investigation	30	100	1	3	1	2
# 00100	Instructions to Bidders	12	100	1	3	1	2
# 00200	Information Available to Bidders	2	100	1	3	1	2
# 00300	Bid Forms	1	100	1	3	1	2
# 00400	Supplements to Bid Forms	3	100	1	3	1	2
# 00500	Agreement Forms	0.5	100	1	3	1	2
# 00600	Bonds and Certificates	2	100	1	3	1	2
# 00700	General Conditions	0.5	100	2	4	1	3
# 00800	Supplementary Conditions	0.5	100	2	4	1	2
# 00850	Drawings and Schedules	1	100	2	4	1	2
# 00900	Addenda and Modifications	1	100	2	4	1	2
	Subtotal:	**53.5**	**100%**				
Phase 1:	**Specifications**						
# 01010	Soils: Reports & Remediations	10	100	3	5	2	2
# 01020	Allowances	1	100	3	5	2	2
# 01025	Measurement & Payment	1	100	3	5	1	2
# 01030	Alternates / Alternatives	0	100	3	5	1	1
# 01040	Coordination	0.5	100	3	6	1	1
# 10150	Field Engineering	3	100	3	6	1	1
# 01060	Regulatory Requirements	1	100	3	6	2	3
# 01070	Abbreviations & Symbols	0.5	100	3	7	2	3
# 01080	Identification Systems	1	100	4	7	3	4
# 01090	Reference Standards	1	100	4	7	3	4
# 01100	Special Project Procedures	1	100	4	7	1	2
# 01200	Project Meetings	1	100	4	8	1	2
# 01300	Submittals	1	100	4	8	1	2
# 01400	Quality Control	1	100	4	8	1	2
# 01500	Const Facilities & Temp Control	1	100	4	8	1	2
# 01600	Material & Equipment	30	100	4	9	1	2
# 01650	Commissioning of Equipment	1	100	4	9	3	4
# 01700	Contract Closeout	1	100	4	9	3	4
# 01800	Maintenance	10	100	4	9	1	2
	Subtotal:	**66**	**100%**				
Phase 2:	**Site Work**						
# 02010	Subsurface Investigation	10	100	5	10	1	2
# 02050	Demolition	3	100	6	15	1	2

FIGURE 7.5 Sort by total float/late start.

#	02100	Site Preparation	30	100	7	17	1	2
#	02140	Dewatering	6	100	8	18	1	2
#	02150	Shoring & Underpinning	3	100	10	20	1	2
#	02160	Excavation Support Systems	3	100	15	22	1	2
#	02170	Cofferdams						
#	02200	Earthwork	7	100	17	26	1	2
#	02300	Tunneling						
#	02350	Piles & Caissons	5	100	20	28	1	2
#	02450	Railroad Work						
#	02480	Marine Work						
#	02500	Paving & Surfacing	3	100	23	32	1	2
#	02600	Piped Utility Materials	2	100	25	38	1	2
#	02660	Water Distribution	3	100	30	45	1	2
#	02680	Fuel Distribution	3	100	35	48	1	2
#	02700	Sewer & Drainage	3	100	40	49	2	3
#	02760	Restoration of Pipelines	3	100	45	50	2	3
#	02770	Ponds & Reservoirs	3	100	50	60	1	2
#	02780	Power & Communications	3	100	53	68	1	2
#	02800	Site Improvements						
#	02900	Landscaping	20	100	55	73	2	3
		Subtotal:	**43**	**100%**				
Phase 3:		**Concrete**						
#	03100	Concrete Formwork	11	100	90	110	1	2
#	03200	Concrete Reinforcement	3	100	92	117	1	2
#	03250	Concrete Accessories						
#	03300	Cast-in-Place Concrete	1	100	94	120	1	2
#	03370	Concrete Curing	15	100	95	125	2	3
#	03400	Precast Concrete						
#	03500	Cementious Decks						
#	03600	Grout	3	100	96	128	2	3
#	03700	Concrete Restoration & Cleaning						
#	03800	Mass Concrete						
#	03850	Site Clean-up	3	100	97	130	2	4
		Subtotal:	**36**	**100%**				
		Phases Totals:	**268.5**	**100%**				
Phase 4:		**Masonry**						
#	04100	Mortar	*(Enter your data here, chain-link macro spreadsheet formulas ,*					
#	04150	Masonry Accessories						
#	04200	Unit Masonry						
#	04400	Stone						
#	04500	Masonry Restoration & Cleaning						
#	045500	Refactories						
#	04600	Corrision Resistant Masonry						
		Subtotal:						
Phase 5:		**Metals**						
#	05010	Metal Materials	*(Enter your data here, chain-link macro spreadsheet formulas ,*					
#	05030	Metal Finishes						
#	05050	Metal Fastening						

# 05100	Structural Metal Framing		
# 05200	Metal Joists		
# 05300	Metal Decking		
# 05400	Cold-Formed Metal Framing		
# 05500	Metal Fabrications		
# 05580	Sheet Metal Fabrications		
# 05700	Ornamental Metal		
# 05800	Expansion Control		
# 05900	Hydraulic Structures		
		Subtotal:	
Phase 6:	**Wood & Plastics**		
# 06050	Fasteners & Adhesives		*(Enter your data here, chain-link macro spreadsheet formulas*
# 06100	Rough Carpentry		
# 06130	Heavy Timber		
# 06150	Wood-Metal Systems		
# 06170	Engineered Structural Wood		
# 06200	Finish Carpentry		
# 06300	Wood Treatment		
# 06400	Architectural Woodwork		
# 06500	Prefabricated Structural Plastics		
# 06600	Plastic Fabrications		
		Subtotal:	
Phase 7:	**Thermal & Moisture**		
# 07100	Waterproofing		*(Enter your data here, chain-link macro spreadsheet formulas*
# 07150	Dampproofing		
# 07190	Vapor & Water Barriers		
# 07200	Insulation		
# 07250	Fireproofing		
# 07300	Roofing Tiles & Shingles		
# 07400	Preformed Roofing Siding		
# 07500	Membrane Roofing		
# 07570	Traffic Topping		
# 07600	Flashing & Sheetmetal		
# 07700	Roof Specialties		
# 07800	Skylights		
# 07900	Joint Sealers		
		Subtotal:	
		Phases Totals:	
Phase 8:	**Doors & Windows**		
# 08100	Metal Doors & Frames		*(Enter your data here, chain-link macro spreadsheet formulas*
# 08200	Wood & Plastic Doors		
# 08250	Door Opening Assemblies		
# 08300	Special Doors		
# 08400	Entrances & Storefronts		
# 08500	Metal Windows		
# 08600	Wood & Plastic Windows		
# 08650	Special Windows		
# 08700	Hardware		

FIGURE 7.5 Continued.

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270 Madison Avenue, New York, New York 10016

# 08800	Glazing	
# 08900	Glazed Curtain Walls	
	Subtotal:	

Phase 9:	Finishes	
# 09100	Metal Support Systems	*(Enter your data here, chain-link macro spreadsheet formulas*
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	
# 09500	Acoustical Treatment	
# 09540	Special Surfaces	
# 09550	Wood Flooring	
# 09600	Stone Flooring	
# 09630	Unit Masonry Flooring	
# 09650	Resilient Flooring	
# 09680	Carpet	
# 09700	Special Flooring	
# 09780	Floor Treatment	
# 09800	Special Coatings	
# 09900	Painting	
# 09950	Wall Coverings	
	Subtotal:	

Phase 10:	Specialities	
# 10100	Chalkboards & Tackboards	*(Enter your data here, chain-link macro spreadsheet formulas*
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

#	10900	Wardrobe & Closet Specialties	
		Subtotal:	
Phase 11:		**Equipment**	
#	11010	Maintenance Equipment	*(Enter your data here, chain-link macro spreadsheet formulas*
#	11020	Security & Vault Equipment	
#	11030	Teller & Service Equipment	
#	11040	Ecclesiastical Equipment	
#	11050	Library Equipment	
#	11060	Theater & Stage Equipment	
#	11070	Instrumental Equipment	
#	11080	Registration Equipment	
#	11090	Checkroom Equipment	
#	11100	Mercantile Equipment	
#	11110	Laundry Equipment	
#	11120	Vending Equipment	
#	11130	Audio-Visual Equipment	
#	11140	Service Station Equipment	
#	11150	Parking Control Equipment	
#	11160	Loading Dock Equipment	
#	11170	Solid Waste Equipment	
#	11190	Detention Equipment	
#	11200	Water Supply / Treatment	
#	11280	Hydraulic Gate Valves	
#	11300	Fluid Waste Equipment	
#	11400	Food Service Equipment	
#	11450	Residential Equipment	
#	11460	Unit Kitchens	
#	11470	Darkroom Equipment	
#	11480	Recreational Equipment	
#	11500	Industrial Process Equipment	
#	11600	Laboratory Equipment	
#	11650	Planetarium Equipment	
#	11660	Observatory Equipment	
#	11700	Medical Equipment	
#	11780	Mortuary Equipment	
#	11850	Navigation Equipment	
		Subtotal:	
		Phases Totals:	
Phase 12:		**Furnishings**	
#	12050	Fabrics	*(Enter your data here, chain-link macro spreadsheet formulas*
#	12100	Artwork	
#	12300	Manufactured Casework	
#	12500	Window Treatment	
#	12600	Furniture & Accessories	
#	12670	Rugs & Mats	
#	12700	Multiples Seating	
#	12800	Interior Plants & Planters	
		Subtotal:	

FIGURE 7.5 Continued.

Phase 13:	Special Construction	
# 13010	Air Supported Structures	(Enter your data here, chain-link macro spreadsheet formulas ,
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	
# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
	Subtotal:	

Phase 14:	Conveying Systems	
# 14100	Dumbwaiters	(Enter your data here, chain-link macro spreadsheet formulas ,
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
	Subtotal:	

Phase 15:	Mechanical	
# 15100	Basic Materials & Methods	(Enter your data here, chain-link macro spreadsheet formulas ,
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	

# 15850	Testing		
		Subtotal:	
Phase 16:	**Electrical**		
# 16100	Basic Materials & Methods		(Enter your data here, chain-link macro spreadsheet formulas ,
# 16110	Power Generation		
# 16200	High Voltage Distribution >600v		
# 16250	Service Distribution <600v		
# 16300	Lighting		
# 16400	Special Systems		
# 16450	Communications		
# 16500	Electric Resistance Heating		
# 16600	Controls		
# 16700	Testing		
		Subtotal:	
		Phases Totals:	

FIGURE 7.5 Continued.

sort will calculate the estimated, current, and projected costs for every item you enter, in every activity you're using. Accurate data for cost tracking require regular inputs from the site supervisor on all field costs and hours of work in each classification at the project site. The project scheduler arranges to receive all such field data from the project manager, at the end of each week. Typically, the monthly pay estimates of the project's contractors' work for progress payments are submitted by the 25th of the month, and all submittals are in the office for payment before the end of the month. Billings from the architect to the owner, however, usually are based on the closing date of the end of the month. Therefore, weekly tabulation of these data should not interfere with the project manager's review of the contractors' pay requests. The cost tracking should be done on a unit basis in all activity items. These are then used to produce the audit trail.

One of the major advantages of computerized CPM is its ability to link items and activities costs to the network schedule milestones. Most major computer programs have linked cost tracking with milestones that exist within those databases to identify the purchasing-versus-cost relationships that combined provide an audit trail of those costs. By setting up the Cost by Activity Number sort in your software program, you create the schedule's audit trail (see Fig. 7.6.).

Schedule of Anticipated Earnings

The computer uses the Schedule of Anticipated Earnings sort to provide calculations under the "What-If" pull-down menu. This forecasting advantage allows the project scheduler to input other numbers into the cost and time columns for computation. The next step is to critically analyze what those

Your Company Name Here			**Cost by Activity Number**				
Prepared For:	***Your Client's Name Here***						
Project:	***Project's Name Here***			Data Date:	*Data Entry Date*		
File Name:	*Your Computer File Name Here*			Run Date:	*Printout Date*		
Description:	*Project Description Here*						
Our Invoice No:	***Your Company's Job Number***			**Page: 1 of**			
Client Invoice:	***Owner's Job Invoice Number***						

Activity Number	I - J Number	Activity Description	Line Float	Avail Float	Cost Estimated	Cost Current	Cost Projected
Phase 0:		**General Conditions**					
# 00010	1	Subsurface Investigation	1	1	$112	0	$112
# 00100	1	Instructions to Bidders	2	3	$40	0	$40
# 00200	1	Information Available to Bidders	1	2	$0	0	$0
# 00300	1	Bid Forms	3	3	$40	0	$40
# 00400	2	Supplements to Bid Forms	2	3	$0	0	$0
# 00500	2	Agreement Forms	3	2	$20	0	$20
# 00600	2	Bonds and Certificates	3	1	$20	0	$20
# 00700	2	General Conditions	2	3	$0	0	$0
# 00800	3	Supplementary Conditions	3	2	$0	0	$0
# 00850	3	Drawings and Schedules	3	3	$40	0	$40
# 00900	3	Addenda and Modifications	3	3	$20	0	$20
		Subtotal:			$292	0	$292
Phase 1:		**Specifications**					
# 01010	4	Soils: Reports & Remediations	1	3	$122	0	$122
# 01020	4	Allowances	3	2	$100	0	$100
# 01025	4	Measurement & Payment	2	3	$240	0	$240
# 01030	4	Alternates / Alternatives	3	3	$100	0	$100
# 01040	4	Coordination	3	2	$180	0	$180
# 10150	4	Field Engineering	2	1	$350	0	$350
# 01060	4	Regulatory Requirements	3	3	$850	0	$850
# 01070	4	Abbreviations & Symbols	3	2	$50	0	$50
# 01080	4	Identification Systems	3	3	$1,856	0	$1,856
# 01090	4	Reference Standards	4	3	$260	0	$260
# 01100	5	Special Project Procedures	1	3	$450	0	$450
# 01200	5	Project Meetings	3	2	$60	0	$60
# 01300	5	Submittals	2	3	$122	0	$122
# 01400	5	Quality Control	3	3	$500	0	$500
# 01500	5	Const Facilities & Temp Control	3	2	$1,280	0	$1,280
# 01600	5	Material & Equipment	2	1	$5,590	0	$5,590
# 01650	6	Commissioning of Equipment	3	3	$4,800	0	$4,800
# 01700	6	Contract Closeout	3	2	$280	0	$280
# 01800	6	Maintenance	3	3	$1,800	0	$1,800
		Subtotal:			$18,990	0	$18,990
Phase 2:		**Site Work**					
# 02010	7	Subsurface Investigation	1	1	$350	0	100
# 02050	7	Demolition	3	3	$1,200	0	100
# 02100	7	Site Preparation	2	2	$1,500	0	100

FIGURE 7.6 Cost by activity number.

# 02140	7	Dewatering	3	3	$580	0	100
# 02150	7	Shoring & Underpinning	3	3	$1,350	0	100
# 02160	7	Excavation Support Systems	2	2	$1,500	0	100
# 02170		Cofferdams					
# 02200	7	Earthwork	3	3	$22,850	0	100
# 02300		Tunneling					
# 02350	8	Piles & Caissons	2	3	$600	0	100
# 02450		Railroad Work					
# 02480		Marine Work					
# 02500	8	Paving & Surfacing	1	3	$50,000	0	100
# 02600	8	Piped Utility Materials	3	2	$2,500	0	100
# 02660	8	Water Distribution	2	3	$1,300	0	100
# 02680	8	Fuel Distribution	3	3	$2,600	0	100
# 02700	8	Sewer & Drainage	3	2	$18,000	0	100
# 02760	8	Restoration of Pipelines	2	3	$3,600	0	100
# 02770	8	Ponds & Reservoirs	1	2	$400	0	100
# 02780	8	Power & Communications	1	3	$18,000	0	100
# 02800		Site Improvements					
# 02900	9	Landscaping	1	2	$5,000	0	100
		Subtotal:			$131,330	0	$131,330
Phase 3:		**Concrete**					
# 03100	10	Concrete Formwork	2	3	$7,000	0	$7,000
# 03200	10	Concrete Reinforcement	1	2	$5,000	0	$5,000
# 03250		Concrete Accessories					
# 03300	10	Cast-in-Place Concrete	1	3	$8,000	0	$8,000
# 03370	11	Concrete Curing	2	2	$650	0	$650
# 03400		Precast Concrete					
# 03500		Cementious Decks					
# 03600	11	Grout	3	3	$1,800	0	$1,800
# 03700		Concrete Restoration & Cleaning					
# 03800		Mass Concrete					
# 03850	12	Site Clean-up	2	3	$5,000	0	$5,000
		Subtotal:			$27,450	0	$27,450
		Phases Totals:			**$178,062**	**0**	**$178,062**
Phase 4:		**Masonry**					
# 04100		Mortar	*(Enter your data here, chain-link formulas)*				
# 04150		Masonry Accessories					
# 04200		Unit Masonry					
# 04400		Stone					
# 04500		Masonry Restoration & Cleaning					
# 045500		Refactories					
# 04600		Corrision Resistant Masonry					
		Subtotal:					
Phase 5:		**Metals**					
# 05010		Metal Materials	*(Enter your data here, chain-link formulas)*				
# 05030		Metal Finishes					
# 05050		Metal Fastening					
# 05100		Structural Metal Framing					

Figure 7.6 Continued.

# 05200	Metal Joists	
# 05300	Metal Decking	
# 05400	Cold-Formed Metal Framing	
# 05500	Metal Fabrications	
# 05580	Sheet Metal Fabrications	
# 05700	Ornamental Metal	
# 05800	Expansion Control	
# 05900	Hydraulic Structures	
	Subtotal:	
Phase 6:	**Wood & Plastics**	
# 06050	Fasteners & Adhesives	*(Enter your data here, chain-link formulas)*
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	
	Subtotal:	
Phase 7:	**Thermal & Moisture Protection**	
# 07100	Waterproofing	*(Enter your data here, chain-link formulas)*
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	
	Subtotal:	
	Phases Totals:	
Phase 8:	**Doors & Windows**	
# 08100	Metal Doors & Frames	*(Enter your data here, chain-link formulas)*
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	
# 08800	Glazing	

# 08900	Glazed Curtain Walls	
	Subtotal:	
Phase 9:	**Finishes**	
# 09100	Metal Support Systems	*(Enter your data here, chain-link formulas)*
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	
# 09500	Acoustical Treatment	
# 09540	Special Surfaces	
# 09550	Wood Flooring	
# 09600	Stone Flooring	
# 09630	Unit Masonry Flooring	
# 09650	Resilient Flooring	
# 09680	Carpet	
# 09700	Special Flooring	
# 09780	Floor Treatment	
# 09800	Special Coatings	
# 09900	Painting	
# 09950	Wall Coverings	
	Subtotal:	
Phase 10:	**Specialities**	
# 10100	Chalkboards & Tackboards	*(Enter your data here, chain-link formulas)*
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	
# 10900	Wardrobe & Closet Specialties	

FIGURE 7.6 Continued.

		Subtotal:	
Phase 11:	**Equipment**		
# 11010	Maintenance Equipment		*(Enter your data here, chain-link formulas)*
# 11020	Security & Vault Equipment		
# 11030	Teller & Service Equipment		
# 11040	Ecclesiastical Equipment		
# 11050	Library Equipment		
# 11060	Theater & Stage Equipment		
# 11070	Instrumental Equipment		
# 11080	Registration Equipment		
# 11090	Checkroom Equipment		
# 11100	Mercantile Equipment		
# 11110	Laundry Equipment		
# 11120	Vending Equipment		
# 11130	Audio-Visual Equipment		
# 11140	Service Station Equipment		
# 11150	Parking Control Equipment		
# 11160	Loading Dock Equipment		
# 11170	Solid Waste Equipment		
# 11190	Detention Equipment		
# 11200	Water Supply / Treatment		
# 11280	Hydraulic Gate Valves		
# 11300	Fluid Waste Equipment		
# 11400	Food Service Equipment		
# 11450	Residential Equipment		
# 11460	Unit Kitchens		
# 11470	Darkroom Equipment		
# 11480	Recreational Equipment		
# 11500	Industrial Process Equipment		
# 11600	Laboratory Equipment		
# 11650	Planetarium Equipment		
# 11660	Observatory Equipment		
# 11700	Medical Equipment		
# 11780	Mortuary Equipment		
# 11850	Navigation Equipment		
		Subtotal:	
		Phases Totals:	
Phase 12:	**Furnishings**		
# 12050	Fabrics		*(Enter your data here, chain-link formulas)*
# 12100	Artwork		
# 12300	Manufactured Casework		
# 12500	Window Treatment		
# 12600	Furniture & Accessories		
# 12670	Rugs & Mats		
# 12700	Multiples Seating		
# 12800	Interior Plants & Planters		
		Subtotal:	
Phase 13:	**Special Construction**		

# 13010	Air Supported Structures	*(Enter your data here, chain-link formulas)*
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	
# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
	Subtotal:	
Phase 14:	**Conveying Systems**	
# 14100	Dumbwaiters	*(Enter your data here, chain-link formulas)*
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
	Subtotal:	
Phase 15:	**Mechanical**	
# 15100	Basic Materials & Methods	*(Enter your data here, chain-link formulas)*
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	
# 15850	Testing	

FIGURE 7.6 Continued.

	Subtotal:	
Phase 16:	**Electrical**	
# 16100	Basic Materials & Methods	*(Enter your data here, chain-link formulas)*
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	
	Subtotal:	
	Phases Totals:	

changes would bring if initiated now. The subtotals of each column can be either totaled or averaged, or both. Printouts can be run at any time, to freeze a particular cost scenario that appeals to the owner.

After critical analysis of all options is complete, the program returns to the original numbers without disturbing any other data. This is especially useful in construction loan interest payment scenarios. Such financial wrap-arounds allow the owner to maximize the potential of the loan funds without dipping into personal lines of credit, thus keeping working capital on hand and available.

This process in cost tracking and audit trail is known as trends analysis. By entering the relative data to your activities on the schedule of anticipated earnings, the computer now links the activities network with the costs and expenses necessary to run the network. In addition, owners using CPM systems have the advantage of control over those costs before they are paid, by having the project scheduler run trends analysis forecasting. The crucial task of monitoring the project field service costs now linked to the project schedule separates those cost expenses from the architect's design costs.

The Schedule of Anticipated Earnings sort tracks and calculates the classifications and amounts of the on-site field labor forces as well as the field office overhead costs. An entire database can be built for expenses of materials and supplies, support services from the home office, vehicle leases and fuel charges, the field office's share of administrative (G&A) costs, outside consultants, legal services, contract services, and separate or combined cost-to-profit ratios. Audit-trail trends analysis is an important function of the schedule of anticipated earnings sort that will provide your client with one of the prime advantages of CPM—that of cost control—and the ability to foresee the commitment of resources before they are needed (see Fig. 7.7).

Your Company Name Here

Schedule of Anticipated Earnings

Prepared For: ***Your Client's Name Here***
Project: ***Project's Name Here*** Data Date: *Data Entry Date*
File Name: *Your Computer File Name Here* Run Date: *Printout Date*
Description: *Project Description Here*
Our Invoice No: ***Your Company's Job Number*** **Page: 1 of**
Client Invoice: ***Owner's Job Invoice Number***

Activity Number	I - J Number	Activity Description	Late Finish	Avail Float	Neg Float	Prior Event	Next Event
Phase 0:		**General Conditions**					
# 00010	1	Subsurface Investigation	24-Nov	1	0	0	# 00100
# 00100	1	Instructions to Bidders	18-Nov	3	0	# 00010	# 00200
# 00200	1	Information Available to Bidders	2-Dec	2	0	# 00100	# 00300
# 00300	1	Bid Forms	12-Dec	3	0	# 00200	# 00400
# 00400	2	Supplements to Bid Forms	20-Dec	3	0	# 00300	# 00500
# 00500	2	Agreement Forms	12-Dec	2	0	# 00400	# 00600
# 00600	2	Bonds and Certificates	14-Dec	1	0	# 00500	# 00700
# 00700	2	General Conditions	19-Dec	3	0	# 00600	# 00800
# 00800	3	Supplementary Conditions	19-Dec	2	0	# 00700	# 00850
# 00850	3	Drawings and Schedules	19-Dec	3	0	# 00800	# 00900
# 00900	3	Addenda and Modifications	21-Dec	3	0	# 00850	# 01010
Phase 1:		**Specifications**					
# 01010	4	Soils: Reports & Remediations	15-Jan	3	15-Jan	# 00900	# 01020
# 01020	4	Allowances	15-Dec	2	15-Dec	# 01010	# 01025
# 01025	4	Measurement & Payment	20-Dec	3	20-Dec	# 01020	# 01030
# 01030	4	Alternates / Alternatives	20-Dec	3	20-Dec	# 01025	# 01040
# 01040	4	Coordination	20-Dec	2	20-Dec	# 01030	# 10150
# 10150	4	Field Engineering	24-Dec	1	24-Dec	# 01040	# 01060
# 01060	4	Regulatory Requirements	30-Dec	3	30-Dec	# 10150	# 01070
# 01070	4	Abbreviations & Symbols	20-Dec	2	20-Dec	# 01060	# 01080
# 01080	4	Identification Systems	20-Dec	3	20-Dec	# 01070	# 01090
# 01090	4	Reference Standards	20-Dec	3	20-Dec	# 01080	# 01100
# 01100	5	Special Project Procedures	15-Dec	3	15-Dec	# 01090	# 01200
# 01200	5	Project Meetings	15-Dec	2	15-Dec	# 01100	# 01300
# 01300	5	Submittals	20-Dec	3	20-Dec	# 01200	# 01400
# 01400	5	Quality Control	15-Dec	3	15-Dec	# 01300	# 01500
# 01500	5	Const Facilities & Temp Control	20-Dec	2	20-Dec	# 01400	# 01600
# 01600	5	Material & Equipment	25-Jan	1	25-Jan	# 01500	# 01650
# 01650	6	Commissioning of Equipment	27-Jan	3	27-Jan	# 01600	# 01700
# 01700	6	Contract Closeout	30-Jan	2	30-Jan	# 01650	# 01800
# 01800	6	Maintenance	15-Feb	3	15-Feb	# 01700	# 02010
Phase 2:		**Site Work**					
# 02010	7	Subsurface Investigation	16-Feb	1	16-Feb	# 01800	# 02050
# 02050	7	Demolition	21-Feb	3	21-Feb	# 02010	# 02100
# 02100	7	Site Preparation	21-Feb	2	21-Feb	# 02050	# 02140
# 02140	7	Dewatering	27-Feb	3	27-Feb	# 02100	# 02150

FIGURE 7.7 Schedule of anticipated earnings.

# 02150	7	Shoring & Underpinning	28-Feb	3	28-Feb	# 02140	# 02160
# 02160	7	Excavation Support Systems	28-Feb	2	28-Feb	# 02150	# 02170
# 02170		Cofferdams					
# 02200	7	Earthwork	7-Mar	3	7-Mar	# 02170	# 02300
# 02300		Tunneling					
# 02350	8	Piles & Caissons	22-Mar	3	22-Mar	# 02300	# 02450
# 02450		Railroad Work					
# 02480		Marine Work					
# 02500	8	Paving & Surfacing	23-Mar	3	23-Mar	# 02480	# 02600
# 02600	8	Piped Utility Materials	23-Mar	2	23-Mar	# 02500	# 02660
# 02660	8	Water Distribution	23-Mar	3	23-Mar	# 02600	# 02680
# 02680	8	Fuel Distribution	23-Mar	3	23-Mar	# 02660	# 02700
# 02700	8	Sewer & Drainage	23-Mar	2	23-Mar	# 02680	# 02760
# 02760	8	Restoration of Pipelines	23-Mar	3	23-Mar	# 02700	# 02770
# 02770	8	Ponds & Reservoirs	23-Mar	2	23-Mar	# 02760	# 02780
# 02780	8	Power & Communications	23-Mar	3	23-Mar	# 02770	# 02800
# 02800		Site Improvements					
# 02900	9	Landscaping	23-Mar	2	23-Mar	# 02800	# 03100

Phase 3:		**Concrete**					
# 03100	10	Concrete Formwork	6-Apr	3-Jan	6-Apr	# 02900	# 03200
# 03200	10	Concrete Reinforcement	11-Apr	2-Jan	11-Apr	# 03200	# 03250
# 03250		Concrete Accessories					
# 03300	10	Cast-in-Place Concrete	15-Apr	3-Jan	15-Apr	# 03250	# 03370
# 03370	11	Concrete Curing	5-Mar	2-Jan	5-Mar	# 03300	# 03400
# 03400		Precast Concrete					
# 03500		Cementious Decks					
# 03600	11	Grout	11-Mar	3-Jan	11-Mar	# 03500	# 03700
# 03700		Concrete Restoration & Cleaning					
# 03800		Mass Concrete					
# 03850	12	Site Clean-up	15-Mar	3-Jan	15-Mar	# 03800	# 03900

Phase 4:	**Masonry**	
# 04100	Mortar	*(Enter your data here, chain-link formulas)*
# 04150	Masonry Accessories	
# 04200	Unit Masonry	
# 04400	Stone	
# 04500	Masonry Restoration & Cleaning	
# 045500	Refactories	
# 04600	Corrision Resistant Masonry	

Phase 5:	**Metals**	
# 05010	Metal Materials	*(Enter your data here, chain-link formulas)*
# 05030	Metal Finishes	
# 05050	Metal Fastening	
# 05100	Structural Metal Framing	
# 05200	Metal Joists	
# 05300	Metal Decking	
# 05400	Cold-Formed Metal Framing	
# 05500	Metal Fabrications	
# 05580	Sheet Metal Fabrications	

# 05700	Ornamental Metal	
# 05800	Expansion Control	
# 05900	Hydraulic Structures	
Phase 6:	**Wood & Plastics**	
# 06050	Fasteners & Adhesives	*(Enter your data here, chain-link formulas)*
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	
Phase 7:	**Thermal & Moisture Protection**	
# 07100	Waterproofing	*(Enter your data here, chain-link formulas)*
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	
Phase 8:	**Doors & Windows**	
# 08100	Metal Doors & Frames	*(Enter your data here, chain-link formulas)*
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	
# 08800	Glazing	
# 08900	Glazed Curtain Walls	
Phase 9:	**Finishes**	
# 09100	Metal Support Systems	*(Enter your data here, chain-link formulas)*
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	

FIGURE 7.7 Continued.

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# 09500	Acoustical Treatment
# 09540	Special Surfaces
# 09550	Wood Flooring
# 09600	Stone Flooring
# 09630	Unit Masonry Flooring
# 09650	Resilient Flooring
# 09680	Carpet
# 09700	Special Flooring
# 09780	Floor Treatment
# 09800	Special Coatings
# 09900	Painting
# 09950	Wall Coverings

Phase 10:	Specialities	
# 10100	Chalkboards & Tackboards	*(Enter your data here, chain-link formulas)*
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	
# 10900	Wardrobe & Closet Specialties	

Phase 11:	Equipment	
# 11010	Maintenance Equipment	*(Enter your data here, chain-link formulas)*
# 11020	Security & Vault Equipment	
# 11030	Teller & Service Equipment	
# 11040	Ecclesiastical Equipmènt	
# 11050	Library Equipment	
# 11060	Theater & Stage Equipment	
# 11070	Instrumental Equipment	
# 11080	Registration Equipment	
# 11090	Checkroom Equipment	

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270 Madison Avenue, New York, New York 10016

# 11100	Mercantile Equipment
# 11110	Laundry Equipment
# 11120	Vending Equipment
# 11130	Audio-Visual Equipment
# 11140	Service Station Equipment
# 11150	Parking Control Equipment
# 11160	Loading Dock Equipment
# 11170	Solid Waste Equipment
# 11190	Detention Equipment
# 11200	Water Supply / Treatment
# 11280	Hydraulic Gate Valves
# 11300	Fluid Waste Equipment
# 11400	Food Service Equipment
# 11450	Residential Equipment
# 11460	Unit Kitchens
# 11470	Darkroom Equipment
# 11480	Recreational Equipment
# 11500	Industrial Process Equipment
# 11600	Laboratory Equipment
# 11650	Planetarium Equipment
# 11660	Observatory Equipment
# 11700	Medical Equipment
# 11780	Mortuary Equipment
# 11850	Navigation Equipment

Phase 12:	Furnishings	
# 12050	Fabrics	*(Enter your data here, chain-link formulas)*
# 12100	Artwork	
# 12300	Manufactured Casework	
# 12500	Window Treatment	
# 12600	Furniture & Accessories	
# 12670	Rugs & Mats	
# 12700	Multiples Seating	
# 12800	Interior Plants & Planters	

Phase 13:	Special Construction	
# 13010	Air Supported Structures	*(Enter your data here, chain-link formulas)*
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	

FIGURE 7.7 Continued.

# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
Phase 14:	**Conveying Systems**	
# 14100	Dumbwaiters	*(Enter your data here, chain-link formulas)*
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
Phase 15:	**Mechanical**	
# 15100	Basic Materials & Methods	*(Enter your data here, chain-link formulas)*
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	
# 15850	Testing	
Phase 16:	**Electrical**	
# 16100	Basic Materials & Methods	*(Enter your data here, chain-link formulas)*
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	

Sort by Early Starts

The Sort by Early Starts is concerned with *time* use. Here in this sort, you might allocate the hours each week of events producing float, by early starts. The sort by early starts is a complex scheduling system sort that compartmentalizes by *activity function*. Percentages of each activity's progress toward completion are the responsibility of that activity's subcontractor, but the

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summary report of that early start progress is the project scheduler's responsibility.

These more complex sorts tend to become hierarchical. They simplify delegation of each activity's responsibilities and corresponding sorts, but de-emphasize total project objectives and are slow to adapt to changes during schedule recycling. In planning the sorts of schedule activities and operations analysis, it is important to reflect the objectives of float in the project schedule.

The degree of project scheduling control versus prime contractor and subcontractor empowerment, and the overall project matrix network, will determine in significant part whether you'll be successful in reaching the project's phases milestones on time. The Sort by Early Starts is the averaging tool the scheduler uses between time-scaled activity events and activity control to accelerate or constrain the activity (see Fig. 7.8).

Daily Field Reports

As stated earlier in the chapter and repeated here for ease in reference, the Daily Field Report is the fundamental sort that records actual job progress, together with all conditions that affect the work. It provides the progress-reporting basis for the actual results of the schedule, as compared to projected progress. It begins the organization's standardization of reporting at the source of causes and effects—the point of production. If actually prepared daily, the daily field report is generally considered to be the best source of job information. This is because it is supposed to be prepared immediately as the information is being generated, with no appreciable time lapse. The inclusions, descriptions, and so on are fresh in the site supervisor's mind. This facilitates proper dealing with all details of the work.

In addition, it is prepared by those with field authority and ultimate responsibility for the production. These people have an interest in the accuracy of the information and a significant incentive to maintain the report's accuracy and completeness. So the courts see the daily field reports because these are reports of the people who actually witnessed the work and are recognized to be the most qualified to describe it. Because they will be the most detailed, accurate, and complete records of all job-site events, the daily field reports will become the cornerstones to support the actual facts. They are so valuable because of the wealth of information recorded.

You will note that the Daily Field Report in the accompanying software is two pages in length but has been condensed into one page for an illustration example in this section (see Fig. 7.9). In the software program, however, the Daily Field Report will expand into however many pages you wish to build.

Your Company Name Here **Sort by Early Starts**

Prepared For: ***Your Client's Name Here***
Project: ***Project's Name Here***
File Name: *Your Computer File Name Here* Data Date: *Data Entry Date*
Description: *Project Description Here* Run Date: *Printout Date*
Our Invoice No: ***Your Company's Job Number***
Client Invoice: ***Owner's Job Invoice Number***

Activity Number	Activity Description	Early Start	Late Start	Early Finish	Late Finish	Critical Path	Free Float	Total Float
Phase 0:	**General Conditions**							
# 00010	Subsurface Investigation	20-Nov	24-Nov	10-Dec	12-Dec	A	1	2
# 00100	Instructions to Bidders	13-Nov	18-Nov	26-Nov	28-Nov	A	1	2
# 00200	Information Available to Bidders	28-Nov	2-Dec	4-Dec	8-Dec	A	1	2
# 00300	Bid Forms	10-Dec	12-Dec	11-Dec	15-Dec	A	1	2
# 00400	Supplements to Bid Forms	18-Dec	20-Dec	20-Dec	24-Dec	A	1	2
# 00500	Agreement Forms	10-Dec	12-Dec	11-Dec	15-Dec	A	1	2
# 00600	Bonds and Certificates	12-Dec	14-Dec	14-Dec	18-Dec	A	1	2
# 00700	General Conditions	17-Dec	19-Dec	17-Dec	20-Dec	A	1	3
# 00800	Supplementary Conditions	17-Dec	19-Dec	17-Dec	20-Dec	A	1	2
# 00850	Drawings and Schedules	18-Dec	19-Dec	17-Dec	20-Dec	A	1	2
# 00900	Addenda and Modifications	19-Dec	21-Dec	20-Dec	25-Dec	A	1	2
Phase 1:	**Specifications**							
# 01010	Soils: Reports & Remediations	20-Nov	24-Dec	10-Jan	15-Jan	A	2	2
# 01020	Allowances	10-Dec	12-Dec	11-Dec	15-Dec	A	2	2
# 01025	Measurement & Payment	17-Dec	19-Dec	17-Dec	20-Dec	A	1	2
# 01030	Alternates / Alternatives	17-Dec	19-Dec	17-Dec	20-Dec	A	1	1
# 01040	Coordination	17-Dec	19-Dec	18-Dec	20-Dec	A	1	1
# 10150	Field Engineering	19-Dec	20-Dec	20-Dec	24-Dec	A	1	1
# 01060	Regulatory Requirements	26-Dec	30-Dec	28-Dec	30-Dec	A	2	3
# 01070	Abbreviations & Symbols	17-Dec	19-Dec	18-Dec	20-Dec	A	2	3
# 01080	Identification Systems	17-Dec	19-Dec	17-Dec	20-Dec	A	3	4
# 01090	Reference Standards	17-Dec	19-Dec	17-Dec	20-Dec	A	3	4
# 01100	Special Project Procedures	10-Dec	12-Dec	11-Dec	15-Dec	B	1	2
# 01200	Project Meetings	10-Dec	12-Dec	11-Dec	15-Dec	A	1	2
# 01300	Submittals	17-Dec	19-Dec	17-Dec	20-Dec	A	1	2
# 01400	Quality Control	10-Dec	12-Dec	11-Dec	15-Dec	A	1	2
# 01500	Const Facilities & Temp Control	17-Dec	19-Dec	17-Dec	20-Dec	A	1	2
# 01600	Material & Equipment	20-Dec	4-Jan	22-Jan	25-Jan	A	1	2
# 01650	Commissioning of Equipment	22-Dec	25-Jan	26-Jan	27-Jan	A	3	4
# 01700	Contract Closeout	28-Dec	29-Jan	29-Jan	30-Jan	B	3	4
# 01800	Maintenance	30-Dec	31-Jan	10-Feb	15-Feb	A	1	2
Phase 2:	**Site Work**							
# 02010	Subsurface Investigation	31-Jan	31-Jan	11-Feb	16-Feb	A	1	2
# 02050	Demolition	16-Feb	18-Feb	19-Feb	21-Feb	A	1	2
# 02100	Site Preparation	16-Feb	18-Feb	19-Feb	21-Feb	A	1	2
# 02140	Dewatering	20-Feb	22-Feb	25-Feb	27-Feb	A	1	2

FIGURE 7.8 Sort by early starts.

# 02150	Shoring & Underpinning	25-Feb	26-Feb	27-Feb	28-Feb	A	1	2
# 02160	Excavation Support Systems	25-Feb	26-Feb	27-Feb	28-Feb	B	1	2
# 02170	Cofferdams							
# 02200	Earthwork	28-Feb	30 Feb	4-Mar	7-Mar	A	1	2
# 02300	Tunneling							
# 02350	Piles & Caissons	10-Mar	12-Mar	19-Mar	22-Mar	B	1	2
# 02450	Railroad Work							
# 02480	Marine Work							
# 02500	Paving & Surfacing	17-Mar	19-Mar	21-Mar	23-Mar	A	1	2
# 02600	Piped Utility Materials	17-Mar	19-Mar	21-Mar	23-Mar	A	1	2
# 02660	Water Distribution	17-Mar	19-Mar	21-Mar	23-Mar	A	1	2
# 02680	Fuel Distribution	17-Mar	19-Mar	21-Mar	23-Mar	A	1	2
# 02700	Sewer & Drainage	17-Mar	19-Mar	21-Mar	23-Mar	A	2	3
# 02760	Restoration of Pipelines	17-Mar	19-Mar	21-Mar	23-Mar	A	2	3
# 02770	Ponds & Reservoirs	17-Mar	19-Mar	21-Mar	23-Mar	A	1	2
# 02780	Power & Communications	17-Mar	19-Mar	21-Mar	23-Mar	A	1	2
# 02800	Site Improvements							
# 02900	Landscaping	17-Mar	19-Mar	21-Mar	23-Mar	B	2	3
Phase 3:	**Concrete**							
# 03100	Concrete Formwork	23-Mar	25-Mar	4-Apr	6-Apr	A	1	2
# 03200	Concrete Reinforcement	6-Apr	8-Apr	9-Apr	11-Apr	A	1	2
# 03250	Concrete Accessories							
# 03300	Cast-in-Place Concrete	11-Apr	12-Apr	13-Apr	15-Apr	A	1	2
# 03370	Concrete Curing	15-Apr	18-Apr	3-Mar	5-Mar	A	2	3
# 03400	Precast Concrete							
# 03500	Cementious Decks							
# 03600	Grout	5-Mar	8-Mar	9-Mar	11-Mar	A	2	3
# 03700	Concrete Restoration & Cleaning							
# 03800	Mass Concrete							
# 03850	Site Clean-up	5-Mar	9-Mar	11-Mar	15-Mar	B	2	4
Phase 4:	**Masonry**							
# 04100	Mortar	*(Enter your data here, chain-link macro spreadsheet formulas*						
# 04150	Masonry Accessories							
# 04200	Unit Masonry							
# 04400	Stone							
# 04500	Masonry Restoration & Cleaning							
# 045500	Refactories							
# 04600	Corrision Resistant Masonry							
Phase 5:	**Metals**							
# 05010	Metal Materials	*(Enter your data here, chain-link macro spreadsheet formulas*						
# 05030	Metal Finishes							
# 05050	Metal Fastening							
# 05100	Structural Metal Framing							
# 05200	Metal Joists							
# 05300	Metal Decking							
# 05400	Cold-Formed Metal Framing							
# 05500	Metal Fabrications							
# 05580	Sheet Metal Fabrications							

FIGURE 7.8 Continued.

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# 05700	Ornamental Metal	
# 05800	Expansion Control	
# 05900	Hydraulic Structures	
Phase 6:	**Wood & Plastics**	
# 06050	Fasteners & Adhesives	*(Enter your data here, chain-link macro spreadsheet formulas*
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	
Phase 7:	**Thermal & Moisture**	
# 07100	Waterproofing	*(Enter your data here, chain-link macro spreadsheet formulas*
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	
Phase 8:	**Doors & Windows**	
# 08100	Metal Doors & Frames	*(Enter your data here, chain-link macro spreadsheet formulas*
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	
# 08800	Glazing	
# 08900	Glazed Curtain Walls	
Phase 9:	**Finishes**	
# 09100	Metal Support Systems	*(Enter your data here, chain-link macro spreadsheet formulas*
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	

# 09500	Acoustical Treatment
# 09540	Special Surfaces
# 09550	Wood Flooring
# 09600	Stone Flooring
# 09630	Unit Masonry Flooring
# 09650	Resilient Flooring
# 09680	Carpet
# 09700	Special Flooring
# 09780	Floor Treatment
# 09800	Special Coatings
# 09900	Painting
# 09950	Wall Coverings

Phase 10:	Specialities	
# 10100	Chalkboards & Tackboards	(Enter your data here, chain-link macro spreadsheet formulas
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	
# 10900	Wardrobe & Closet Specialties	

Phase 11:	Equipment	
# 11010	Maintenance Equipment	(Enter your data here, chain-link macro spreadsheet formulas
# 11020	Security & Vault Equipment	
# 11030	Teller & Service Equipment	
# 11040	Ecclesiastical Equipment	
# 11050	Library Equipment	
# 11060	Theater & Stage Equipment	
# 11070	Instrumental Equipment	
# 11080	Registration Equipment	
# 11090	Checkroom Equipment	

FIGURE 7.8 Continued.

# 11100	Mercantile Equipment
# 11110	Laundry Equipment
# 11120	Vending Equipment
# 11130	Audio-Visual Equipment
# 11140	Service Station Equipment
# 11150	Parking Control Equipment
# 11160	Loading Dock Equipment
# 11170	Solid Waste Equipment
# 11190	Detention Equipment
# 11200	Water Supply / Treatment
# 11280	Hydraulic Gate Valves
# 11300	Fluid Waste Equipment
# 11400	Food Service Equipment
# 11450	Residential Equipment
# 11460	Unit Kitchens
# 11470	Darkroom Equipment
# 11480	Recreational Equipment
# 11500	Industrial Process Equipment
# 11600	Laboratory Equipment
# 11650	Planetarium Equipment
# 11660	Observatory Equipment
# 11700	Medical Equipment
# 11780	Mortuary Equipment
# 11850	Navigation Equipment

Phase 12:	Furnishings	
# 12050	Fabrics	*(Enter your data here, chain-link macro spreadsheet formulas*
# 12100	Artwork	
# 12300	Manufactured Casework	
# 12500	Window Treatment	
# 12600	Furniture & Accessories	
# 12670	Rugs & Mats	
# 12700	Multiples Seating	
# 12800	Interior Plants & Planters	

Phase 13:	Special Construction	
# 13010	Air Supported Structures	*(Enter your data here, chain-link macro spreadsheet formulas*
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	

# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	

Phase 14:	Conveying Systems	
# 14100	Dumbwaiters	*(Enter your data here, chain-link macro spreadsheet formulas*
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	

Phase 15:	Mechanical	
# 15100	Basic Materials & Methods	*(Enter your data here, chain-link macro spreadsheet formulas*
# 15200	Mechanical Insulation	
# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	
# 15850	Testing	

Phase 16:	Electrical	
# 16100	Basic Materials & Methods	*(Enter your data here, chain-link macro spreadsheet formulas*
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	

FIGURE 7.8 Continued.

Simply select All under the Edit menu, paste to open spreadsheet, and a new page will continue for you.

Remember never to use the back of a field report to continue information, because it will be overlooked when faxing, during a review, or when photocopying. Because it is impossible to tell in advance what will become the important information, all categories must be accurately maintained. It is up to the owner and project team to regularly audit the reports.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Your Company Name Here

Daily Field Report

Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***	**Page: 1 of**	
Client Invoice:	***Owner's Job Invoice Number***		

Date:	*Today's date*	**Temp:**	*Begin / End*	**Critical or Principal Activities Completed:**
Phase #:	*Phase project is in*	**Wind:**	*Dir / mph*	
Filed by:	*Site supervisor preparing report*	**Sky:**	*Clr / Clds*	
Vistors:	*Visitors to the job site today (other than regular workers)*	**Precip:**	*% Rain*	
Reason for visit:	*Why were they here?*			
Work force:	*Who were the labor force present today on site?*			
Trades:	*What were their project's employment classification?*			
Activity performed:	*What was done by each of the above?*			
Equip on-site:	*What equipment is on-site today?*			
Equip work performed:	*What was done by each of the above?*			
Items received:	*Items received at jobsite today*			
Items sent:	*Items sent from jobsite today*			
Location of work performed:	*Where exactly in the project the work was done*			
C.O. number:	*Change order numbers if any*			
Problems:	*Problems or delays encountered by site supervisor*			
Comments:	*Solutions proposed by the site supervisor*			
Copy to:	*Project manager, owner, etc.*			

FIGURE 7.9 Daily field report.

Bar Chart by Early Start

By making a separate bar chart from the master Bar Chart by Early Start in the accompanying software, for any day or weekly planner you may need, such as tracking contract documents and then making a related calendar entry in a the master network timeline sort, then saving both to a separate file, you create synchronicity between the two sorts in each distinct and dedicated file.

The advantage of using CPM project scheduling systems on capital projects versus bar charts is in the increased control over the interrelationships between events and higher accuracy of detailed summary sorts. The Bar Chart by Early Start provides instantaneous critical data regarding actual progress by early schedule start by activity. The data are made readily available on the computer monitor screen at any given time and are essential for any modern production under a deadline. The CPM system with an integrated bar chart by early start can handle the hundreds of work activities on large commercial and industrial projects with ease (see Fig. 7.10).

Computerized CPM scheduling programs produce a bar chart by early sorts printout sort, which is sorted from the activities' early starts. Bar charts are included in the weekly meetings as progress reports of scheduled progress versus actual progress. These bar chart sorts are essential tools for presentation of network scheduling details in the CPM project schedule to the owner and the project team.

Bar Chart by Early Start charts are effective at activity scheduling and tracking as a job logic diagram. Bar charts, however, do not provide the interdependency relationship between activities, whereas CPM networking from bar chart schedules shows the dependence (constraints) between one starting activity and the finish of the activity preceding it. Further, bar charts do not allow for variable float control at those activities' events.

There are also limits to the number of activities, usually around 50, that can be tracked on a bar chart before the chart becomes a victim of data overload and the milestones within the bar chart schedule miss their marks. Presentation bar charts are typically structured with a three-month timeline.

Many subactivities and work items within subtasks within the larger activities should be broken out with individual computer numbers for dedicated cell address data storage. All activities are made up of smaller activities that need attention and control.

Network Timeline

This is the time-scale directory that establishes the data the computer uses for factoring time computations throughout the integrated sorts. This report anchors each phase and the activities within each phase, to the network

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Your Company Name Here

Bar Chart by Early Start

Prepared Fo *Your Client's Name Here*
Project: ***Project's Name Here***
File Name: *Your Computer File Name Here*
Description: *Project Description Here*
Our Invoice I ***Your Company's Job Number***
Client Invoic ***Owner's Job Invoice Number***

Data Date: *Data Entry Date*
Run Date: *Printout Date*

Page: 1 of

Activity Number	Activity Description	6	13	20	27	1	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16
Phase 0:	**General Conditions**																								
# 00010	Subsurface Investigation	X	X	X																					
# 00100	Instructions to Bidders			X	X	X																			
# 00200	Information Available to Bidders				X	X																			
# 00300	Bid Forms					X	X																		
# 00400	Supplements to Bid Forms						X	X																	
# 00500	Agreement Forms							X																	
# 00600	Bonds and Certificates				X	X																			
# 00700	General Conditions		X																						
# 00800	Supplementary Conditions			X																					
# 00850	Drawings and Schedules				X																				
# 00900	Addenda and Modifications				X	X																			
Phase 1:	**Specifications**																								
# 01010	Soils: Reports & Remediations						X	X																	
# 01020	Allowances							X																	
# 01025	Measurement & Payment							X	X																
# 01030	Alternates / Alternatives								X																
# 01040	Coordination								X	X															
# 10150	Field Engineering									X	X														
# 01060	Regulatory Requirements									X	X	X													
# 01070	Abbreviations & Symbols											X	X												
# 01080	Identification Systems							X	X	X															
# 01090	Reference Standards									X	X														
# 01100	Special Project Procedures										X	X													
# 01200	Project Meetings									X	X	X													
# 01300	Submittals											X	X												
# 01400	Quality Control												X	X											

FIGURE 7.10 Bar chart by early start.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

# 01500	Const Facilities & Temp Control										X	X	X											
# 01600	Material & Equipment											X	X	X										
# 01650	Commissioning of Equipment												X	X										
# 01700	Contract Closeout													X										
# 01800	Maintenance													X	X									
Phase 2:	**Site Work**																							
# 02010	Subsurface Investigation													X	X									
# 02050	Demolition														X	X	X							
# 02100	Site Preparation																X	X						
# 02140	Dewatering																	X	X	X				
# 02150	Shoring & Underpinning																		X	X	X			
# 02160	Excavation Support Systems																			X	X	X		
# 02170	Cofferdams																				X	X		
# 02200	Earthwork																X	X	X					
# 02300	Tunneling																		X	X	X			
# 02350	Piles & Caissons																							
# 02450	Railroad Work																							
# 02480	Marine Work																							
# 02500	Paving & Surfacing																				X	X	X	
# 02600	Piped Utility Materials																					X	X	X
# 02660	Water Distribution																						X	X
# 02680	Fuel Distribution																							X
# 02700	Sewer & Drainage																							
# 02760	Restoration of Pipelines																							
# 02770	Ponds & Reservoirs																							
# 02780	Power & Communications																							
# 02800	Site Improvements																							
# 02900	Landscaping																							
Phase 3:	**Concrete**																							
# 03100	Concrete Formwork																							
# 03200	Concrete Reinforcement																							
# 03250	Concrete Accessories																							
# 03300	Cast-in-Place Concrete																							
# 03370	Concrete Curing																							
# 03400	Precast Concrete																							
# 03500	Cementious Decks																							
# 03600	Grout																							
# 03700	Concrete Restoration & Cleaning																							

FIGURE 7.10 Continued.

Code	Item	
# 03800	Mass Concrete	
# 03850	Site Clean-up	
Phase 4:	**Masonry**	
# 04100	Mortar	
# 04150	Masonry Accessories	
# 04200	Unit Masonry	
# 04400	Stone	
# 04500	Masonry Restoration & Cleaning	
# 045500	Refactories	
# 04600	Corrision Resistant Masonry	
Phase 5:	**Metals**	
# 05010	Metal Materials	
# 05030	Metal Finishes	
# 05050	Metal Fastening	
# 05100	Structural Metal Framing	
# 05200	Metal Joists	
# 05300	Metal Decking	
# 05400	Cold-Formed Metal Framing	
# 05500	Metal Fabrications	
# 05580	Sheet Metal Fabrications	
# 05700	Ornamental Metal	
# 05800	Expansion Control	
# 05900	Hydraulic Structures	
Phase 6:	**Wood & Plastics**	
# 06050	Fasteners & Adhesives	
# 06100	Rough Carpentry	
# 06130	Heavy Timber	
# 06150	Wood-Metal Systems	
# 06170	Engineered Structural Wood	
# 06200	Finish Carpentry	
# 06300	Wood Treatment	
# 06400	Architectural Woodwork	
# 06500	Prefabricated Structural Plastics	
# 06600	Plastic Fabrications	
Phase 7:	**Thermal & Moisture**	

Figure 7.10 Continued.

Code	Description	
# 07100	Waterproofing	
# 07150	Dampproofing	
# 07190	Vapor & Water Barriers	
# 07200	Insulation	
# 07250	Fireproofing	
# 07300	Roofing Tiles & Shingles	
# 07400	Preformed Roofing Siding	
# 07500	Membrane Roofing	
# 07570	Traffic Topping	
# 07600	Flashing & Sheetmetal	
# 07700	Roof Specialties	
# 07800	Skylights	
# 07900	Joint Sealers	
Phase 8:	**Doors & Windows**	
# 08100	Metal Doors & Frames	
# 08200	Wood & Plastic Doors	
# 08250	Door Opening Assemblies	
# 08300	Special Doors	
# 08400	Entrances & Storefronts	
# 08500	Metal Windows	
# 08600	Wood & Plastic Windows	
# 08650	Special Windows	
# 08700	Hardware	
# 08800	Glazing	
# 08900	Glazed Curtain Walls	
Phase 9:	**Finishes**	
# 09100	Metal Support Systems	
# 09200	Lath and Plaster	
# 09230	Aggregate Coatings	
# 09250	Gypsum Board	
# 09300	Tile	
# 09400	Terrazzo	
# 09500	Acoustical Treatment	
# 09540	Special Surfaces	
# 09550	Wood Flooring	
# 09600	Stone Flooring	
# 09630	Unit Masonry Flooring	
# 09650	Resilient Flooring	

FIGURE 7.10 Continued.

# 09680	Carpet	
# 09700	Special Flooring	
# 09780	Floor Treatment	
# 09800	Special Coatings	
# 09900	Painting	
# 09950	Wall Coverings	
Phase 10:	**Specialities**	
# 10100	Chalkboards & Tackboards	
# 10150	Compartments & Cubicles	
# 10200	Louvers & Vents	
# 10240	Grilles & Screens	
# 10250	Service Wall Systems	
# 10260	Wall & Corner Guards	
# 10270	Access Flooring	
# 10280	Specialty Modules	
# 10290	Pest Control	
# 10300	Fireplaces & Stoves	
# 10340	Prefabricated Exterior Specialties	
# 10350	Flagpoles	
# 10400	Identifying Devices	
# 10450	Pedestrian Control Devices	
# 10500	Lockers	
# 10520	Fire Protection Specialties	
# 10530	Protective Covers	
# 10550	Postal Specialties	
# 10600	Partitions	
# 10650	Operable Partitions	
# 10670	Storage Shelving	
# 10700	Exterior Sun Control Devices	
# 10750	Telephone Specialties	
# 10800	Toilet & Bath Specialties	
# 10880	Scales	
# 10900	Wardrobe & Closet Specialties	
Phase 11:	**Equipment**	
# 11010	Maintenance Equipment	
# 11020	Security & Vault Equipment	
# 11030	Teller & Service Equipment	
# 11040	Ecclesiastical Equipment	

FIGURE 7.10 Continued.

# 11050	Library Equipment	
# 11060	Theater & Stage Equipment	
# 11070	Instrumental Equipment	
# 11080	Registration Equipment	
# 11090	Checkroom Equipment	
# 11100	Mercantile Equipment	
# 11110	Laundry Equipment	
# 11120	Vending Equipment	
# 11130	Audio-Visual Equipment	
# 11140	Service Station Equipment	
# 11150	Parking Control Equipment	
# 11160	Loading Dock Equipment	
# 11170	Solid Waste Equipment	
# 11190	Detention Equipment	
# 11200	Water Supply / Treatment	
# 11280	Hydraulic Gate Valves	
# 11300	Fluid Waste Equipment	
# 11400	Food Service Equipment	
# 11450	Residential Equipment	
# 11460	Unit Kitchens	
# 11470	Darkroom Equipment	
# 11480	Recreational Equipment	
# 11500	Industrial Process Equipment	
# 11600	Laboratory Equipment	
# 11650	Planetarium Equipment	
# 11660	Observatory Equipment	
# 11700	Medical Equipment	
# 11780	Mortuary Equipment	
# 11850	Navigation Equipment	
Phase 12:	**Furnishings**	
# 12050	Fabrics	
# 12100	Artwork	
# 12300	Manufactured Casework	
# 12500	Window Treatment	
# 12600	Furniture & Accessories	
# 12670	Rugs & Mats	
# 12700	Multiples Seating	
# 12800	Interior Plants & Planters	

FIGURE 7.10 Continued.

Phase 13:	Special Construction	
# 13010	Air Supported Structures	
# 13020	Integrated Assemblies	
# 13030	Special Purpose Rooms	
# 13080	Sound, Vibration, Seismic	
# 13090	Radiation Protection	
# 13100	Nuclear Reactors	
# 13120	Pre-Engineered Structures	
# 13150	Pools	
# 13160	Ice Links	
# 13170	Kennels	
# 13180	Site Constructed Incinerators	
# 13200	Gas / Liquid Storage Tanks	
# 13220	Filter Underdrains & Media	
# 13230	Tank Covers	
# 13240	Oxygenation Systems	
# 13260	Sludge Conditioning Systems	
# 13300	Utility Control Systems	
# 13400	Industrial / Process Controls	
# 13500	Recording Instruments	
# 13550	Transportation Controls	
# 13600	Solar Energy Systems	
# 13700	Wind Energy Systems	
# 13800	Building Automation Systems	
# 13900	Fire Suppression Systems	
Phase 14:	**Conveying Systems**	
# 14100	Dumbwaiters	
# 14200	Elevators	
# 14250	Moving Stairs & Walkways	
# 14300	Lifts	
# 14350	Material Handling Systems	
# 14400	Hoists & Cranes	
# 14500	Turntables	
# 14600	Scaffolding	
# 14700	Transportation Systems	
Phase 15:	**Mechanical**	
# 15100	Basic Materials & Methods	
# 15200	Mechanical Insulation	

FIGURE 7.10 Continued.

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#	15300	Fire Protection
#	15400	Plumbing
#	15500	HVAC
#	15550	Heat Generation
#	15570	Heat Transfer
#	15600	Refrigeration
#	15700	Air Handling
#	15750	Air Distribution
#	15800	Controls
#	15850	Testing
Phase 16:		**Electrical**
#	16100	Basic Materials & Methods
#	16110	Power Generation
#	16200	High Voltage Distribution >600v
#	16250	Service Distribution <600v
#	16300	Lighting
#	16400	Special Systems
#	16450	Communications
#	16500	Electric Resistance Heating
#	16600	Controls
#	16700	Testing

FIGURE 7.10 Continued.

timeline. The master format is set up in a one-year duration but can be extended by the end user when needed. The weekly milestones are set on Fridays to coincide with the weekly field reports meeting and are readjustable each year by simple input of new dates. To input new calendar dates or insert new milestones, move to the relative cell address and input the data as per instructions in data entry.

The network timeline is an extremely functional sort in linkage with bar chart sorts. By making a separate bar chart from the master in the accompanying software, for any day or weekly planner you may need, such as tracking contract documents and then making a related calendar entry in the master network timeline sort, then saving both to a separate file, you create synchronicity between the two sorts in that distinct and dedicated file (see Fig. 11).

Your Company Name Here

Network Velocity Timeline

Prepared For. ***Your Client's Name Here***
Project: ***Project's Name Here*** Data Date: *Data Entry Date*
File Name *Your Computer File Name Here* Run Date. *Printout Date*
Description: *Project Description Here*
Our Invoice No. ***Your Company's Job Number*** **Page: 1 of**
Client Invoice: ***Owner's Job Invoice Number***

Activity Number	Activity Description	6	13	20	27	1	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9
Phase 0:	**General Conditions**																							
# 00010	Subsurface Investigation	X	X	X																				
# 00100	Instructions to Bidders		X	X	X	X																		
# 00200	Information Available to Bidders		X	X	X	X																		
# 00300	Bid Forms			X	X	X	X																	
# 00400	Supplements to Bid Forms				X	X	X	X																
# 00500	Agreement Forms						X	X																
# 00600	Bonds and Certificates			X	X	X																		
# 00700	General Conditions		X	X	X	X	X	X																
# 00800	Supplementary Conditions			X	X	X																		
# 00850	Drawings and Schedules				X	X	X	X																
# 00900	Addenda and Modifications				X	X	X																	
Phase 1:	**Specifications**																							
# 01010	Soils: Reports & Remediations					X	X	X																
# 01020	Allowances						X	X	X															
# 01025	Measurement & Payment							X	X	X														
# 01030	Alternates / Alternatives								X	X	X													
# 01040	Coordination								X	X	X	X												
# 10150	Field Engineering									X	X	X	X											
# 01060	Regulatory Requirements									X	X	X												
# 01070	Abbreviations & Symbols											X	X											
# 01080	Identification Systems							X	X	X														
# 01090	Reference Standards									X	X													
# 01100	Special Project Procedures										X	X												
# 01200	Project Meetings									X	X	X												
# 01300	Submittals											X	X											
# 01400	Quality Control											X	X	X										

FIGURE 7.11 Network timeline.

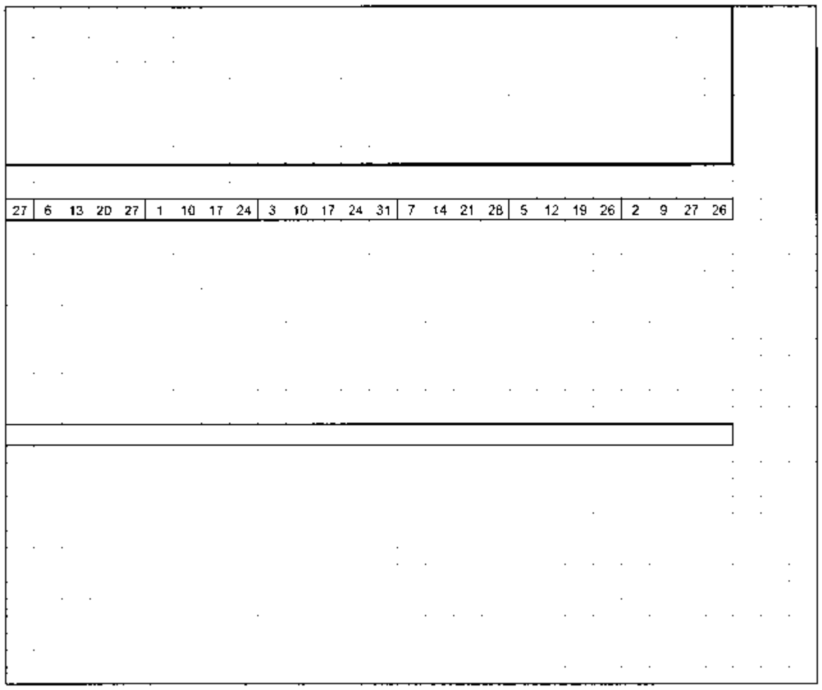

FIGURE 7.11 Continued.

Shop Drawings Log

The Shop Drawings Log sort should be started prior to commencement, so that when the shop drawings start arriving from subcontractors and suppliers, each drawing can be properly logged into the computer for tracking. A log of shop drawing activity will allow a project scheduler to keep track of what drawings have been received and will also show where the drawings have been sent and how long they have been there. The project scheduler needs to prod each subcontractor and supplier to submit his drawings promptly. At the first job meeting, the major subcontractors and/or material suppliers should be requested to submit a preliminary shop drawing then submission schedule.

The log should include the major pieces of equipment for which shop drawings are required and the anticipated date when each drawing will be

# 01500	Const Facilities & Temp Control	X	X	X										
# 01600	Material & Equipment		X	X	X									
# 01650	Commissioning of Equipment		X	X	X									
# 01700	Contract Closeout		X	X	X									
# 01800	Maintenance			X	X	X								
Phase 2:	**Site Work**													
# 02010	Subsurface Investigation			X	X	X								
# 02050	Demolition					X	X	X						
# 02100	Site Preparation					X	X	X	X					
# 02140	Dewatering						X	X	X	X	X			
# 02150	Shoring & Underpinning							X	X	X	X	X		
# 02160	Excavation Support Systems									X	X	X	X	
# 02170	Cofferdams									X	X	X	X	
# 02200	Earthwork							X	X	X				
# 02300	Tunneling									X	X	X		
# 02350	Piles & Caissons											X	X	
# 02450	Railroad Work													
# 02480	Marine Work											X	X	X
# 02500	Paving & Surfacing											X	X	X
# 02600	Piped Utility Materials												X	X
# 02660	Water Distribution													X
# 02680	Fuel Distribution													
# 02700	Sewer & Drainage													
# 02760	Restoration of Pipelines													
# 02770	Ponds & Reservoirs													
# 02780	Power & Communications													
# 02800	Site Improvements													
# 02900	Landscaping													
Phase 3:	**Concrete**													
# 03100	Concrete Formwork													
# 03200	Concrete Reinforcement													
# 03250	Concrete Accessories													
# 03300	Cast-in-Place Concrete													
# 03370	Concrete Curing													
# 03400	Precast Concrete													
# 03500	Cementious Decks													
# 03600	Grout													
# 03700	Concrete Restoration & Cleaning													

submitted. The subcontractor and/or supplier should also include the approximate delivery date of equipment after the approved shop drawings have been returned to them. Once shop drawings have been received, the next hurdle is getting them approved in a timely manner.

The project manager and the owner should review the incoming shop drawings before the project scheduler logs them into the computer, to determine whether they conform to the project specifications and requirements. If compliance is questionable, they should contact the party who made the submission and ask them to re-examine the shop drawings for contract specifications. If deviations exist, it might be best to note them before submitting the drawings to the architect. At this point the project manager must establish credibility with the architect and engineers and must show that the shop drawings are being reviewed for compliance with the plans and

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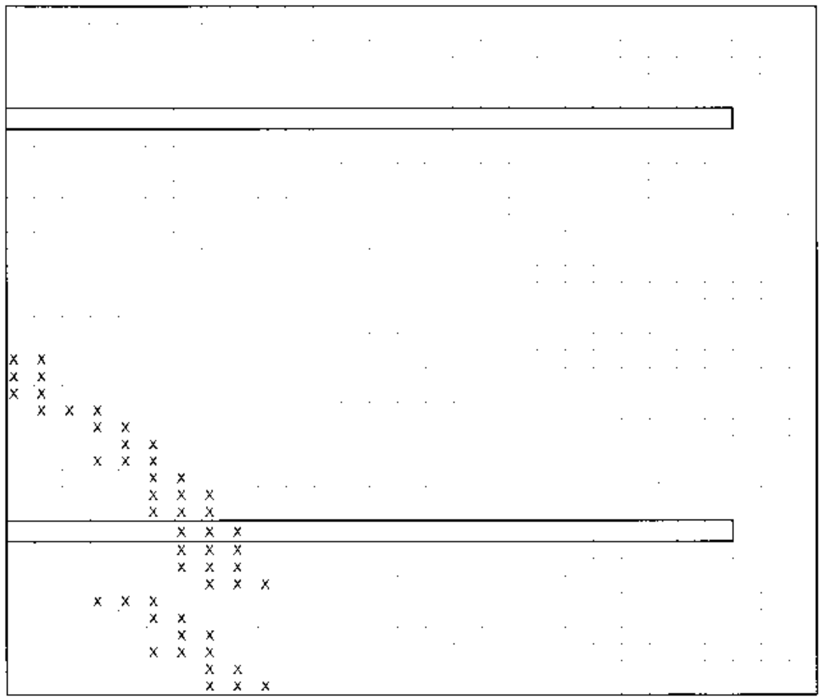

FIGURE 7.11 Continued.

specifications, and are not merely being passed through without any scrutiny whatsoever (see Fig. 7.12).

Submittal Items Tracking

The Submittal Items Tracking sort is used on all long-lead and fabricated items procurement tracking. In addition, a separate file should be kept for each trade that will be submitting large numbers of drawings, such as structural steel, plumbing, HVAC, sprinkler system, and electrical.

Several software programs on the market today allow the project scheduler to create a fax modem transmittal forwarding the shop drawing to the architect or engineer and transferring this information automatically onto a shop drawing log. The information inserted at the time of preparation

# 03800	Mass Concrete
# 03850	Site Clean-up
Phase 4:	**Masonry**
# 04100	Mortar
# 04150	Masonry Accessories
# 04200	Unit Masonry
# 04400	Stone
# 04500	Masonry Restoration & Cleaning
# 045500	Refactories
# 04600	Corrision Resistant Masonry
Phase 5:	**Metals**
# 05010	Metal Materials
# 05030	Metal Finishes
# 05050	Metal Fastening
# 05100	Structural Metal Framing
# 05200	Metal Joists
# 05300	Metal Decking
# 05400	Cold-Formed Metal Framing
# 05500	Metal Fabrications
# 05580	Sheet Metal Fabrications
# 05700	Ornamental Metal
# 05800	Expansion Control
# 05900	Hydraulic Structures
Phase 6:	**Wood & Plastics**
# 06050	Fasteners & Adhesives
# 06100	Rough Carpentry
# 06130	Heavy Timber
# 06150	Wood-Metal Systems
# 06170	Engineered Structural Wood
# 06200	Finish Carpentry
# 06300	Wood Treatment
# 06400	Architectural Woodwork
# 06500	Prefabricated Structural Plastics
# 06600	Plastic Fabrications
Phase 7:	**Thermal & Moisture**

is also stored and transferred to the shop drawing log. Although the shop drawing log contains material from various subcontractors, separate computer files and summary report sorts can be created for individual trades.

Care must be taken to discern which subcontractors should receive informational copies of shop drawings from the submittal items tracking sort. For instance, when a mechanical subcontractor is being sent an approved copy of his boiler shop drawing, the electrical contractor should have an informational copy to confirm the line voltage requirements. All too often a piece of equipment is ordered with electrical characteristics at variance with the voltage requirements shown in the drawings. If an error such as this can be caught in the shop drawing stage, little or no additional cost may be required to make the equipment compatible with the building's electrical system see Fig. 13.

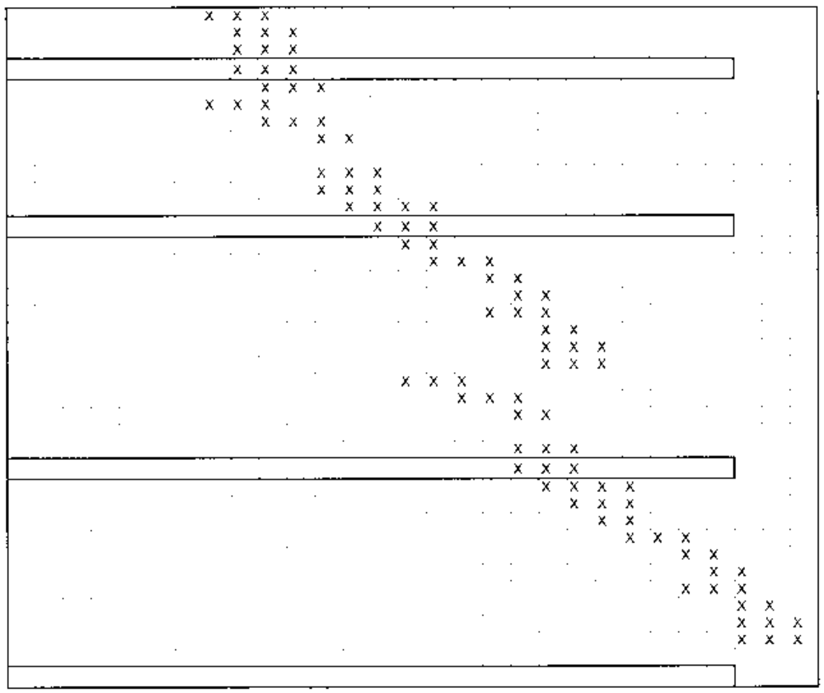

FIGURE 7.11 Continued.

Correspondence Transmittals

Much of the actual day-to-day work of a project involves correspondence of schedules, unforeseen problems, and changes. All correspondence relative to your network schedule must be tracked for quick recordation access. This sort has three levels. The first records each correspondence, the date and time it was sent, its description, from whom, and to whom. It then records when the correspondence's detail is required to be on the project, when it is required to be done, the date the detail was sent to the party concerned, and the amount of days the return is late.

The sort, through its third factoring, then tracks the item's value as well as it status for an audit trail. The correspondence from vendors, materials suppliers, and various subcontractors through this sort including change orders, shop drawings, or other documents can be automatically transmitted

# 07100	Waterproofing
# 07150	Dampproofing
# 07190	Vapor & Water Barriers
# 07200	Insulation
# 07250	Fireproofing
# 07300	Roofing Tiles & Shingles
# 07400	Preformed Roofing Siding
# 07500	Membrane Roofing
# 07570	Traffic Topping
# 07600	Flashing & Sheetmetal
# 07700	Roof Specialties
# 07800	Skylights
# 07900	Joint Sealers
Phase 8:	**Doors & Windows**
# 08100	Metal Doors & Frames
# 08200	Wood & Plastic Doors
# 08250	Door Opening Assemblies
# 08300	Special Doors
# 08400	Entrances & Storefronts
# 08500	Metal Windows
# 08600	Wood & Plastic Windows
# 08650	Special Windows
# 08700	Hardware
# 08800	Glazing
# 08900	Glazed Curtain Walls
Phase 9:	**Finishes**
# 09100	Metal Support Systems
# 09200	Lath and Plaster
# 09230	Aggregate Coatings
# 09250	Gypsum Board
# 09300	Tile
# 09400	Terrazzo
# 09500	Acoustical Treatment
# 09540	Special Surfaces
# 09550	Wood Flooring
# 09600	Stone Flooring
# 09630	Unit Masonry Flooring
# 09650	Resilient Flooring

to the concerned party and then transferred automatically to a summary report for the owner and project team members (see Fig. 7.14).

Change Order Tracking

Interlocking the activity number, type, and description with the status and value does change order tracking. This accounts for where the money is going and who's responsible for authorization and procurement. This sort also has three levels of factoring.

The first records each change order by contract number, the date and time it was authorized, who authorized it, who will procure it, its description, from whom, and to whom. It then records when the change order must be initiated, when is must be completed, and the date the change order was sent to the party concerned.

# 09680	Carpet
# 09700	Special Flooring
# 09780	Floor Treatment
# 09800	Special Coatings
# 09900	Painting
# 09950	Wall Coverings
Phase 10:	**Specialities**
# 10100	Chalkboards & Tackboards
# 10150	Compartments & Cubicles
# 10200	Louvers & Vents
# 10240	Grilles & Screens
# 10250	Service Wall Systems
# 10260	Wall & Corner Guards
# 10270	Access Flooring
# 10280	Specialty Modules
# 10290	Pest Control
# 10300	Fireplaces & Stoves
# 10340	Prefabricated Exterior Specialties
# 10350	Flagpoles
# 10400	Identifying Devices
# 10450	Pedestrian Control Devices
# 10500	Lockers
# 10520	Fire Protection Specialties
# 10530	Protective Covers
# 10550	Postal Specialties
# 10600	Partitions
# 10650	Operable Partitions
# 10670	Storage Shelving
# 10700	Exterior Sun Control Devices
# 10750	Telephone Specialties
# 10800	Toilet & Bath Specialties
# 10880	Scales
# 10900	Wardrobe & Closet Specialties
Phase 11:	**Equipment**
# 11010	Maintenance Equipment
# 11020	Security & Vault Equipment
# 11030	Teller & Service Equipment
# 11040	Ecclesiastical Equipment

FIGURE 7.11 Continued.

The sort, through its third factoring, then tracks the change order's value as well as its status for an audit trail. As with the correspondence transmittals sort, the change orders from activity subcontractors through the change order tracking sort can forward documentation to the concerned party and then transfer this information automatically to a summary report for the owner and project team members (see Fig. 7.15).

Audit-Trail Tracking

The Audit-Trail Tracking sort factors its summary report by the computer database computed from the activity's assigned i–j number, the activity description, the item number, the date it was linked to procurement, who sent it and to whom, and who's responsible for authorization and procurement. Interlocking the item number, type, and description with the status and value does tracking. This accounts for where the money is going; by entering

# 11050	Library Equipment
# 11060	Theater & Stage Equipment
# 11070	Instrumental Equipment
# 11080	Registration Equipment
# 11090	Checkroom Equipment
# 11100	Mercantile Equipment
# 11110	Laundry Equipment
# 11120	Vending Equipment
# 11130	Audio-Visual Equipment
# 11140	Service Station Equipment
# 11150	Parking Control Equipment
# 11160	Loading Dock Equipment
# 11170	Solid Waste Equipment
# 11190	Detention Equipment
# 11200	Water Supply / Treatment
# 11280	Hydraulic Gate Valves
# 11300	Fluid Waste Equipment
# 11400	Food Service Equipment
# 11450	Residential Equipment
# 11460	Unit Kitchens
# 11470	Darkroom Equipment
# 11480	Recreational Equipment
# 11500	Industrial Process Equipment
# 11600	Laboratory Equipment
# 11650	Planetarium Equipment
# 11660	Observatory Equipment
# 11700	Medical Equipment
# 11780	Mortuary Equipment
# 11850	Navigation Equipment
Phase 12:	**Furnishings**
# 12050	Fabrics
# 12100	Artwork
# 12300	Manufactured Casework
# 12500	Window Treatment
# 12600	Furniture & Accessories
# 12670	Rugs & Mats
# 12700	Multiples Seating
# 12800	Interior Plants & Planters

the appropriate data on the cost by activity number sort, you can have the computer link the activities network with the costs and expenses necessary to run the network.

In addition, owners using CPM systems have the advantage of control over those costs before they are paid, by having the project scheduler run trends analysis forecasting. The crucial task of monitoring the project field service costs is now linked to the project schedule and separates those cost expenses from the architect's design costs. The Audit-Trail Tracking sort tracks and calculates these in series.

Audit-trail trends analysis is an important function of your schedule estimating that will provide your client with one of the prime advantages of CPM—cost control and the ability to foresee the commitment of resources before they are needed. The sort can also forward documentation to the concerned party and then transfer this information automatically to a summary report for the owner and project team members (see Fig. 7.16).

Phase 13:	Special Construction
# 13010	Air Supported Structures
# 13020	Integrated Assemblies
# 13030	Special Purpose Rooms
# 13080	Sound, Vibration, Seismic
# 13090	Radiation Protection
# 13100	Nuclear Reactors
# 13120	Pre-Engineered Structures
# 13150	Pools
# 13160	Ice Links
# 13170	Kennels
# 13180	Site Constructed Incinerators
# 13200	Gas / Liquid Storage Tanks
# 13220	Filter Underdrains & Media
# 13230	Tank Covers
# 13240	Oxygenation Systems
# 13260	Sludge Conditioning Systems
# 13300	Utility Control Systems
# 13400	Industrial / Process Controls
# 13500	Recording Instruments
# 13550	Transportation Controls
# 13600	Solar Energy Systems
# 13700	Wind Energy Systems
# 13800	Building Automation Systems
# 13900	Fire Suppression Systems
Phase 14:	**Conveying Systems**
# 14100	Dumbwaiters
# 14200	Elevators
# 14250	Moving Stairs & Walkways
# 14300	Lifts
# 14350	Material Handling Systems
# 14400	Hoists & Cranes
# 14500	Turntables
# 14600	Scaffolding
# 14700	Transportation Systems
Phase 15:	**Mechanical**
# 15100	Basic Materials & Methods
# 15200	Mechanical Insulation

FIGURE 7.11 Continued.

Contract Purchase Order Summary

This sort provides a summary report by the computer database computed from the purchase order's assigned number, the activity description, the date it was issued, who's responsible for authorization, who sent it, and to whom. Original date, the revised date, and the status do tracking.

Cost changes are shown as either approved or pending. This pending column is further defined to show available resources. This allows the owner to commit resources as priorities may dictate. See Fig. 7.17.

CHANGE ORDER MANAGEMENT

Change orders and construction claims against the owner in a CPM network schedule are, far and away, most often generated from changes in the schedule during production operation phases. Contract law does not allow the prime

# 15300	Fire Protection	
# 15400	Plumbing	
# 15500	HVAC	
# 15550	Heat Generation	
# 15570	Heat Transfer	
# 15600	Refrigeration	
# 15700	Air Handling	
# 15750	Air Distribution	
# 15800	Controls	
# 15850	Testing	
Phase 16:	**Electrical**	
# 16100	Basic Materials & Methods	
# 16110	Power Generation	
# 16200	High Voltage Distribution >600v	
# 16250	Service Distribution <600v	
# 16300	Lighting	
# 16400	Special Systems	
# 16450	Communications	
# 16500	Electric Resistance Heating	
# 16600	Controls	
# 16700	Testing	

FIGURE 7.11 Continued.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Your Company Name Here

Shop Drawings Log

Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***	**Page: 1 of**	
Client Invoice:	***Owner's Job Invoice Number***		

Vendor Number	Vendor Address	Phone Number	Contact Person	Date Sent	Date Due	Check By:	Appvd By:	Activity I - J No.

FIGURE 7.12 Shop drawings log.

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Your Company Name Here

Submittal Items Tracking

Prepared For: ***Your Client's Name Here***
Project: ***Project's Name Here***
File Name: *Your Computer File Name Here*
Description: *Project Description Here*
Our Invoice No: ***Your Company's Job Number***
Client Invoice: ***Owner's Job Invoice Number***

Data Date *Data Entry Date*
Run Date: *Printout Date*

Page: 1 of

Item Name	Vendor Name Address and Phone	Item Number	Item Status	Req'd Start	Req'd Finish	Date Sent	Days Over	Item Value

FIGURE 7.13 Submittal items tracking.

Your Company Name Here

Correspondence Transmittals

Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date:	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***	**Page: 1 of**	
Client Invoice:	***Owner's Job Invoice Number***		

Sent Date/Time	Correspondence Description	Sent To:	Sent From:	Days Over	Item Status	Value

FIGURE 7.14 Correspondence transmittals.

Your Company Name Here		**Change Order Tracking**	
Prepared For:	***Your Client's Name Here***		
Project:	***Project's Name Here***	Data Date:	*Data Entry Date*
File Name:	*Your Computer File Name Here*	Run Date:	*Printout Date*
Description:	*Project Description Here*		
Our Invoice No:	***Your Company's Job Number***	**Page: 1 of**	
Client Invoice:	***Owner's Job Invoice Number***		

Activity Number	Activity Title	Sent To:	Rcv'd From:	Change Number	Resp Contr	Appv'd By:	Order Status	C. O. Value

FIGURE 7.15 Change order tracking.

Your Company Name Here **Audit Trail Tracking**

Prepared for: ***Your Client's Name Here***
Project: ***Project's Name Here*** **Data Date:**
File Name: ***Your File Name Here*** **Run Date:**
Description: ***Project Description Here*** **Page 1 of**
Our Invoice: ***Your Job Number Here***
Client Invoice: ***Owner's Job Invoice***

Date Linked	Item Number	Item Description	Date Appv'd	I-J Number	Order Status	Item Value	Check No.

FIGURE 7.16 Audit-trail tracking.

or subcontractors to make any changes to an existing contract. An addendum in specified work requires the contractor to write up a contract change order and then seek written approval from the owner. The owner is not obligated to sign a change order, but the owner's approval is absolutely necessary to avoid litigation problems.

The owner cannot be forced to pay for work that was not authorized. Contract law specifies that "all changes to the original contract must be in writing and signed by both the property owner and contractor." Specify that ordering materials must be done after the contractor reviews plans and specifications. Visiting a job site is not sufficient to see all the details of the job. During project operations, if materials or items are ordered on an "as-needed" basis, delays will occur if the materials or items are unavailable or on

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Your Company Name Here		Contract/P.O. Summary
Prepared for:	Your Client's Name Here	
Project:	Project's Name Here	Data Date:
File Name:	Your File Name Here	Run Date:
Description:	Project Description Here	Page 1 of
Our Invoice:	Your Job Number Here	
Client Invoice:	Owner's Job Invoice	

To:	From:	Item Description	Date Opened	P.O. Number	Order Status	Cost	Appv'd

FIGURE 7.17 Contract/P.O. summary.

back-order. Repeated here for ease of reference are the management techniques for limiting delay claims in a CPM schedule.

The *first* management technique is to require written notice by the contractor to the owner or project team if any events have occurred that later will be asserted as justifying delay damages. This is the method currently taking preference in the industry, as it provides warning of potential claims in time for someone to do something about the situation in the mediation-dispute-resolution stage and resolve it at the activity level. Typically, this notice is stated to be a condition precedent to any right to delay damages. Historically, although such clauses have not been looked on favorably by the courts, noncompliance with a notice provision can be the basis for barring a claim for delay damages and because it's a contractual obligation, it can

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"bulletproof" the situation as well as is currently possible without undue and unjustifiable constraint on the contractor.

The *second* management technique is to deny the delay damage problem outright by not setting up notice conditions or specifying what can be recovered. The method is to configure the contract with no-damage or no-pay-for-delay clauses. Such clauses attempt to place the entire risk for delay damages on the contractor, and to limit the contractor to time extensions.

Generally, such clauses are upheld but not looked on favorably by the courts and much less by contractors. A current modification on the "no-pay" or "no-damage" provision clauses is to provide that the contractor can recover delay damages only after a designated number of days' delay by the owner.

CONSTRUCTIVE CHANGES

In project scheduling, a constructive change is an informal act authorizing or directing a modification to the contract, caused by the owner or architect through an act or a failure to act. In contrast to the mutually recognized need for a change, certain acts or failures to act by the owner that increase the contractor's costs and/or time of performance may be considered grounds for a change order. This is termed a *constructive change*. However, the contractor must claim it in writing within the time specified in the contract documents. Otherwise, the contractor may waive its rights to collect. Types of constructive changes include

- Defective plans and specifications
- Architect or engineer interpretation of documents
- Higher standard of performance than specified
- Improper inspection and rejection of work
- Change in the method of performance by owner
- Change in the production sequence by owner
- Owner nondisclosure of pertinent facts
- Impracticability or impossibility of performance

CHANGED CONDITIONS

Sometimes referred to as "unforeseen conditions" or "differing site conditions," the term *changed conditions* is typically used in all federal contracts. There is also a growing trend by many public agencies and a few private owners to adopt similar wording in their contracts. Failure of an owner to provide payment for changed conditions places the contractor in a difficult position. If the owner takes a hard-line position on this issue, the contractor may find it necessary to seek relief from the court, a process that is both lengthy and costly to both parties.

The federal policy is to make adjustments in time and/or price where an unknown subsurface exist or the contractor encounters latent conditions at the project site. The purpose is to have the owner accept certain risks and thus reduce the large contingency amounts in bids to cover such unknown conditions. The federal government and many local agencies include provisions in their construction contracts that will grant a price increase and/or time extension to a contractor who has encountered subsurface or latent conditions.

Under the legal conditions for changed conditions, an existing underground pipeline that either was not shown on the plans at all or was incorrectly located on the contract drawings would qualify as a changed condition. Unusually severe weather conditions for the time of year and location of the project may also qualify. The discovery of expansive clays in the excavation areas, if not accounted for on the geological site survey and not detected in prior soil investigations, also qualify as changed conditions. Severe rains or similar weather that prevent work from being done, or which in any way delay the project, may not always be excusable delays, and in some cases have been ruled by the court to be excusable only and not compensable.

AS-PLANNED, AS-BUILT, AND ADJUSTED SCHEDULES

Construction schedules are also used in the context of justifying time extensions and delays in project operations. The kind of analysis that can accomplish these demonstrations is performed either before the situation is actually encountered in a claim situation, or immediately afterward. In the first case, reasoning is presented to convince the owner that a potential change will affect the schedule by a precise number of days. This is accomplished with the use of two separate but related schedules. The first is the as-planned schedule. This is the schedule that indicates the new sequence of work, incorporating all the influences of the change along with the ultimate effect on the project end date. That end date change is attributable to the change.

The second situation is the one in which construction schedules must be used to demonstrate where you would have been had it not been for the subject change. It involves an "ex post facto" analysis, often in a delay claim situation. This particular kind of analysis is most useful in those cases where the project has been affected by a change, but the usually complex interaction that makes up the total project history confuses any clear cause–effect relationships.

The dilemma is solved with the use of three schedules. First, again, is the as-planned schedule. Next is the historical as-built schedule that through its periodic updates incorporates all the complicated effects on the construction sequence. Finally is the adjusted schedule. This schedule reconstructs each update as necessary, removing the effects of the change of interest. The result is a schedule that includes all the other effects without the effects of the change being considered. The difference in the end dates between the as-built and adjusted schedules becomes the amount of time attributable to the single change.

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8

OSHA Project Inspections

THE 25 MOST FREQUENTLY VIOLATED OSHA REGULATIONS

The Occupational Safety and Health (OSH) Act was written into law on December 29, 1970, and took effect 120 days after that date. The federal agency formed to oversee the enactment of the law, the Occupational Safety and Health Administration (OSHA), was designed and mandated with the intent to assure safe and healthy working conditions for every American worker by authorizing enforcement of the safety standards developed under the act. OSHA specifies the duties of both the subcontractor and the worker with respect to safety laws.

Every subcontractor's use of workers on your project is governed by the regulations of the Department of Industrial Relations, whose function in the labor codes pertaining to your project operations is to protect the welfare of the American worker. This department also administers the states' plans for the development and enforcement of occupational safety and health standards, which is OSHA's domain. The Department of Industrial Relations also has a subdivision called the Department of Industrial Accidents, which deals with workers' compensation. However, the Department of Industrial Relations' regulations more influence project accounting than project scheduling so only OSHA is covered in this book.

OSHA is given the responsibility to make sure subcontractors provide healthful and safe working conditions for their workers. To do this, OSHA is authorized to enforce production safety standards and laws. OSHA enforces these standards by levying sizable fines on noncompliant contractors and

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developers. This is the best place to provide you with an overview of which construction regulation violations are currently being most cited for residential contractors. So here we go with the top 25 hit list from OSHA. (This is a nationwide average.)

1. 1926.501(b)(1), Unprotected sides and edges. Each worker on a walking or working surface (horizontal and vertical) with an unprotected side or edge which is 6 ft or more above a lower level must be protected from falling by the use of guardrail systems, safety net systems, or personal fall arrest systems.

2. 1926.21(b)(2), Safety training and education is activity contractor's responsibility. Subcontractors must instruct workers in the recognition and avoidance of unsafe conditions and of the regulations applicable to the work environment to control or eliminate hazards or exposures to injuries or illnesses.

3. 1926.451(d)(10), Scaffolding. Tubular welded frame scaffolds. Guardrails and toeboards must be installed at all open sides and ends of all scaffolds more than 10 ft above the ground or floor. Guardrails are to be made of not less than 2. in × 4 in. lumber, or other material providing equivalent protection, and must be approximately 42 in. high with a midrail of 1 in. × 6 in. lumber (or other material providing equivalent protection). Toeboards must have a minimum height of 4 in. Wire mesh must be installed where persons are required to work or pass under the scaffold. The mesh must be from 18 gauge U.S. standard wire 1/2-inch mesh or its equivalent and must extend along the entire opening between the toeboard and the guardrail.

4. 1926.100(a), Head protection. Workers must use protective helmets if they work in areas where there is a danger of head injury from an impact by falling or flying objects or from electrical shocks and burns.

5. 1926.404(b)(1) Wiring design and protection. Ground-fault protection. Either ground-fault circuit interrupters (GFCIs) or an assured equipment grounding conductor program must be used to protect workers on all construction sites from electrical shock. These requirements are in addition to any other requirements for equipment grounding conductors.

6. 1926.652(a)(1), Requirements for protective systems. Protection in excavations. Workers in an excavation must be protected from cave-ins by an adequate protective system unless the excavation is made entirely in stable rock or the excavation is less than 5 ft in depth and a competent person has determined there is no indication of a potential cave-in. Protective systems that may be used include sloping and benching systems, shield systems, or support systems such as timber shoring or aluminum hydraulic shoring.

7. 1926.451(a)(13), Scaffolding. General requirements. An access ladder or an equivalent safe access must be provided. The above citation is

from the old scaffold rule. The new citation number is 1926.451(e), "Access." Access to scaffolds now has its own section in the new rule. Section 926.451(e)(1) sums the section up as: "When scaffold platforms are more than two feet above or below a point of access, portable, hook-on, and attachable ladders, stair towers (scaffold stairways/towers), stairway-type ladders (such as ladder stands), ramps, walkways, integral prefabricated scaffold access, or direct access from another scaffold, structure, personnel hoist, or similar surface must be used." Cross braces must not be used as a means of access.

8. 1926.20(b)(2), General safety and health. Accident prevention responsibilities. The prime contractor must initiate and maintain programs necessary to provide for frequent and regular inspections of the job site, materials, and equipment. Inspections are to be made by the project team.

9. 1926.59(e)(1), Hazard communication. Written hazard communication program. A written hazard communication program must be developed, implemented, and maintained at each project job site. The written program must describe how labeling, MSDSs, and training requirements will be met. In addition, the written program must contain a list of hazardous chemicals in the workplace and describe how all workers will be informed of the hazards associated with chemicals contained in pipes in their work areas. The written program must be available to the workers. OSHA has cited companies for not having a copy of the written program available at the construction site. This costly citation can be easily avoided by following the directions in this book. See Fig. 8.1.

10. 1926.20(b)(1), General safety and health. Accident prevention responsibilities. It is the responsibility of the activity subcontractor to initiate and maintain programs necessary to comply with the requirements of part 1926.

11. 1926.405(a)(2), Wiring methods. Temporary wiring. Temporary electric power and lighting wiring methods may be of a class less than would be required for a permanent installation. Except as specifically modified in paragraph 1926.405(a)(2), all wiring must meet the requirements for permanent wiring. Temporary wiring must be removed upon completion of construction or the purpose for which the wiring was installed.

12. 1926.404(f)(6), Wiring design and protection. Grounding. The path to ground from circuits, equipment, and enclosures must be permanent and continuous.

13. 1926.503(a)(1), Fall protection training program. The subcontractor must provide a training program for each worker who might be exposed to fall hazards. The program must enable each worker to recognize the hazards of falling and must train each worker in the procedures to follow in order to minimize these hazards.

Your Company Name Here

Safety Selections for Our Construction Company

This Safety Selection can be used to conduct periodic safety meetings at our construction sites. The material can be used by the jobsite supervisor for the safety discussion.

Hazard Communication

The Hazard Communication Standard requires your employer to inform you of the hazards of the chemicals at your worksite. The rule is designed for your protection. Knowing about its provisions and applying them in your daily work goes a long way in a cooperative effort between you and your boss.

Elements of the Hazardous Communication Standard

The items required by the Haz-Com Standard include:

- Determining what is a hazard on your typical jobsite
- Health hazards
- Physical hazards
- Common types of hazardous chemicals
- Container labels
- Material safety data sheets (MSDS)
- Personal protective equipment (PPE)
- Safe work practices
- Storage considerations
- First aid
- Clean-up and disposal of hazardous waste

Each of the sections covers important information in one topic area, providing employees with general knowledge about working safely with potential hazards. Upon completion of the Haz-Com training session, employees should have an increased awareness about the Hazard Communication Standard and the nature of hazards encountered in your company's typical business operations.

FIGURE 8.1 Haz-Com.

14. 1926.1053(b)(1), Ladder use. When portable ladders are used for access to an upper landing surface, the ladder siderails must extend at least 3 ft above the upper landing surface to which the ladder is used to gain access. If this is not possible because of the ladder's length, the ladder must be secured at the top to a rigid support and a grasping device, such as a grab rail, must be provided to assist in mounting and dismounting.

15. 1926.651(k)(1), Excavations. General requirements: Inspections. A competent person must inspect excavations, areas adjacent to excavations, and protective systems on a daily basis when worker exposure can reasonably be anticipated. The inspection must take place prior to the start of work, as needed throughout the shift, and after every rainstorm or other hazard-increasing occurrence. The person inspecting the area must look for evidence of a situation that could result in a possible cave-in, indications of failure of the protective shoring system, any possible hazardous atmospheres, or other hazardous conditions.

16. 1926.1052(c)(1), Stairways. Stair rails and handrails. A stairway having four or more stairs or rising more than 30 in., whichever is less, must be equipped with at least one handrail and one stair rail system along each unprotected side or edge.

17. 1926.451(a)(4), Scaffolding. General requirements. Guardrails and toeboards must be installed on all open sides and ends of platforms more than 10 ft above the ground or floor. Needle beam scaffolds and floats are the exception and are covered in paragraphs (p) and (w) of OSHA section 926.451. Scaffolds 4 ft to 10 ft in height, having a minimum horizontal dimension in either direction of less than 45 in., must have standard guardrails installed on all open sides and ends of the platform.

18. 1926.501(b)(4), Fall protection. Holes. Each worker on walking or working surfaces must be protected from falling through holes (including skylights) more than 6 ft above lower levels by personal fall arrest systems, covers, or guardrail systems erected around such holes, tripping in or stepping into or through holes (including skylights) by covers, or objects falling through holes (including skylights) by covers.

19. 1926.651(c)(2), Excavations. General requirements. Access and egress. A stairway, ladder, ramp, or other safe means of egress must be located in trench excavations that are 4 ft or more in depth so as to require no more than 25 ft of lateral travel for workers. (This was changed from the old regulation of 1 ladder every 50 ft and the depth of the trench has been shallowed from 5 ft to 4 ft.) Be advised, this regulation holds for residential utility and sewer taps as well.

20. 1926.25(a), Housekeeping. All debris and all form and scrap lumber with protruding nails must be kept cleared from work areas,

passageways, and stairs in and around buildings or other structures during the course of construction.

21. 1926.651(j)(2), Excavations. Protection of workers from loose rock and soil. Workers must be protected from excavated or other materials or equipment that could pose a hazard by falling or rolling into excavations. Protection must be provided by placing and keeping materials or equipment at least two feet from the edge of excavations, by using retaining devices that are sufficient to prevent materials or equipment from falling or rolling into excavations, or by a combination of both if necessary.

22. 1926.405(g)(2), Electrical. Identification, splices, and terminations. A conductor of a flexible cord or cable that is used as a grounded conductor or an equipment grounding conductor must be distinguished from other conductors. Related regulations are

Marking. Type SJ, SJO, SJT, SJTO, S, SO, ST, and STO cords must not be used unless durably marked on the surface with the type designation, size, and number of conductors.

Splices. Flexible cords must be used only in continuous lengths without splice or tap. Hard service flexible cords form 12 or larger may be repaired if spliced so that the splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.

Strain relief. Flexible cords must be connected to devices and fittings so that strain relief is provided that will prevent pull from being directly transmitted to joints or terminal screws.

Cords passing through holes. Flexible cords and cables must be protected by bushings or fittings where passing through holes in covers, outlet boxes, or similar enclosures.

23. 1926.501(b)(10), Roofing work on low-slope roofs. Except as otherwise provided in OSHA Section 1926.501(b), each worker engaged in roofing activities on low-slope roofs, with unprotected sides and edges 6 ft or more above lower levels, must be protected from falling by guardrail, safety net, or personal fall arrest systems, or a combination of warning line and guardrail systems, warning line and safety net systems, warning line and personal fall arrest systems, or warning line and safety monitoring systems. On roofs 50 ft or less in width the use of a safety monitoring system alone (i.e., without the warning line system) is permitted.

24. 1926.501(b)(13), Construction fall protection. Each worker engaged in construction activities 6 ft or more above lower levels must be protected by guardrail, safety net, or personal fall arrest systems unless another provision as listed in OSHA Section 1926.501(b) provides for an alternative fall protection measure. **Exception**: When the subcontractor can demonstrate that it is infeasible or creates a greater hazard to use these

systems, the subcontractor must develop and implement a fall protection plan that meets the requirements of OSHA Section 1926.502(k), Fall protection plan. *Note*: There is a presumption that it is feasible and will not create a greater hazard to implement at least one of the above-listed fall protection systems. Accordingly, the subcontractor has the burden of establishing that it is appropriate to implement a fall protection plan that complies with all the regulations of OSHA Section 1926.502(k) for a particular workplace situation, in lieu of implementing those systems.

25. 1926.59(h), Right-to-Know program. Worker information and training. Subcontractors must provide workers with information and training on hazardous chemicals in their work area at the time of their initial work

Your Company Name Here

Safety Selections for Our Construction Company

This Safety Selection can be used to conduct periodic safety meetings at our construction sites. The material can be used by the jobsite supervisor for the safety discussion.

Hazard Communication—Worker Right to Know

The Hazard Communication Standard requires your employer to inform you of the hazards of the chemicals at your worksite. The rule is designed for your protection. Knowing about its provisions and applying them in your daily work goes a long way in a cooperative effort between you and your boss.

Elements of the Right-to-Know Standard

The items required by the Right-to-Know Standard include:

- A hazard assessment. This identifies the specific chemicals you work with.
- A written program. Your company is required to have a written hazard communication program.
- Labels. These are needed on items to warn, caution, and inform you about any dangers or risks.
- Material safety data sheets. These provide thorough, accurate information on each hazardous chemical in your work.
- Employee training. This is required at the time of your initial employment or assignment as well as whenever a new hazard is introduced into your workplace.

FIGURE 8.2 Right-to-Know.

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assignment and whenever a new hazard is introduced into their work area (see Fig. 8.2).

CONSTRUCTION SAFETY ORDERS

OSHA has laws grouped in safety orders that obligate the activity subcontractor to develop and maintain written programs on specific subjects. These programs are all generally tied into required training and reporting programs. Not all these standards are relevant to all activity subcontractors. The most common types of these required training programs relevant to both prime and subcontractors are as follows:

Emergency action plans
Fire prevention plans
Hazard communication
Safety-related work practices
Emergency response
Lockout and tag out of defective equipment
Hazardous-waste operations and disposal
Permit-required confined spaces

Project construction safety orders are listed here by OSHA article number:

1. Introduction
2. Definitions
3. General Requirements
4. Dust, Fumes, Mists, Vapors, Gases
5. Rock Drilling
6. Excavations
7. Bins, Bunkers, Material Storage
8. Explosives
9. Derricks, Cranes, Excavators
10. Haulage and Earth Moving
11. Vehicles, Traffic Control, Flaggers, Barricades, and Warning Signs
12. Pile Driving
13. Work Over Water
14. Construction Hoists
15. Hoisting Apparatus
16. Standard Railings
17. Ramps, Runways, Stairwells, and Stairs
18. Access and Egress
19. Floor and Roof Openings
20. Temporary Floors

21. Scaffolds: General
22. Scaffolds: Various
23. Suspended Scaffolds
24. Safety Belts and Nets
25. Ladders
26. Saws: Power
27. Powder-actuated Tools
28. Construction Equipment
29. Roofing Operations
30. Demolition
31. Oxygen, Acetylene Gas
32. Electrical Requirements
33. Non-Ionizing Radiation
34. Fire Protection

OSHA Standard 1502 establishes minimum safety standards whenever employment exists in connection with the construction, alteration, painting, repairing, construction maintenance, renovation, removal, or wrecking of any fixed structure or its parts. These laws also apply to all excavations not covered by other safety orders for a specific industry or operation. On construction projects, these standards take precedence over any other general orders that are inconsistent with them, except for *Tunnel Safety Orders* or *Compressed Air Safety Orders*. Machines, equipment, processes, and operations not specifically covered by these standards are determined to be governed by other applicable general safety orders.

For certain high-hazard activities including construction of trenches or excavations that are 5 ft or deeper, and into which a person is required to descend, and the construction or demolition of any scaffolding, falsework, building, or structure more than three stories high, permits must first be obtained from OSHA before a local building department will issue a construction permit.

Standard 1509 is the Injury and Illness Prevention Program, which mandates that every subcontractor establish, implement, and maintain an effective Injury and Illness Prevention Program in accordance with Section 3203 of the General Industry Safety Orders. Further, every subcontractor must adopt a written Code of Safe Practices that relates to the subcontractor's operations, and it must be posted at a visible, conspicuous location at each job-site office or be provided to each supervisory worker who must have it readily available.

Periodic meetings of supervisory members of the project team must be held under the direction of management for the discussion of safety problems and accidents that have occurred. Activity subcontractors must conduct tailgate safety meetings (or equivalent) with their crews at least every 10 working days to emphasize safety. Daily, before workers begin to work, the subcontractor must make a thorough survey of the conditions of the job site to determine, so far as practicable, the predictable hazards to workers and the kind and extent of safeguards necessary to execute the work in a safe manner.

There is a subtle but important difference between required programs and performance standards. This differentiation is rarely known or made use of by activity subcontractors. The requirement to assess the need for personal protective equipment is a good example, as is the requirement to properly train workers. The subcontractor is required to have a certification of the assessment and training. However, strange as it may seem, the subcontractor is not required to show OSHA the actual assessment or training programs. This may seem insignificant, but it can have a legal impact in defending against citations. And regarding personal protective equipment, activity subcontractors are definitely mandated to the personal protection performance standards as well as the hazard communication standard. Additional performance standards exist concerning hearing conservation, respiratory protection, and other hazardous-substances operations such as lead and asbestos removal. We will look at each of these standards in depth, beginning with (as OSHA does) personal protective equipment.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Anywhere in the project's workplace where OSHA mandates the wearing of PPE, subcontractors have the obligation to ensure that their workers wear it at all times when operations are underway. When workers furnish their own PPE, the subcontractor is responsible to ensure its adequacy and that the equipment is properly maintained and in a sanitary condition. All PPE must be of safe design and construction for the work to be performed.

One of the most common citations issued to project teams and activity subcontractors is a worker not wearing PPE. Carpenters are notorious for hating hardhats and safety glasses. They'll put the equipment on while the boss or visitors are on-site, but ditch the gear as soon as they are alone again. Their preference for sports or tennis shoes over steel-toe work boots is another area of citations being generated by OSHA. The subcontractor is not within compliance by simply mandating that workers wear PPE and making it available to them. OSHA stipulates that subcontractors have the obligation to ensure it is used at all times during operations. OSHA has interpreted its general PPE standard to require that subcontractors provide and pay for the equipment needed by workers to carry out the routine and special tasks relative to the business operations.

The largest majority of PPE violations cited by OSHA relative to builders and contractors concern the eyes and face (impact-resistant safety glasses and full face shields), the ears (hearing protection and earplugs), respiratory protection and dust masks, the feet (nail punctures and crushed toes from lack of wearing metatarsal work boots equipped with steel shanks and steel toes), the hands (gloves adequate for the required task), and the head (approved hardhats with suspension liners). It is important to remember that required worker training includes not only general wearing instructions but also how to adjust equipment, parameters of the equipment's limitations; proper storage, care and maintenance; and useful life.

The use of dust masks and respirators can be a bigger problem than most contractors realize. OSHA requires a comprehensive written respiratory program, including fit tests, even if only one worker wears a cartridge respirator. OSHA will issue a citation if any of the following occur:

A worker has facial hair that can impede the effectiveness of the unit.
A worker is granted a specific medical clearance without a specifically related unit.
A worker is being exposed over the permissible exposure limit (PEL) for the unit.
A worker is above the action level for those PELs.

Personal protective equipment must be kept clean and in good repair. Safety devices, including protective clothing worn by the worker, must not be interchanged among the workers until properly cleaned. The exception here are safety devices worn over skin or outer clothing, no part of which contacts the skin of the wearer, such as metal foot guards. Where workers are engaged in the application of paints or coatings or in other operations involving substances that may be harmful to the workers, cleansing facilities must be provided in proximity of the work site and must be so equipped as to enable workers to remove such substances from themselves. Depending on the problem, these facilities may be in the form of ordinary soap and water or in the form of special compounds designed specifically for the removal of the harmful material from skin surfaces.

The subcontractor must mandate that his or her workers use the required PPE. Personal protective equipment required by this section must be approved and distinctly marked so as to facilitate identification. Personal protective equipment must be used in strict accordance with the manufacturer's instructions. The subcontractor must assure that worker-owned PPE complies with these regulations and that this equipment is maintained in a safe, sanitary condition. Protectors must be of such design, fit, and durability as to provide adequate protection against the hazards for which they are designed and must be reasonably comfortable and not unduly encumber the worker's movement.

FALL PROTECTION

Working at heights off the ground exposes the project workers to severe risks every moment. So OSHA requires harnesses, lanyards, lifelines, and waist belts for many conditions in elevated work areas. A full-body harness combined with a lanyard or lifeline is the best choice for fall protection. In the event of a fall, it evenly distributes the fall-arresting forces among the worker's shoulders, legs, and buttocks, reducing the chance of internal injuries. Made from lightweight nylon webbing and forged steel hardware, it is designed without a tight waist belt so workers have a full range of motion while climbing and working.

Whether nylon or polyester harnesses and ropes are best depends on your job application. Both nylon and polyester are high-strength, flexible, and abrasion-resistant fibers. Nylon is lighter than polyester, more weather-resistant, and the best all-around choice for most construction applications. But, when it comes to chemical resistance, polyester may be the best choice. It resists most mineral acids, chemicals, bleaching, and other oxidizing agents.

Shock-absorbing lanyards are preferred over traditional lifelines as safety connectors for harnesses. Specially treated lanyards have a built-in shock-absorbing system to greatly reduce fall-arresting forces like a bungee cord, lowering them to less than 900 pounds. OSHA lanyard force comparison testing using a 130-lb test weight showed polyester webbing exerted 2410 lb in fall arrest, 9/16 in. spun nylon rope exerted 1730 lb in fall arrest, and shock-absorbing lanyards exerted 900 lb in fall arrest. (*Caution*! Lanyards must be taken out of service after being subject to a fall arrest, per OSHA 29 CFR 1910.66 regulations. They cannot be reused even if they appear undamaged.)

Waist belts should be used for lateral positioning only. They are not recommended for fall protection, because if a worker falls wearing a waist belt, all the fall-arresting forces are centered on the abdomen. This greatly increases the chance of damage to internal organs. Even more serious is the fact that workers have actually slipped out of a waist belt while awaiting rescue, resulting in serious injury or death. As a further note, OSHA 29 CFR 1926.502 (d) states that effective January 1, 1998, body belts are not acceptable as part of a personal fall arrest system.

Lifelines, safety belts, and lanyards must be used only for worker safeguarding. Any lifeline, safety belt, or lanyard actually subjected to in-service loading must be immediately removed from service and not be used again for worker safeguarding. Lifelines must be secured above the point of operation to an anchorage or structural member capable of supporting a minimum dead weight of 5400 pounds.

Safety nets must be provided when workplaces are more than 25 ft above the surface where the use of ladders, scaffolds, catch platforms, temporary floors, safety lines, or safety belts is impractical. Where nets are required, operations must not be undertaken until the net is in place and has been tested. Nets must extend 8 ft beyond the edge of the work surface where workers are exposed and must be installed as close as possible under the work surface, but no more than 25 ft below the work surface. The mesh area of safety nets must not exceed 6 in. by 6 in.

Workers working over or near water, where the danger of drowning exists, must be provided with Coast Guard-approved life jackets or buoyant work vests. Ring buoys with at least 90 ft of line must be provided and readily available. The distance between ring buoys must not exceed 200 ft. At least one lifesaving skiff must be immediately available where workers are working over or near water.

RESPIRATORS

Respirators are a diversified and complex matter for subcontractors. OSHA concerns are proper match (unit to PEL); proper use, sanitation, and storage; proper types of cartridge filters; compatible parts of the unit; medical suitability; and comprehensive training in usage. In addition, respirators should not be shared among other workers as there is a definite risk of respiratory disease transmission.

Workers required to use respiratory protective equipment approved for use in atmospheres dangerous to health must be thoroughly trained in its use. Workers required to use other types of respiratory protective equipment must be instructed in the use and limitations of such equipment. The worker must use the provided respiratory protection in accordance with instructions and training received. The correct respirator must be specified for each job. A qualified individual supervising the respiratory protective program usually specifies the respirator type in the work procedures. The individual issuing them must be adequately instructed to ensure that the correct respirator is issued. Written procedures must be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies. Personnel must be familiar with these procedures and the available respirators.

Respiratory protection is no better than the respirator in use, even though it is worn conscientiously. A qualified individual to assure that respirators are properly selected, used, cleaned, and maintained must conduct frequent random inspections. For safe use of any respirator, it is essential that the user be properly instructed in its selection, use, and maintenance. Both supervisors and workers must be so instructed by competent persons. Training must provide the workers an opportunity to handle the respirator, have it fitted properly, test its face-piece-to-face seal, wear it in normal air for a long familiarity period, and, finally, wear it in a test atmosphere.

Respirators must not be worn when conditions prevent a good face seal. Such conditions may be a growth of beard, sideburns, a skull cap that projects under the face piece, or temple pieces on glasses. Also, the absence of one or both dentures can seriously affect the fit of a face piece. The worker's diligence in observing these factors must be evaluated by periodic check. To assure proper protection, the face-piece fit must be checked by the wearer each time he or she puts on the respirator. Following the manufacturer's face-piece fitting instructions may do this.

Where these OSHA regulations require monitoring of airborne contaminants "as often as necessary," the competent person must make a reasonable determination as to which substances to monitor and how frequently to monitor. The following should be taken into consideration: location of the job site; geology of the job site; presence of air contaminants in nearby job sites and changes in levels of substances monitored on prior shifts; and work practices and job-site conditions including use of diesel engines, explosives, fuel gas, volume and flow of ventilation, visible atmospheric conditions, decompression of the atmosphere, welding, cutting, hot work, and workers' physical reactions to working conditions.

The responsible activity subcontractor must establish and maintain a respiratory protective program. The program, at a minimum, must contain 11 designated elements and must be regularly evaluated to determine its continued effectiveness. In emergencies, or when feasible engineering or administrative controls are not effective in controlling toxic substances, appropriate respiratory protective equipment must be provided by the subcontractor and must be used. Respiratory protective devices must be approved by the Mine Safety and Health Administration/National Institute for Occupational Safety and Health or be acceptable to the U.S. Department of Labor for the specific contaminant to which the worker is exposed. Respiratory protective devices must be appropriate for the hazardous material involved and the extent and nature of the work requirements and conditions. Written procedures must be prepared covering selection, safe use, and care of respirators in dangerous atmospheres encountered in normal operations and emergencies.

Both the forepersons and the workers must be properly instructed in the selection, use, and maintenance of respirators. Respirators must be regularly cleaned and disinfected and inspected during cleaning. Deteriorating parts must be replaced. Respirators for emergency use must be inspected at least once a month and after each use. When not in use, respirators must be stored in a convenient, clean, and sanitary location. Surveillance of work area conditions and the degree of worker exposure or stress must be maintained. Persons must not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment.

Breathing protection respirators are grouped into two divisions: air-purifying respirators (particulate masks, cartridge-style respirators, gas masks, and powered air protection respirators) and supplied-air respirators [self-contained breathing apparatus (SCBA), airline systems, and emergency escape breathing apparatus (EEBA)]. Choosing the right respirator for the specific application needs is a three-step process:

1. **Identify the contaminant**. Always consult the MSDS on file for each chemical used in your work processes. This will give you a good starting point for dealing with the hazards the workers face. The physical form of the chemical will help you determine the type of respiratory protection that is required.

Dusts are tiny, suspended particles resulting from a mechanical process such as grinding. Depending on the material, an air-purifying respirator (a particulate mask or a cartridge-style face piece with filters) may provide adequate protection.

A *mist* is an aerosol composed of liquid particles. To meet minimum protection requirements, an air-purifying respirator having a filter specifically designed for use with mists is mandated.

Fumes are even smaller particles formed by a condensing gas or vapor (as in welding). At a minimum, use a filter specific to fume protection.

A *vapor* is the gaseous form of a liquid or solid material. Depending on the chemical, an air-purifying respirator with hazard-specific chemical cartridges may provide adequate protection.

2. **Determine the concentration level**. OSHA has established a PEL for many contaminants in your workplace. The PEL is the maximum permitted 8-hour time-weighted average concentration of an airborne contaminant. The maximum permitted time-weighted average exposures to be utilized are those published in OSHA 29 CFR 1910.1000. Any worker exposed to a concentration level higher than the PEL for that substance must take precautionary measures, including respiratory protection. Modern sensitive monitoring instruments will give you a precise reading of the concentration level. This determines which type of respirator to use. For example, if the

concentration level is above the immediately dangerous to life or health (IDLH) level, you have only two options: an SCBA or a pressure-demand airline system equipped with an escape bottle.

3. **Evaluate the conditions of exposure**. Any number of variables can affect the choice of protection. Always keep these factors in mind: *The nature of the task*. How long will the worker be exposed to each hazard? Is the work strenuous, requiring a higher level of oxygen? *The characteristics of the work area*. Is the area well ventilated? Is it a confined space? Will air temperatures be hot or cold? Could mixings of hazards occur? *The work process itself*. The way chemicals are combined, treated, or applied will often result in new hazards. For example, when using an air-purifying respirator for a spraying operation, you'll probably need both a filter for the mists and a cartridge for the vapors.

Air-purifying and airline respirators are not designed to be used in conditions that are immediately dangerous to life or health. Failure by the user to properly select the appropriate respirator for all the materials and concentrations to which the respirator wearer may be exposed may result in serious illness, disability, or death. The respirator must fit the wearer properly. Fitting directions, fit tests, and fit checks in the manufacturer's instructions accompany each respirator to ensure proper fit and operation. Save these directions in your MSDS file. Tight-fitting respirators should not be used by individuals with beards or other facial hair that passes between the sealing flange of the respirator's face piece and the wearer's face. Facial hair may cause leakage or interfere with the proper operation of the respirator exhalation valve, thereby exposing the wearer to hazardous contaminants. If the worker is exposed to two or more contaminants for which different air-purifying elements are recommended (e.g., ammonia and benzene) and a combination element is not available, then a supplied-air respirator should be used.

Some toxic contaminants are readily absorbed through the skin. In these cases, appropriate gloves and/or protective clothing may be required to protect other areas of the body. Air-purifying respirators should not be used for sandblasting or for gas or vapor contaminants with poor warning properties. Any air-purifying respirator, when properly selected and fitted, will always significantly reduce, but not completely eliminate, airborne contaminants. The wearer, when working in atmospheres containing substances that are reputed to cause cancer in amounts below their PEL, will obtain better protection from a continuous-flow or positive-pressure air-supplied respirator. Always check the MSDS for substance PEL and other information before mixing and working with chemicals. When in doubt, call the manufacturer or OSHA for any needed information. A phone call is far better than a funeral.

HAZARD COMMUNICATION

OSHA law requires all activity subcontractors to maintain an ongoing safety and hazard communication program. I'll give it to you in their own words, from an excerpt from section 29 CFR 1910.1200, Hazard Communication:

> The purpose of this section is to ensure that the hazards of all chemicals produced or imported are evaluated, and that information concerning their hazards is transmitted to both contractors and workers. This transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, material safety data sheets (MSDS) and worker training.

The communication begins with understanding the hazard warning label that must be on both shipped and on-site containers and is intended to convey specific information regarding the hazard. Many labels at the time the Hazard Communication Standard (HCS) was finalized included only precautionary statements. Phrases such as "caution," "danger," or "harmful if inhaled" generally do not meet the intent of the law by themselves. If, when inhaled, the chemical causes lung damage, then that is the appropriate warning. Lung damage is the hazard, not inhalation. When it is known, the specific target organ effect should be part of the hazard warning. If the substance attacks the lungs, or the skin, or the brain, it must be indicated. There are some situations where the specific target organ effect is not known. Where this is the case, OSHA would permit the more general warning statement. A warning of carcinogenicity (cancer causation by contact) is required under certain circumstances. In general, those chemicals identified as being known to be carcinogenic and those that may reasonably be anticipated to be carcinogenic by the National Toxicology Program must have carcinogen warnings on the label.

The Hazard Communication Standard is OSHA's most frequently cited standard for activity subcontractors. Thoroughness in this communication of job operations hazards to workers is mandated and cannot be dealt with in an apathetic or haphazard manner. However, the number one reason for noncompliance is still lack of knowledge. According to OSHA, the three areas most often cited for noncompliance are: records, documents, notices, and warnings; written compliance programs; and training and worker qualifications.

The subcontractor must communicate information concerning hazards according to the requirements of OSHA's Hazard Communication Standard for the construction industry, 29 CFR 1926.59, including but not

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limited to the requirements concerning warning signs and labels, MSDS, and worker information and training. In addition, subcontractors must comply with the following requirements: The subcontractor must provide a training program and assure worker participation. The subcontractor must provide the training program as initial training prior to the time of job assignment or prior to the start-up date for this requirement, whichever comes last. The subcontractor must also provide the training program at least annually for each worker who is subject to lead exposure at or above the action level on any day.

Concerning gases, vapors, fumes, dusts, and mists, the subcontractor must assure that each worker is trained in the following: the contents of OSHA-related standards and the specific nature of the operations that could result in exposure to PEL amounts; the purpose, proper selection, fitting, use, and limitations of respirators; the purpose and a description of the medical surveillance program; and the medical removal protection program including information concerning the adverse health effects associated with excessive exposure to lead (with particular attention to the adverse reproductive effects on both males and females and hazards to fetuses and additional precautions for workers who are pregnant).

All workers working on-site (such as but not limited to equipment operators and general laborers) who are exposed to hazardous substances, health hazards, or safety hazards and their supervisors and project management team responsible for the site development must receive training meeting the requirements of paragraph 1926.59 before they are permitted to engage in hazardous-waste operations. They must receive review training at least annually. Workers must not be permitted to participate in or supervise field activities until they have been trained to a level required by their job function and responsibility.

Subcontractors must provide workers with effective information and training on hazardous chemicals in their work area at the time of their initial assignment and whenever a new physical or health hazard the workers have not previously been trained in is introduced into their work area. Worker training must include at least the following: methods and observations that may be used to detect the presence or release of a hazardous chemical in the work area (such as monitoring conducted by the subcontractor, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released) the physical and health hazards of the chemicals in the work area; and the measures workers can take to protect themselves from these hazards, including appropriate work practices, emergency procedures, and PPE to be used.

The details of the hazard communication program developed by the subcontractor, including an explanation of the labeling system and the

MSDS, and how workers can obtain and use the appropriate hazard information must be documented and available for general inspection. The subcontractor must provide workers with information and training, in accordance with 29 CFR 1910.1200(h), at the time of initial assignment and at least annually thereafter. In addition to the information required under 29 CFR 1910.1200, the subcontractor must provide access to training materials. The subcontractor must make readily available to all affected workers, without cost, all written materials relating to the worker training program, including a copy of this regulation.

Communication among subcontractors on multicontractor work sites is mandatory. Any subcontractor performing work involving the application of MSDSs or materials containing MSDSs for which establishment of one or more regulated areas is required must inform the other subcontractors on the job site of the nature of the work, MSDSs, and requirements pertaining to any regulated areas. The subcontractor must provide to OSHA, upon request, all information and training materials relating to the worker information and training program.

Hazardous communication (Haz-Com) training must contain the following minimum elements: names of personnel and alternates responsible for site safety and health; safety, health, and other hazards present on the site; use of personal protective equipment; work practices by which the worker can minimize risks from hazards; safe use of engineering controls and equipment on the site; medical surveillance requirements, including recognition of symptoms and signs that might indicate overexposure to hazards and the contents of OSHA's Right-to-Know paragraphs relative to that exposure.

General site workers such as equipment operators, general laborers, and supervisory personnel engaged in hazardous-substance removal or other activities that expose or potentially expose workers to hazardous substances and health hazards must receive a minimum of 40 hours of instruction off-site and a minimum of 3 days in actual field experience under the direct supervision of a trained, experienced supervisor. Workers who are on site only occasionally for a specific limited task (such as, but not limited to, groundwater monitoring, land surveying, or geophysical surveying) and who are unlikely to be exposed over permissible exposure limits and published exposure limits must receive a minimum of 24 hours of instruction off the site, and a minimum of one day's actual field experience under the direct supervision of a trained, experienced supervisor.

Workers who are regularly on site and who work in areas that have been monitored and fully characterized indicating that exposures are under permissible and published exposure limits where respirators are not necessary, and the characterization indicates that there are no health hazards or the possibility of an emergency developing, must receive a minimum of 24 hours of instruction off-site and a minimum of 1 day of actual field experience under the direct supervision of a trained, experienced supervisor. Workers with 24 hours of training who become general site workers or who are required to wear respirators, must have the additional 16 hours and 2 days of training necessary to total the training specified in OSHA regulations.

On-site management and subcontractors directly responsible for, or who supervise workers engaged in, hazardous-waste operations must receive 40 hours of initial training, 3 days of supervised field experience, and at least 8 additional hours of specialized training at the time of job assignment on such topics as, but not limited to, the subcontractor's safety and health program and the associated worker training program, personal protective equipment program, spill-containment program, and health hazard monitoring procedures and techniques.

TRAINER QUALIFICATIONS

Hazard communication session trainers must be qualified to instruct workers about the subject matter that is being presented in training. Such trainers must have satisfactorily completed a training program for teaching the required

Your Company Name Here

Safety Selections for Our Construction Company

This Safety Selection can be used to conduct periodic safety meetings at our construction sites. The material can be used by the jobsite supervisor for the safety discussion.

OSHA Fact Plate B-1

To find –

(a) The circumference of a circle, multiply the diameter by 3.1416 (approx. $3\,^{1}/_{7}$).
(b) The diameter of a circle, multiply the circumference by 0.31831.
(c) The area of a circle, multiply the square of the diameter by 0.7854.
(d) The area of a triangle, multiply the base by one half the perpendicular height.
(e) The volume of a sphere, multiply the cube of the diameter by 0. 5236.

A gallon of water weighs 8 ½ lb.
A gallon of water contains 231 cu in,
A cubic foot of water contains 7 ½ gals., 1728 cu in, and weighs 62 ½ lb.

In board measure, all boards are assumed to be 1 in thick. The area of a lineal foot multiplied by length in feet will give the surface contents in square feet.

FIGURE 8.3 Fact training plate.

subjects, or they must have appropriate academic credentials and instructional experience and demonstrate competent instructional skills and knowledge of the applicable subject matter. Training certification is required.

Workers and supervisors that have received and successfully completed the training and field experience must be certified by their instructor or the head instructor and trained supervisor as having successfully completed the necessary training. A written certificate must be given to each person so certified. Any person who has not been so certified or who does not meet the requirements of this section must be prohibited from engaging in hazardous operations. Trainers must also provide fact plates to attendees, as shown in Fig. 8.3.

EMERGENCY RESPONSE PLAN

Sometimes our human instincts, our need to help others in trouble, keep us from thinking of our own safety and put us in harm's way. OSHA has taken plenty of heat after an inspector cited an Iowa contractor because his workers made rescue efforts in which they ended up getting hurt. The good Samaritans did not stop to don the proper protective equipment before making the rescue efforts. This incident caused OSHA to rethink its position and issue an interpretive rule addressing the agency's citation policy regarding rescue attempt in life-threatening danger. OSHA is aware of many instances in which workers have voluntarily rescued coworkers or rendered emergency assistance in the aftermath of workplace accidents, sometimes at considerable risk to themselves.

Until recently, there have been no written instructions to OSHA inspectors providing guidance in such situations. It is not OSHA's policy to interfere with or to regulate every decision by workers to place themselves at risk to save other individuals, nor is it OSHA's policy to issue citations to subcontractors whose workers voluntarily undertake acts of heroism to save a coworker from imminent harm. This policy would not include situations where rescue operations are a part of the worker's job responsibilities and the likelihood that a rescue may become necessary is reasonably foreseeable.

Activity subcontractors who have workers working in situations where the possibility of life-threatening accidents is reasonably foreseeable are required by various OSHA standards and the general duty clause to take appropriate "before work" precautions to assure that the rescuers themselves do not become victims. Possible accidents requiring rescue efforts are reasonably foreseeable in many work situations such as

Trenches and excavations
Hazardous-waste operations
Emergency response work

Construction work over water
Confined spaces

An emergency response plan is required for all potential emergencies involving hazardous substances. Training is required for all workers who respond to any emergencies involving hazardous substances on your job site. Training must cover the necessary information to perform these jobs safely including information on the proper personal protective equipment and procedures to safeguard workers against hazards and effects of exposure to toxic substances. A safety and health program that delineates responsibilities and methods for assuring worker safety is necessary for workers engaged in any hazardous-waste cleanup. Personal protective equipment must be selected and used to protect workers from hazardous substances and physical hazards. When necessary, a decontamination procedure must be used to assure that hazardous substances are removed from workers before they leave the worksite, as well as from equipment that is to be taken off-site.

Note: On August 22, 1994, OSHA added Appendix E to the HAZWOPER regulations. The nonmandatory Training Curriculum Guidelines may be used for assistance in developing site-specific training curriculum used to meet the training requirements of 29 CFR 1926.65(e); 29 CFR 1926.65(p)(7), (p)(8); and 29 CFR 1926.65(q)(6), (q)(7), and (q)(8). They are generic guidelines and are not intended to be a complete training curriculum for any specific subcontractor. Site-specific training programs must be developed on the basis of a needs assessment of the particular job site or emergency response operation in accordance with 29 CFR 1926.65. Workers who are engaged in responding to emergency situations at hazardous-waste cleanup sites that may expose them to hazardous substances must be trained in how to respond to such expected emergencies.

Training for emergency response workers must be completed before they are called upon to perform in real emergencies. Such training must include the elements of the emergency response plan, standard operating procedures the subcontractor has established for the job, the personal protective equipment to be worn, and procedures for handling emergency incidents. There are two exceptions:

1. A subcontractor need not train all workers to the degree specified if the subcontractor divides the workforce in a manner such that a sufficient number of workers who have responsibility to control emergencies have the training specified and all other workers, who may first respond to an emergency incident, have sufficient awareness training to recognize that an emergency response situation exists and are instructed in that case to summon the fully trained workers and not attempt control activities for which they are not trained.

2. A subcontractor need not train all workers to the degree specified if arrangements have been made in advance for an outside fully trained emergency response team to respond in a reasonable period and all workers, who may come to the incident first, have sufficient awareness training to recognize that an emergency response situation exists and have been instructed to call the designated outside response team for assistance.

Workers, managers, and supervisors must receive 8 hours of refresher training annually on any critique of incidents that have occurred in the past year that can serve as training examples of related work and other relevant topics. Subcontractors who can show by documentation or certification that an worker's work experience and/or training has resulted in equivalent training to OSHA's satisfaction are not required to provide the initial training requirements of those paragraphs to such workers. However, certified workers new to a site must receive appropriate, site-specific training before site entry and have appropriate supervised field experience at the new site. Equivalent training includes any academic training or the training that existing workers might have already received from actual hazardous-waste site work experience.

GUARDING OF ELECTRICAL PARTS

OSHA Section 1518 provides regulations covering protection from electric shock. Suitable protective equipment or devices must be provided and used on or near energized equipment for the protection of workers where there is a recognized hazard of electric shock or burns. When protective insulating equipment is used, it must comply with OSHA's Electrical Safety Orders. In lieu of other protective equipment, barricades may be used to provide protection from exposed energized equipment. OSHA requires those live parts of electrical equipment operating at 50 V or more are guarded against accidental contact by approved enclosures or by any of the following methods:

Location in a room, vault, or similar enclosure accessible only to qualified persons

Substantial permanent partitions or screens so constructed as to minimize accidental contact with the live parts and be accessible only to qualified persons

Elevation of 8 ft (2.44 m) or more above the floor or working surface

This section provides for the protection of electrical equipment exposed to physical damage and for the placing of conspicuous warning signs forbidding unqualified individuals from entering rooms or other guarded locations on the job site containing live parts. OSHA also provides regulations for ground-fault protection for workers working with live circuits. The specific and very important provisions are as follows for dwelling units:

1. All 125-V, single-phase, 15- and 20-ampere (A) receptacles installed in all bathrooms must have ground-fault circuit interrupter (GFCI) protection.
2. All 125-V, single-phase, 15- and 20-A receptacles installed in garages must have GFCI protection.
3. All 125-V, single-phase, 15- and 20-A receptacles installed outdoors where there is direct grade-level access to the dwelling unit and to the receptacles must have GFCI protection.

For all construction sites, the provision for temporary wiring on a job site is mandated as follows: All 125-V, single-phase, 15- and 20-A receptacle outlets that are not a part of the permanent wiring of the building or structure, and that are in use by workers, must have GFCI protection for personnel. Ground-fault circuit interrupters are defined in article 100 of the OSH Act.

People are, of course, the most important safety consideration. The major thrust in safe practice should therefore be toward the preservation of worker life and limb. But equipment and property are also important, primarily because they represent your business investment. Equipment damage due to faulty workmanship is extremely costly in both repair and production downtime. Indirectly also, improper installation procedures can cause injury by starting electrical fires. Ground-fault circuit interrupters are an important safeguard against human and equipment damage. Section 230-95 of the OSH Act addresses ground-fault protection of related equipment. Specifically, this section states that ground-fault protection of equipment must be provided for solidly grounded wye electric services of more than 150 V to ground but not exceeding 600 V phase-to-phase for each service disconnecting means rated 1000 A or more.

Article 280 of the OSH Act outlines installation and construction requirements for surge arrestors. A surge arrestor is defined in the OSH Act (section 280-2) as a protective device for limiting surge voltages by discharging or bypassing surge current, and it also prevents continued flow of follow current while remaining capable of repeating these functions. A good example of surge voltage would be lightning. When lightning strikes, unusually high voltages are introduced into normal circuits. Without arrestors, there is the risk of equipment damage or fire. Grounding of electric tools and equipment is one of the most important methods of controlling the hazards of low-voltage electricity.

If the insulation in electric equipment degenerates, or if a wire works loose and comes into contact with the frame or some other part that does not normally carry current, these parts can become energized. The electricity is

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now no longer controlled. It is ready to follow any path to the ground. The unprotected human body will complete the circuit and the consequences could be fatal. The OSH Act prescribes grounding for motor frames, elevators and cranes, electric signs, cord and plug-connected power tools used in damp locations, and portable work lamps.

These are just a few of the many electrical articles and sections that have a direct bearing on your project production safety. Project managers and contractors are strongly advised to read and become more familiar with all of their provisions. OSHA also deals with some further stipulations for safe electrical practice as prescribed by the National Electrical Code (NEC).

Articles within the NEC and related sections of OSHA deal with the requirements for electrical equipment and wiring for all voltages in locations where fire or explosion hazards may exist. These hazards include flammable liquids, combustible dust, or ignitable fibers and their locations are termed Hazardous (Classified) Locations. Classified sections recommend that transformers and capacitors containing a flammable liquid be installed only in approved vaults as specified in Sections 450-41 and 450-48.

Among the features of these prescribed vaults are walls, roof, and floor materials with a minimum fire resistance of 3 hours. Section 502-2 also prescribes that no transformer or capacitor should be installed in locations where there is dust from magnesium, aluminum, aluminum-bronze powders, or other materials with similar hazardous characteristics.

ELECTRICAL SYSTEMS PRE-INSPECTION TEST

Perform the following electrical system inspection tests after all structural assembly, metal and trim installations, and electrical crossover connections are complete. The grounding continuity test is to be performed before connecting the home to the electrical service, and the polarity and operation tests are to be performed after the electrical installation is complete.

Perform the following procedure checks for grounding continuity, polarity, and operation of the electrical system. Before the home is connected to 120/240-V service, proceed as follows: Connect one clip of a flashlight continuity tester to a convenient ground (metal skin, window frame on metal skinned units, floor duct rise, etc.) and touch the other clip to each fixture canopy. The continuity light should go on if each fixture is properly grounded. Using the continuity tester, check every direct-connected appliance or fan. The tester must be hooked to a convenient ground and to the metal frame of the appliance. Using the continuity tester, check the continuity between the following:

One riser of furnace duct and convenient ground
Metal roof and steel frame

Metal skin and steel frame
Metal gas piping and steel frame
Metal water piping and steel frame
Metal raceway below distribution panel and steel frame

Note: Continuity to ground is not required on the metal inlet of a plastic-piped water system.

When plumbing fixtures such as metallic sinks, tubs, faucets, and shower risers are connected only to plastic water piping and plastic drain piping, continuity to ground is not required. Any loss of grounding continuity will require investigation and correction. After the building is connected to the electrical service, proceed as follows: Plug an alternating-current receptacle wiring tester into each receptacle in the building to check for reversed polarity, open grounds, and shorts. Any reverse polarity, open grounds, or shorts found will require investigation and repair.

Install light bulbs and fluorescent tubes where not already installed in the fixtures. Make sure each light fixture is operable by turning the appropriate switch to the ON position. Shut off all light switches in the building and perform tests on smoke detectors. Repair or replace any defective items.

PREPARING FOR INSPECTIONS

Under the OSH Act of 1970, OSHA is authorized to conduct project workplace inspections to determine whether prime and subcontractors are complying with standards issued by the agency for safe and healthful workplaces. OSHA also enforces Section 5(a)(1) of the act, known as the General Duty Clause, which requires that every project worker be provided with a safe and healthful workplace. OSHA compliance safety and health officers to ensure enforcement of those OSHA standards perform workplace inspections. Inspections are usually conducted without advance notice. In fact, alerting an activity subcontractor without proper authorization in advance of an OSHA inspection is punishable by a fine of up to $1000 and/or a 6-month jail term. This is true for OSHA inspectors as well as state inspectors. However, there are special circumstances under which OSHA may give notice to the subcontractor, but such a notice will normally be less than 24 hours in advance. These circumstances include

Imminent danger situations that require correction as soon as possible
Inspections that must take place after regular business hours or that require special preparation
Cases where notice is required to assure that the subcontractor and worker representative or other personnel will be present

Cases where an inspection must be delayed for more than 5 working days when there is good cause

Situations in which the OSHA area director determines that advance notice would produce a more thorough or effective inspection

Subcontractors who receive advance notice of an inspection must inform their workers' representative or arrange for OSHA to do so. If an activity subcontractor refuses to admit an OSHA inspector or if a subcontractor attempts to interfere with the inspection, OSHA will take appropriate legal action. Based on a 1978 Supreme Court ruling (*Marmust v. Barlow's Inc.*), OSHA usually may not conduct warrantless inspections without valid consent. OSHA may inspect after acquiring a judicially authorized search warrant based on administrative probable cause or on evidence of a violation. With over 6 million workplaces in America, OSHA had to establish a system of inspection priorities with the worst situations getting attention first.

Compliance inspectors represent OSHA and are expected to demonstrate their knowledge and expertise in the safety and health field in a courteous and professional manner. Prior to the inspection, the compliance inspector becomes familiar with as many relevant facts as possible about the workplace, such as the inspection history of the project, the nature of the construction, and the particular standards likely to apply. This preparation provides the inspector with knowledge of the potential hazards and industrial processes that may be encountered and aids in selecting appropriate personal protective equipment for protection against these hazards during the inspection.

When the inspector arrives at the establishment, he or she must display official credentials and ask to meet an appropriate project team representative. Project managers and prime contractors should always ask to see the compliance inspector's credentials. An OSHA compliance inspector carries U.S. Department of Labor credentials bearing photograph and a serial number that can be verified by calling the nearest OSHA office. OSHA compliance inspectors may not collect a penalty at the time of inspection or promote the sale of a product or service at any time; anyone who attempts to do so is not an OSHA inspector, and the FBI or local law enforcement officials should be contacted immediately.

The inspector should then explain the purpose of the visit, the scope of the inspection, and the standards that apply. The project manager will be given copies of applicable safety and health standards as well as a copy of any worker complaint that may be involved (with the worker's name deleted, if the worker has requested anonymity). The prime contractor is then asked to select a subcontractor representative to accompany the inspector during the inspection. An authorized worker representative also is given the opportunity to attend the opening conference and to accompany the inspector during the inspection. If the workers are represented by a labor union, the union agent ordinarily will designate the worker representative to accompany the inspector. The law does not require that there be a worker representative for each inspection. However, when there is no authorized worker representative, the inspector must consult with a reasonable number of workers concerning safety and health matters in the workplace.

The compliance inspector and accompanying representatives then proceed through the project to inspect work areas for safety or health hazards. The inspector determines the route and duration of the inspection. While talking with workers, the inspector should make every effort to minimize any work interruptions. The inspector observes safety and health conditions and practices; consults with workers privately, if necessary; takes photos and instrument readings; examines records; collects air samples; measures noise levels; surveys existing engineering controls; and monitors worker exposure to toxic fumes, gases, and dusts.

An inspection tour may cover part or all of a project, even if the inspection resulted from a specific complaint, fatality, or catastrophe. Trade secrets observed by the inspector will be kept confidential. An inspector who releases confidential information without authorization is subject to a $1000 fine and/or 1 year in jail. The prime contractor may require that the worker representative have confidential clearance for any area in question. The inspector may stop and question workers, in private, about safety and health conditions and practices in their workplaces. Each worker is protected, under the act, from discrimination for exercising his or her safety and health rights.

OSHA places special importance on posting and record keeping. The inspector will inspect records of deaths, injuries, and illnesses that the project team is required to keep. He or she will check to see that a copy of the totals from the last page of OSHA form 200 has been posted and that the OSHA workplace poster (OSHA 2203), which explains workers' safety and health rights, is prominently displayed. When records of worker exposure to toxic substances and harmful physical agents have been required, they are also examined for compliance with the record-keeping requirements. The inspector also explains that while the following items are not required for all OSHA standards they should be recorded to accurately monitor and assess occupational hazards:

Initial and periodic monitoring, including the date of measurement, for operations involving exposure; sampling and analytical methods used and evidence of their accuracy; number, duration, and results of samples taken; type of respiratory protective devices worn; and name, social security number, and results of all worker exposure measurements. This record should be kept for 30 years.

Worker physical examinations, including the name and social security number of the worker; physician's written opinions; any worker medical complaints related to exposure to toxic substances; and information provided to the examining physician. These records should be maintained for the duration of employment plus 30 years.

Worker training records should be kept for 1 year beyond the last date of employment of that worker.

The inspector also explains the requirements of the Hazard Communication Standard. Under that rule, subcontractors must establish a written, comprehensive hazard communication program that includes provisions for container labeling, material safety data sheets, and a worker training program. The program must contain a list of the hazardous chemicals in each work area and the means the subcontractor will use to inform workers of the hazards of nonroutine tasks. During the course of the inspection, the inspector will point out to the project manager any unsafe or unhealthful working conditions observed. At the same time, the inspector will discuss possible corrective action if the project manager so desires. Some apparent violations detected by the inspector can be corrected immediately. When they are corrected on the spot, the inspector records such corrections to help in judging the project team's good faith in compliance. Even though corrected, however, the apparent violations may still serve as the basis for a citation and, if appropriate, a notice of proposed penalty. An inspection tour may cover part or all of a project and its operations, even if the inspection resulted from a specific complaint, fatality, or catastrophe.

After the inspection tour, a closing conference is held between the inspector, the prime contractor, and the project team's safety director. It is a time for free discussion of problems and needs and for frank questions and answers. The inspector also will give the project team a copy of *Rights and Responsibilities Following an OSHA Inspection* and then briefly discuss the information in the booklet and answer any questions. The inspector discusses with the project team all unsafe or unhealthful conditions observed during the inspection and indicates all apparent violations for which a citation and a proposed penalty may be issued or recommended. The project team is also informed of appeal rights. The inspector will not indicate any specific proposed penalties. Only the OSHA area director has that authority and only after having received a full report.

During the closing conference, the project team may wish to produce records to show compliance efforts and to provide information that can help OSHA determine how much time may be needed to abate an alleged violation.

When appropriate, more than one closing conference may be held. This is usually necessary when health hazards are being evaluated or when laboratory reports are required. A closing discussion will be held with the workers, or their representative, to discuss matters of direct interest to workers. The subcontractor's representative may be present at the closing conference.

The inspector explains that OSHA area offices are full-service resource centers that inform the public of OSHA activities and programs, such as new or revised standards. Other services also include information on the status of proposed standards; comment periods or public hearings; provisions of technical experts and materials, including courses offered at the OSHA Training Institute. The area offices will refer callers to other agencies as appropriate and promote safety programs through voluntary protection programs. If a worker representative does not participate in either the opening or the closing conference held with the project team, a separate discussion is held with the worker representative, if requested, to discuss matters of direct interest to workers. After the inspector reports his or her findings, the area director determines if citations will be issued and if penalties will be proposed.

CITATIONS

Citations inform the project team, prime contractor, and respective activity subcontractor of the regulations and standards alleged to have been violated and of the proposed length of time set for their abatement. Obviously, this will have an adverse impact on your project schedule if not rectified immediately. The subcontractor will receive citations and notices of proposed penalties by certified mail. The subcontractor must post a copy of each citation at or near the place a violation occurred for 3 days or until the violation is abated, whichever is longer. These are the most frequently cited recordation violations for construction projects:

1904.2(a) Log and Summary of Occupational Injuries and Illnesses. Each subcontractor must maintain a log and summary of all recordable occupational injuries and illnesses for that job site. Each recordable injury and illness must be entered on the log and summary as early as practicable but no later than 6 working days after receiving information that a recordable injury or illness has occurred. OSHA form 200, or an equivalent form, must be used to record the information. The log and summary must be completed in the detail provided in the form OSHA form 200 (see Fig. 8.4).

5(a)(1) General duty clause. This is not a regulation, but rather Section 5(a)(1) of the OSH Act. It specifically states, "Each subcontractor must furnish to each of his workers employment and a place of employment which is free from recognized hazards that are causing or are likely to cause death or

Your Company Name Here

Safety Selections for Our Construction Company

This Safety Selection can be used to conduct periodic safety meetings at our construction sites. The material can be used by the jobsite supervisor for the safety discussion.

OSHA Form 200 Instructions

Every employer must maintain OSHA Form 200 as a log of the injury and illness experience of that establishment complete and current to a date within 45 calendar days. The log consists of three parts: a descriptive section which identifies the employee and briefly describes the injury or illness; a section covering the extent of the injuries recorded; and a section on the type and extent of illnesses. The following information pertains to the descriptive section of the log:

Column A. Enter a number that is unique for each case. This is very important because each case must be identified and examined separately. The simplest method of numbering may be the best, i.e., 1, 2, 3. Employers may also number cases by month; for example, 7-15 would indicate the fifteenth case occurring during July.
Column B. For occupational injuries, enter the date of the work accident which resulted in injury. For occupational illnesses, enter the date of initial diagnosis of illness, or, if the absence from work occurred before diagnosis, enter the first day of absence contributable to the illness which was later diagnosed or detected. Cases do not necessarily fall consecutively by date, because injuries and illnesses are recorded as an employer learns that a case has occurred.
Column C. Insert one of two entries: (1) first name, middle initial, and last name; or (2) first initial, middle initial, and last name.
Column D. Specify the injured or ill employee's regular job title even if the employee was working outside his or her regularly assigned occupation at the time of the injury or illness exposure.
Column E. State the department in which the injured or ill person is regularly employed. Enter the department in which the injury or illness exposure occurred only if it is the regularly assigned work task.
Column F. Briefly describe the nature of the injury or illness and parts of the body affected. For example, the description "amputation—finger" is not sufficiently detailed. A correct entry would be "amputation—second joint, forefinger, left hand." This tells which hand, which finger, and to what degree.

FIGURE 8.4 OSHA Form 200.

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serious physical harm to his workers.'' OSHA cites the General Duty Clause in many of its enforcement actions whenever there is not a specific OSHA standard that applies to the situation or if hazards still exist for the worker even after the subcontractor has complied with a particular OSHA standard.

OSHA's recent action on ergonomic hazards in the workplace is a good example of the application of the General Duty Clause in situations where a standard does not currently exist. There are no standards governing job or workstation design to reduce or prevent cumulative trauma disorders or other injuries. However, OSHA has cited many companies under the General Duty Clause for failing to address ergonomic hazards in the workplace. OSHA has also issued General Duty Clause citations on many other issues where no apparent safety standard exists. Citations have been issued for lack of training, failure to have additional safety or alarm equipment to detect or warn of chemical leaks, and failure to provide safe locations or safe access to valves or other instruments necessary to an worker's job.

1904.8 Reporting of Fatality or Multiple Hospitalization Incidents. Within 8 hours after the death of any worker from a work-related incident or the in-patient hospitalization of three or more workers as a result of a work-related incident, the subcontractor of any workers so affected must orally report the fatality or multiple hospitalization by telephone or in person to the area office of OSHA, U.S. Department of Labor, that is nearest to the site of the incident, or by using the OSHA toll-free central telephone number. This requirement applies to each such fatality or hospitalization of three or more workers that occurs within 30 days of an incident.

Exception: If the subcontractor does not learn of a reportable incident at the time it occurs and the incident would otherwise be reportable under paragraphs (a) and (b) of Section 1904.8, the subcontractor must make the report within 8 hours of the time the incident is reported to any agent or worker of the subcontractor. Each report required by this section must relate the following information: establishment name, location of incident, time of the incident, number of fatalities or hospitalized workers, contact person, phone number, and a brief description of the incident.

1904.4 Recording and Reporting Occupational Injuries and Illnesses: Supplementary Record. In addition to the log of occupational injuries and illnesses provided for under Section 1904.2, each subcontractor must have a supplementary record for each occupational injury or illness for that establishment available for inspection at each establishment within 6 working days after receiving information that a recordable case has occurred. The record must be completed in the detail prescribed in the instructions accompanying OSHA form 101. Worker's compensation, insurance, or other reports are acceptable alternative records if they contain the information required by OSHA form 101. If no acceptable alternative record is maintained for other purposes, OSHA form 101 must be used or the necessary information must be otherwise maintained.

1904.2(b)(2) Recording and Reporting Occupational Injuries and Illnesses Log Copy. At each of the subcontractor's establishments, there must be available a copy of the log that separately reflects the injury and illness experience of that establishment complete and current to a date within 45 calendar days.

1904.5(a) Annual Summary. Each subcontractor must post an annual summary of occupational injuries and illnesses for each job site. OSHA form 200 must be used in presenting the summary. If no injuries or illnesses occurred in the year, zeros must be entered on the totals line, and the form must be posted. The summary must consist of a copy of the year's totals from the OSHA form 200 and the following information from that form:

Calendar year covered
Company name
Establishment name and address
Certification signature, title, and date

1904.5(c) Annual summary. Each subcontractor who supervises the preparation of the log and summary of occupational injuries and illnesses, must certify that the annual summary is true and complete.

PENALTIES

In order to determine the amount of a penalty, the violation itself must first be categorized. Violations can be classified as serious, other than serious, willful, repeat, or failure to abate. Once a violation is classified, the severity of the violation and the probability of an injury or illness occurring as a result of the violation will be considered in order to determine a base penalty amount. The base penalty may then be adjusted downward when factors such as size, good faith, and violation history of the activity subcontractor are considered. The adjustment factors used by OSHA include

A size adjustment factor. The base penalty will be reduced 60% for subcontractors with 1 to 25 workers; 40% for subcontractors with 26 to 100 workers; and 20% for subcontractors with 101 to 250 workers. Subcontractors with more than 250 workers will not get a penalty reduction for size.

A good-faith adjustment. There may be up to an additional 25% reduction for evidence that the subcontractor is making a good-faith effort to provide good workplace safety and health. In order to qualify for the full 25% good-faith reduction, a subcontractor must have a written and implemented safety and health program such as is described in OSHA's voluntary Safety and Health Management Guidelines. The program should include programs required under the OSHA standards such as hazard communication, lockout and tag out, or safety and health programs for construction required in Section 1926.20.

A history adjustment. An additional 10% reduction can be given if the subcontractor has not been cited by OSHA for any serious, willful, or repeat violations in the past three years.

The computation of base penalties for the various violations is based on the following OSHA guidelines:

Serious violations. A serious violation is one where there is a substantial probability that death or serious physical harm could result, and the subcontractor knew or should have known of the hazard. The typical range of proposed penalties for serious violations is $1500 to $5000. The regional administrator does have the authority, however, to propose a penalty fine of up to $9000. The severity of the violation and the probability of an injury or illness occurring are then considered in order to determine the dollar amount of the proposed penalty. For example, the base penalty for a severe serious violation where the probability of an injury or illness occurring is great is $5000. A base penalty of $2500 is proposed, however, if the serious violation is severe, but the probability of an injury or illness occurring as a result of the violation is low. Penalties for serious violations are only adjusted downward for company size and violation history of the subcontractor.

Other-than-serious violations. This is a violation that has a direct relationship to job safety and health, but probably would not cause death or serious physical harm. No penalties are usually proposed for other-than-serious violations that have a low probability of resulting in an injury or illness. A base penalty of $1000 is used if the violation has a greater probability of resulting in an injury or illness. Again, the regional administrator does have some discretion to increase this base penalty up to $7000 if he or she feels it is warranted. A base penalty of $1000 has been established for failure to post the OSHA notice (form 2203) or the annual summary of workplace injuries and illnesses. Failure to post an OSHA citation in the workplace is subject to a $3000 base penalty. Base penalties of $1000 and $5000 are used, respectively, for failure to maintain OSHA 200 and OSHA 101 logs or for failure to report a workplace fatality or catastrophe within 24 hours. In these instances, OSHA will only adjust the penalties downward for size and violation history of the subcontractor.

Willful violations. A willful violation is one that the subcontractor intentionally and knowingly commits. For a willful violation, OSHA calculates the penalty for the underlying serious violation, adjusts it for size and industry, and multiplies it by 7. The multiplier may be adjusted upward or downward at the discretion of the regional administrator. The minimum penalty for a willful violation, however, is $5000.

Repeat violations. A repeat violation is a violation of any standard, regulation, rule, or order where, upon reinspection, a substantially similar violation is found and the original citation has become a final order. Repeat violations are only adjusted downward for size. The adjusted penalty is then multiplied by 2, 5, or 10, depending on the size of the subcontractor.

Failure to abate. Failure to correct a prior violation within the prescribed abatement period could result in a penalty for each day the violation continues beyond the abatement date. The daily penalty is usually equal to the amount of the initial penalty with an adjustment for size only.

All penalty amounts issued with a citation are proposed. Subcontractors may contest the penalty amount as well as the citation within the 15-day contestment period. After that, the penalty may be adjudicated by the Occupational Safety and Health Review Commission, or OSHA may negotiate with the subcontractor to settle for a reduced penalty amount if this will lead to speedy abatement of the hazard. Additional violations for which citations and proposed penalties may be issued are listed here. Falsifying records, reports, or applications can bring a fine of $10,000 or up to 6 months in jail, or both. Interfering with an inspector in the performance of his or her duties is a criminal offense and is subject to a fine of not more than $5000 and imprisonment for not more than 3 years. Citation and penalty procedures may differ somewhat in states with their own occupational safety and health programs.

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9

Risk Management

JOB-SITE HAZARD ANALYSIS

A significant part of risk management in project production is done through a thorough hazard analysis. Safety hazards are not always obvious and if not addressed in prior planning will always deter a smooth flow in any project schedule. When you think of hazards, you might picture deep pits workers could fall into, exposed rebar, or puddles of sulfuric acid eating through rubber boots. The reality is far more mundane but just as lethal.

Any construction site may contain numerous safety hazards such as holes or ditches; unlabeled chemical containers; precariously positioned objects, such as drums or boards that may fall; sharp objects, such as nails, metal shards, and broken glass; unsafe ladders and scaffolding; slippery surfaces; steep grades; uneven terrain; and unstable surfaces, such as walls that may cave in or flooring that may give way.

Some safety hazards are a function of the production work itself. For example, heavy equipment creates an additional hazard for workers in the vicinity of the operating equipment. Protective equipment can impair a worker's agility, hearing, and vision, which can result in an increased risk of an accident. Accidents involving physical hazards can directly injure workers and can create additional hazards, for example, increased chemical exposure due to damaged protective equipment, or danger of explosion caused by the mixing of chemicals.

Whether you are concerned with a specific health or safety hazard on the job-site or just want to do a general risk management assessment for the production schedule, you must do a careful determination of the hazards and potential hazards that the subcontractors' workers are exposed to. You cannot prepare contingencies if you are unaware of the scope of hazards that may be present. You must do a complete on-site survey of your job-site, compiling information as to the presence and concentration of physical hazards, chemicals, the location of entries and exits, the availability of emergency equipment, and potential trouble spots. At a minimum, you should do a survey of the presence of any obvious hazards. What is just an annoyance now can be greatly magnified in the presence of an emergency situation. An uneven flooring that should have corrected yesterday can present a serious tripping hazard when a heavy beam they are carrying today obscures the vision of workers.

So do a complete physical mapping of each job-site area. Note the types of containers or other storage systems; paper or wood packages; metal or plastic barrels or drums (especially anything unlabeled); underground tanks; aboveground tanks; compressed gas cylinders; and pits, ponds, or lagoons. Note the condition of waste containers and storage systems. Are they sound (undamaged) or visibly rusted, corroded, or leaking?

Note the types and quantities of material in containers. Check labels on containers indicating corrosive, explosive, flammable, radioactive, or toxic materials. Note the physical condition of the materials, such as gas, liquid, or solid; color and turbidity; behavior (e.g., corroding, foaming, or vaporizing); and if conditions are conducive to splash or contact. Identify natural wind barriers such as buildings, hills, or tanks. Then determine the potential pathways of dispersion.

Note any indicators of potential exposure to hazardous substances like dust or spray in the air, fissures or cracks in solid surfaces that expose deep waste layers, pools of liquid, foams or oils on liquid surfaces, gas generation or effervescence, or deteriorating containers.

JOB-SITE OPERATIONS CHECKLIST

Project schedule risk management involves concentrating on evaluating, managing, and controlling production losses. The fundamentals of risk management in project operations analysis require a reverse perspective; start from the hazard and work backward. First examinations begin by identifying violations of sound construction safety principles and practices within all normal operations, tasks, and activities.

Look with a keen and unbiased eye, and you will see much that needs to be tuned up. Typical concerns of the project schedule production control regarding required on-site safety items in project operations are

Personal protective equipment
Approved first aid kit (portable and fully stocked at all times)

Fire protection apparatus
Noise attenuating items
Equipment and power tool guards (in place and in good working order)
Equipment and power tool cords (nontaped, nonfrayed, and in good working order)
Ladders (good condition and extension locks in working order)
Electrical extension cords (nontaped, nonfrayed, and in good working order)
Scaffolds (no cracks or welds and in good working order)
Ground-fault circuit interrupters in gang boxes
Compressed air gun psi-restricting nozzles
Lockout and tag out devices for table saws and other power tools not considered portable
Paints, tapes, and barricades for demarcation
Emergency eyewash station (portable)
Approved safety cans for gas and diesel fuel
Bonding and grounding equipment for flammable liquid transfer
Material safety data sheets for all hazardous liquids and compounds used on the job; spill containment and cleanup items
Equipment guards

Begin the job-site tour by checking to see that there is enough light for the operations to be carried out safely. OSHA Section 1523 covers the hazards and requirements for job-site illumination. Construction areas, ramps, corridors, offices, shops, and storage areas must be lighted to not less than the minimum illumination intensities given in Table 9.1 while work is in progress.

TABLE 9.1 Minimum Illumination Intensities in Food-Candles (fc)

fc	Area of operation
3	General construction area lighting low activity
5	Outdoor active construction areas, concrete placement, excavation and waste areas, access ways, active storage areas, loading platforms, refueling and field maintenance areas
5	Indoors: warehouses, corridors, hallways, stairways, and exit ways
10	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active storerooms, barracks, living quarters, locker or dressing rooms, mess halls, indoor toilets, and workrooms)
30	First aid stations, infirmaries, and offices

Note: For areas or operations not covered above, refer to the American National Standard A11.1-1973, Practice for Industrial Lighting, for recommended values of illumination.

Site personnel should constantly look out for potential safety hazards and should immediately inform their supervisors of any new hazards so that mitigative action can be taken. Risk management in project scheduling begins by looking at the following major job-site hazards.

ELECTRICAL HAZARDS

Overhead power lines, downed electric wires, and buried primary or secondary alternating current (ac) cables all pose a danger of shock or electrocution if workers contact or sever them during site operations. Electrical equipment used on-site may also pose a hazard to workers. To help minimize this hazard, low voltage equipment with ground-fault interrupters and watertight, corrosion-resistant connecting cables should be used on-site.

In addition, lightning is a hazard during outdoor operations, particularly for workers handling metal containers or equipment. To eliminate this hazard, monitor weather conditions and suspend work during electrical storms.

An additional electrical hazard involves capacitors that may retain a charge. All such items should be properly grounded before handling. OSHA's Standard 29 CFR Part 1910.137 describes clothing and equipment to be used as protection against electrical hazards.

HEAT STRESS

Heat stress is a major job-site hazard, especially for roofers and workers wearing protective clothing. The same protective materials that shield the body from hazards and exposure also limit the dissipation of body heat and moisture. Personal protective clothing can therefore create a hazardous condition.

Depending on the ambient conditions and the work being performed, heat stress can occur very rapidly—within as little as 15 min. It can pose as great a danger to worker health as chemical exposure. In its early stages, heat stress can cause rashes, cramps, discomfort, and drowsiness, resulting in impaired functional ability that threatens the safety of both the individual and coworkers.

Continued heat stress can lead to heat stroke and death. Careful training, avoiding any unnecessary protective clothing, and frequent monitoring of personnel who wear protective clothing, as well as judicious scheduling of work and rest periods with frequent replacement of potable drinking water, can protect against this hazard.

COLD EXPOSURE

Cold injury (frostbite and hypothermia) and impaired ability to work are dangers at low temperatures and when the wind-chill factor is low. To guard against them, have your workers wear appropriate clothing, carefully schedule work and rest periods, and monitor workers' physical conditions.

Noise

Work around large equipment often creates excessive noise. The effects of noise can include workers being startled, annoyed, or distracted; physical damage to the ear; pain; and temporary and/or permanent hearing loss. Communication interference may increase potential hazards due to the inability to communicate danger warnings and the proper safety precautions to be taken.

If employees are subjected to noise exceeding an 8-hour, time-weighted average sound level of 90 dBA (decibels on the A-weighted scale), feasible administrative or engineering controls must be utilized. In addition, whenever employee noise exposures equal or exceed an 8-hour, time-weighted average sound level of 85 dBA, employers must administer a continuing, effective hearing conservation program as described in OSHA Regulation 29 CFR Part 1926.52.

Confined Space Entry

Safety and health hazards are involved in responding to incidents in confined spaces. A confined space is a space that has limited openings for entry and exit and unfavorable natural ventilation. The openings are usually small in size and are difficult to move through easily, which makes the transport of protective equipment a chore. Because air may not move in or out of confined spaces freely due to the design, the atmosphere inside a confined space can be very different from the atmosphere outside. Deadly gases may be trapped inside or there may not be enough oxygen to support life. Therefore, occasional worker entry into confined spaces for inspection, maintenance, repair, cleanup, or similar tasks is often difficult and dangerous due to chemical or physical hazards within the space.

FIRE PROTECTION

A fire-fighting program must be developed and followed throughout all phases of construction and/or demolition work involved in the project. It must provide for effective fire-fighting equipment to be available without delay and designed to effectively meet all fire hazards as they occur. Fire-fighting equipment must be conspicuously located on the job site and readily accessible at all times. It must be periodically inspected and be maintained in operating condition. Carbon tetrachloride and other toxic vaporizing liquid fire extinguishers are prohibited.

If the construction includes the installation of automatic sprinkler protection, the installation must closely follow the rough construction and be placed in service, as soon as applicable laws permit, following completion of each story. A fire extinguisher, rated not less than 2A, must be provided for each 3000 sq. ft. of the protected building area, or major fraction thereof. The travel distance from any point of the protected area to the nearest fire extinguisher must not exceed 100 ft. One or more fire extinguishers, rated not less than 2A, must be provided on each floor. In two-story construction, at least one fire extinguisher must be located adjacent to the stairway. The employer must establish an alarm system at the job site so that employees and the local fire department can be alerted for an emergency.

FIRE PREVENTION

The project's contractors must provide training and equipment for fire fighting to assure adequate protection to life. Portable fire extinguishers must be inspected periodically and maintained in accordance with NFiPA form 10A-1990, Maintenance and Use of Portable Fire Extinguishers. The project management team has an obligation for the care and use of these extinguishers at all times. By doing so, they are contributing to the protection of life and property. The nameplates and instruction manual should be read and thoroughly understood by all persons who may be expected to use extinguishers.

To discharge this obligation, the project manager should give proper attention to the inspection, maintenance, and recharging of this fire protective equipment. The subcontractors should train all personnel in the correct use of fire extinguishers on the different types of fires that may occur during business operations. They must also train employees designated to inspect, maintain, operate, or repair fire-extinguishing systems and annually review their training to keep them up to date in the functions they are to perform.

Smoking must be prohibited in the vicinity of operations that constitute a fire hazard. Signs stating "no smoking" or "open flame" must be conspicuously posted. Equipment powered by internal combustion engines must be located so that the exhausts are well away from combustible materials. Combustible materials must be piled with due regard to the stability of piles and in no case higher than 20 ft. No combustible material may be stored outdoors within 10 ft of a building or structure.

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In outdoor storage areas, portable fire-extinguishing equipment, suitable for the fire hazard involved, must be provided at convenient, conspicuously accessible locations in the yard area. The extinguishers must be placed so that the maximum travel distance to the nearest unit does not exceed 100 ft. In indoor storage areas, storage must not obstruct or adversely affect exits. A barrier having a fire resistance of at least one hour must segregate non compatible materials that may create a fire hazard.

FLAMMABLE AND COMBUSTIBLE LIQUIDS

Only approved containers and portable tanks may be used for the storage and handling of flammable and combustible liquids. No more than 25 gallons (gal) of flammable or combustible liquids can be stored in a room outside an approved storage cabinet. No more than 60 gal of flammable or 120 gal of combustible liquids can be stored in any one storage cabinet. No more than three storage cabinets may be located in a single storage area.

Inside storage rooms for flammable and combustible liquids must be of fire-resistive construction, have self-closing fire doors at all openings, 4-in. sills or depressed floors, a ventilation system that provides at least six air changes within the room per hour, and electrical wiring and equipment approved for class 1, division I locations. Storage in containers outside buildings must not exceed 1100 gallons in any one pile or area. The storage area must be graded to divert possible spills away from buildings or other exposures or must be surrounded by a curb or dike. Storage areas must be located at least 10 ft from any building and must be free from weeds, debris, and other combustible materials (unless necessary to create the storage).

Flammable liquids must be kept in closed containers when not actually in use. Conspicuous and legible signs prohibiting smoking must be posted in service and refueling areas. Storage tanks for flammable and combustible liquids must be constructed and placed in accordance with Section 1910.106(b). The design, fabrication, assembly, test, and inspection of piping systems containing flammable or combustible liquids must be suitable for the working pressures and structural stresses and must be in accordance with the provisions of 1910.106(c) and the ANSI B31 series, Pressure Piping. Tanks and pumps not integral to the dispensing unit must be on shore or on a pier of the solid-fill type, except under certain specified circumstances.

A readily accessible valve to shut off the supply from shore must be provided in each pipeline at or near the approach to the pier and at the shore end of each pipeline. Piping handling Class I liquids must be grounded to control stray currents.

LIQUEFIED PETROLEUM GAS

Each system must have containers, valves, connectors, manifold valve assemblies, and regulators of an approved type. All cylinders must meet DOT specifications. Every container and vaporizer must be provided with one or more approved safety relief valves or devices.

Containers must be placed upright on firm foundations or otherwise firmly secured. Portable heaters must be equipped with an approved automatic device to shut off the flow of gas in the event of flame failure. Storage of liquefied petroleum gas within buildings is prohibited. Storage locations must have at least one approved portable fire extinguisher, rated not less than 20-B: C.

POTABLE WATER

An adequate supply of potable water must be provided in all places of employment. Portable containers used to dispense drinking water must be equipped with a faucet or drinking fountain; must be capable of being tightly closed; and must be otherwise designed, constructed, and serviced so that sanitary conditions are maintained. Water must not be dipped from containers. Any container used to store or dispense drinking water must be clearly marked as to the nature of its contents and must not be used for any other purpose.

Where drinking fountains are not provided, single-service cups (to be used only once) must be supplied. Where single-service cups are supplied, a sanitary container for the unused cups and a receptacle for disposing of the used cups must be provided. Nonpotable water cannot be used for the purposes of drinking, washing, or food preparation.

Outlets for nonpotable water, such as water for industrial or firefighting purposes, must be posted in a manner understandable to all workers to indicate that the water is unsafe and is not to be used for drinking, washing, or cooking purposes. Nonpotable water systems or systems carrying any other nonpotable substance must be maintained so as to prevent backflow or back siphonage into a potable water system.

TOILETS ON JOB SITES

A minimum of one separate toilet facility must be provided for each 20 employees or fraction thereof of each gender. Such facilities may include both toilets and urinals, provided that the number of toilets is not less than one-half the minimum required number of facilities. The exception to this is that when there are less than five employees, separate toilet facilities for each gender are not required, provided the toilet facilities can be locked from the inside and contain at least one toilet.

Under temporary field conditions, not less than one toilet must be provided. Toilet facilities must be kept clean, maintained in good working order in a manner that will assure privacy, and provided with an adequate supply of toilet paper. Where the provision of water closets is not feasible due to the absence of a sanitary sewer or the lack of an adequate water supply, nonwater carriage disposal facilities must be provided.

Unless prohibited by applicable local regulations, these facilities may include privies (where their use will not contaminate either surface or underground waters), chemical toilets, recirculating toilets, or combustion toilets. The requirements of this section do not apply to mobile crews having readily available transportation to nearby toilet facilities.

SPOTTING ACCIDENT TRENDS

Case logs can serve as an excellent guide to hazard identification. Some trends can be spotted more easily than others. Look for them when there are multiple cases involving the same operation, trade occupation, part of the body, or victim. An even more detailed study could show, for example, that workers are being injured early in the workday due to frost sickness or late in the workday due to excessive heat exertion or while working overtime. Some obvious trends can highlight the need for the production operation's safety process review, followed by implementation of written procedures to the subcontractors involved, and then the issuance of related personal protective equipment. Proper equipment guarding would also be doubled-checked at this point.

As an example, certain tasks performed with portable circular power saws can be dangerous, and workers who regularly perform these tasks are therefore at a high risk for injury. Job-site conditions or lack of safety in operations may increase the chances of an accident occurring. Examine these areas of operations carefully and make sure all workers qualified to operate circular saws are aware of the dangers of kickback. Their training in defensive safety with this tool must be documented in their safety training.

The discovery and evaluation of any or all of these types of trends can form the basis of a sophisticated risk location map. In turn, this can be an invaluable aid in the detection of various contributing causes that had been previously overlooked. Trends develop with links that appear to be subtle or substantive. Information in the accident investigation can be applied to help formulate the probing questions of accident causation in risk management.

Some trends may call for a more profound analysis. Is overtime fatigue a factor? Is the enforcement of the company's personal protective equipment and safety directives lax on a certain job or with a specific subcontractor? Were there several cases relating to similar back strains, and is there a developing problem in that operation? Do particular employees function better and more safely? The questions are only limited by your particular style of project scheduling and scope of project operations. The hunt for answers is a unique challenge to every project manager and an important mechanism for the prevention of job-site accidents.

ACCIDENT INVESTIGATION

All accidents should be viewed as representing defects in a project's overall safety system. Claims by subcontractors of "employee misconduct" and "isolated incident" in cases where OSHA has documented that the required personal protective equipment was not worn are simply not going to work. Such defenses against citation are very rarely successful. These types of claims also tend to incur negative implications of the subcontractor, which often lead to further investigation of other areas of the project's operations. Recurrence of injuries and accidents can be reasonably predicted and prevented by a thorough accident investigation.

The main purpose of an accident investigation is to preclude or greatly reduce the chances of a recurrence. Through comprehensive accident investigations, accidents can be reasonably predicted and prevented in the great majority of potential cases. Unfortunately, accident investigations are after-the-fact summaries of injury and illness investigations. In reality, if no one was hurt but there was a near-miss incident, an investigation is rarely called for. This is a huge mistake. What is an opportunity to avoid injury is passed over in favor of silence and no one knowing the incident occurred. Any unsafe condition including damage to equipment or property should be investigated. Such damage may well be just one step away from a situation resulting in an injury.

The initial step in conducting an accident investigation is a full accounting of the chain of events leading to the accident. Then the cause of the accident must be determined. In most accident investigation cases more than one cause can be identified. In breaking down the sequence of events leading to the accident, the primary cause along with any other causes must be evaluated. Each cause must be analyzed thoroughly, with the greatest emphasis being placed on the major cause.

Contributing causes involve such factors as the lack of adequate communication, inadequate skill, or noncompliance with the safety program by the subcontractor's workers. Primary causes involve such factors as unsafe conditions, operations, or unsafe acts. We will examine two of the new systematic techniques to accident investigation that are currently widely acclaimed in accident investigation, which are

Job hazard analysis
Fault tree analysis
Critical incident technique
Critical path analysis
Flow analysis
Contingency analysis
Single-point failure analysis
Effects analysis

JOB HAZARD ANALYSIS

Job hazard analysis is the simplest and easiest technique for accident investigation. Job hazard analysis, even with its elemental format, can produce excellent results. Statistics should be reviewed, but there are deeper questions relating to the evaluation of the spawning of unsafe incidents. Journey-level workers can often provide practical information and suggestions on the day-to-day operations of their tasks. In all probability, they can also provide substantial clues on how to avoid the types of accidents that are typical in piecework.

FAULT TREE ANALYSIS

Fault tree analysis is founded on the concept that every accident or potential accident results from interacting causes within an operations system and that every accident cause can be logically separated into basic or component system or human failures. The point of fault tree analysis is that solutions can be developed to control each of the failures. Even when there were numerous contributing events that can be listed as causes, the elimination of one of those causes might have been sufficient to break the chain of events leading to the accident.

Fault tree analysis seeks to identify and correct sources of failures and malfunctions within the operations system. The system generally consists of persons, machines and tools, and materials that operate within an environment to perform a specific task using prescribed methods. Systems are normally defined in terms of the task or function they perform. The theory is that the components of the system (i.e., persons, machines and tools, materials, and methods) and its environment are interrelated, and a failure in any part can affect the other parts.

The fault tree is a logic diagram. The first step in constructing the fault tree is to start with the accident. Each of the primary causes and how they interacted to produce the undesired event are identified. The causes are then broken down into the events that led to them. The logic process is continued until all potential causes have been identified. Throughout the logic process, a tree diagram is used to record the events as they are identified and labeled. The accident is represented at the top of the tree. The primary causes are depicted immediately below the accident. The events that led to the primary causes are shown at the next-lower level and so on. The tree branches are terminated when all the events that could eventually have led to the accident are shown. Fault tree analysis has five basic steps:

1. Define the accident to be studied.
2. Acquire an understanding of the system.
3. Construct the fault tree.
4. Evaluate the fault tree.
5. Eliminate or control the hazards identified.

CATEGORIES OF ACCIDENTS

According to OSHA, if you wish to categorize accidents or potential accidents by types, the following list should cover almost every scenario:

1. Struck against
2. Struck by (falling, flying, shattering, sliding, moving)
3. Caught in, on, or between (in-running nip, pinching, shearing, rotating, reciprocating, punching, pulling and jerking, carrying actions)
4. Fall on same level
5. Fall on different level
6. Slip or overexertion (strain, hernia, etc.)
7. Gradual onset and ergonomic (cumulative trauma disorders, repetitive stress injuries)
8. Exposure to temperature extremes (burning, frostbite, heat exhaustion, sunstroke, hypothermia, scalding, freezing)
9. Inhalation, absorption, ingestion (asphyxiation, poisoning, drowning)
10. Noise or distraction

If an injury or occupational illness is sustained, no matter how minor, a record should be maintained. In many cases, there is not an OSHA requirement to do so. Nevertheless, I advise you to always keep a record, which may be as simple as the first aid log. One reason for this is because nonrecordable first aid cases may evolve into recordable cases. It is also good practice to record significant exposures (relative to permissible exposure limits) to toxic and hazardous substances, even when there is no apparent legal overexposure and when no symptoms have been reported. Those exposures may have been detected through analysis of sampling data. By doing this recording, medical surveillance can be brought into play and a foundation has been laid for protection against possible delayed legal action.

AUDITS

The number and complexity of environmental and workplace safety regulations have increased dramatically in the last few years. Construction site managers responsible for OSHA or Environmental Protection Agency (EPA) compliance try their best to comply, but they may often wonder if they are missing something. Safety and compliance audits can determine your regulatory compliance and what more you may need to do on-site.

An audit is a systematic assessment of regulatory compliance. For construction companies, an audit usually involves a survey of the job-sites. This survey achieves three objectives: It identifies what regulations apply to each particular site; it determines whether environmental and work site safety requirements and company policies and procedures regarding compliance are being followed; and it assesses management systems in place to ensure compliance, such as employee training or required reports. An audit may also look at and evaluate the methods used to achieve compliance.

Audits may be done for a variety of reasons. An on-site audit may be performed to ensure that the site is fully complying with all applicable regulations. An audit can also be limited in scope to ensure that certain regulations are being complied with, such as storm water regulations, or to ensure that there are no compliance problems in a particular area of the site, like a trenching or excavation area. Audits may be voluntary or required. In a voluntary audit, the project team decides that it is advantageous to conduct an audit on its own to evaluate compliance status and to identify any problems.

Audits may be mandatory if part of an agency–company settlement of an enforcement action. The EPA and OSHA regularly include an audit requirement in their settlement agreements with companies that have violated environmental or safety regulations. Audits may also be mandatory if required by a regulation. Under the Clean Air Act Amendments of 1990, the EPA has the authority to require auditing by regulation. Recent OSHA regulations, such as the lockout and tag out and process safety management regulations, also include self-audit requirements.

Conducting an Audit

Gather background information on site operations subject to the audit. Determine what regulations or other requirements you want to verify compliance with. Develop audit checklists. To assess and verify compliance, information can be gathered in several ways: during a walk around the construction site; by reviewing records and paperwork; or by testing and sampling as might be the case for wastewater streams and noise or chemical exposures.

Once compliance information has been assembled, the findings should be listed in a written report. The findings should be discussed with any personnel who might have compliance responsibility.

Audit Follow-Up

Follow-up occurs after compliance has been assessed. An action plan should be prepared based on audit findings to correct any identified deficiencies in the compliance program. Additional follow-up activities are also critical to ensure that the action plan has been implemented. In 1998, the EPA's Environmental Auditing Policy Statement outlined elements of an effective audit. They are as follows;

Top management support
A commitment to follow up on audit findings
Adequate training for risk management auditors
Specific audit program goals, objectives, and resources
Procedures to collect, analyze, and interpret audit information
Procedures for preparing written reports on audit findings, corrective actions, and implementation schedules
Procedures to assure the accuracy and thoroughness of an audit

Benefits of an Audit

First, an audit can help identify and correct regulatory problems. This can improve job-site safety and help reduce project and personal liability that is the purpose of risk management. A second benefit of an audit is that it can serve as an educational tool. It can increase subcontractors' awareness and understanding of environmental and safety regulations. The audit also creates an opportunity to demonstrate a project team's commitment to compliance. Third, audits can potentially identify ways to improve the efficiency and cost-effectiveness of the compliance program. Finally, workplace audits may be viewed favorably by regulatory agencies and criminal prosecutors.

A thoroughly completed audit with proper follow-up shows that a project management team is making a good faith effort to comply with applicable regulations. The Department of Justice has formally indicated that environmental compliance audits, if properly performed, may be taken into consideration when deciding whether to criminally prosecute a company for violating an environmental law.

Drawbacks of an Audit

Before conducting an audit, consider what you will do if a violation of a regulation or law is discovered. Will it be disclosed to the regulatory agency? For example, what would happen if you discovered that you were operating a phase of the project schedule on a job-site without a necessary specific permit? As another example, various state and federal laws may obligate a company to report uses of regulated substances when they are discovered during an audit. An audit may uncover unknown problems like these, and the solutions may not always be simple. Know what you will do with the results of your audit.

Failure to correct problems identified in an audit can potentially lead to more problems. Implementing corrective actions in a timely manner is vital. If problems are identified in an audit and nothing is done to correct them, this information could be used against a project development company in future enforcement proceedings. OSHA and the EPA do not, usually, require the disclosure of audit reports during an inspection, since the agencies do not want to discourage companies from self-auditing to improve environmental and safety compliance.

However, there have been instances when the agencies have subpoenaed audit information during an investigation and have used it against the companies in enforcement actions. Consult with legal counsel to find out whether audit information must be disclosed to OSHA or the EPA.

How to Conduct a Site Audit

Must you do an audit of your construction sites? Yes. An increasing number of regulations are requiring site assessments, hazard analyses, workplace inspections, and equipment inspections. For timely completion of your project schedule, the project team's financial protection, for the subcontractors' workers' safety and health, for the preservation of your company's good reputation, do an audit.

Here are some common-sense tips on how to perform a site audit. Use a project team approach. Rotate members of the audit team; new eyes see different things. Be thorough; cover every nook and cranny on the job-site. If you have multiple job-sites, audit each one. If you have a warehouse or equipment yard, be sure to audit that facility using OSHA 910 standards. Be frequent. The day after an audit, unlabeled containers can reappear. Be comprehensive; overlooking little things can create big problems. Set up a system for corrective action after the audit.

Defending Against Citations

The validity of citation defense is built upon two factors: your history and your record-keeping system. Strategic defense is enhanced by the involvement of all participants in the record-keeping and reporting system. The project team needs accurate and meaningful injury and illness information so that they can focus safety and health efforts on high-risk areas and activities to eliminate workplace hazards. A well-documented history of just such motivation is always your best defense. Consequently, the project team should make every effort to accurately record their firm's injury and illness experience. In addition, OSHA periodically reviews workplace records to verify their accuracy. Further, the posting and access provisions in Part 1904 of the regulations allow all project employees to review the records themselves, to ensure the validity of the record-keeping determinations.

There are severe penalties for falsification of records or reports, laid out in specific detail in Part 1904.9(a). This part incorporates the language of Section 17(g) of the act:

> Whoever knowingly makes any false statement, representation, or certification in any application, record, report, plan or other document filed or required to be maintained pursuant to this Act shall, upon conviction, be punished by a fine of not more than a $10,000 fine or by imprisonment, for not more than 6 months, or both.

We'll start here by first looking at complaint-generated citations. As a part of the congressional effort to improve government, OSHA has adopted new complaint investigation procedures. The new rules will cut the response to workplace hazard complaints from 40 to as few as 5 days. According to OSHA, the policy is to see that workers get their complaints resolved quickly. (Some cases in the pilot test were resolved in less than 24 hours.) Employers get a chance to correct problems and verify their actions without the threat of possible penalties from an OSHA inspection. And OSHA can better manage its resources by inspecting only when necessary.

Under the new policy, when OSHA receives a complaint, it will determine whether to immediately inspect or investigate the alleged hazards. If an investigation is appropriate, the agency will telephone the employer, describe the alleged hazards, and follow up with a fax or letter. The employer can respond in kind, identify and correct problems found, and note corrective actions taken or planned. An adequate response generally negates the need for an inspection. OSHA developed the new policy following careful pilot testing, a critical aspect of the agency's improvement efforts. OSHA intends to implement these and other programs that offer greater protection to workers, easier compliance for employers, or more effective use of OSHA's resources. This complaint policy meets not just one but all three of these criteria.

OSHA will continue to guarantee the right of employees and their representatives to an on-site inspection of rule violations. However, employees will be encouraged to attempt to resolve lower-priority complaints more swiftly through the phone-and-fax procedure. Complaints about hazardous working conditions should be reported to local OSHA offices or to state OSHA programs. OSHA maintains a 24-hour toll-free hotline (1-800-321-OSHA) for workers to report imminent danger situations only. Complaints reported to this number are relayed to local offices for follow-up.

The system is detailed in a compliance directive, OSHA Instruction CPL 2.115, Complaint Policies and Procedures. The following is a summary of the directive. Complaints are no longer identified as "formal" or "informal." Based on new criteria, complaints will now be classified as those that result in investigations using telephone and fax or similar means and those that result in on-site inspections. In a complaint investigation, OSHA will advise the employer of the alleged hazards by telephone and fax or by letter if necessary (e-mail may be available in the near future). The employer is to provide a written response, and OSHA will provide a copy of the response to the complainant. If OSHA receives an adequate response and the complainant does not dispute or object to the response, an on-site inspection generally will not be conducted. OSHA initiates a complaint inspection at a work site when one of the following criteria occurs:

A written complaint signed by a current subcontractor's employee or employee representative indicates that there are reasonable grounds to believe that danger or a violation of a safety or health standard exists on the project job-site under the requirements of the OSH Act.

A complaint alleges that physical harm, such as disabling injuries or illnesses, has occurred and it is believed the hazard still exists.

There is a complaint of an imminent danger situation.

A complaint identifies a hazard or establishment.

The subcontractor or prime contractor fails to provide an adequate response to a complaint or there is evidence that the response is false or does not adequately address the hazard.

The subcontractor or prime contractor has a history of egregious, willful, or failure-to-abate citations within the area and within the last 3 years.

An OSHA discrimination investigator requests an inspection in response to a worker's allegation of discrimination for complaining

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about safety or health conditions or for refusing to do an imminently dangerous job or task.

If an inspection is scheduled or has begun at an establishment and a complaint that normally would be investigated by phone and fax is received, the area office can schedule the complaint for inspection as a companion complaint.

Independent Contractor or Employee?

This section covers questions that often arise regarding record-keeping decisions that must be made at the owner/project team/prime contractor level. It focuses on the legislative and regulatory assignment of decision-making authority to subcontractor employers and describes the safeguards built into the system to ensure the integrity of the records and the validity of the statistics that the records provide. OSHA and Part 1904 of Title 29 CFR require subcontractors to maintain injury and illness records for their own employees at each of their job-sites. Prime contractors are not responsible for maintaining records for employees of other firms or for independent subcontractors, even though these individuals may be temporarily at work on one of their job-sites at the time an injury or illness exposure occurs. Therefore, before deciding whether a case is recordable, an employment relationship first needs to be determined.

The project management team decides which cases are to be entered on the OSHA records. This decision must be made in good faith, according to the requirements of the OSH Act. Chapter V of this act provides a detailed description of these record-keeping requirements and furnishes criteria for determining recordability. It presents an overview of the Department of Labor's record-keeping interpretations and guidelines. The project management team must also determine the extent and outcome of the recordable cases. Part 1904.12(c) of the regulations provides the categories in which recordable cases must be classified.

Defending against liability begins by differentiating between employees and independent contractors for record-keeping purposes. This should be evaluated on a case-by-case basis, with the degree of supervision being the primary determinant. Employee status generally exists when the subcontractor supervises not only the output, product, or result to be accomplished by the person's work, but also the details, means, methods, and processes by which the person's work, but also the details, means, methods, and processes by which the work objective is accomplished accomplish the work objective. This means that the subcontractor who supervises a worker's day-to-day activities is responsible for recording his or her injuries and illnesses.

Independent contractors are primarily subject to supervision by the using firm only in regard to the result to be accomplished or end product to be delivered. Independent contractors keep their own injury and illness records.

In defending against outside service claims, it is important to remember the courts use these factors in determining employee versus independent contractor status:

Who does the worker considers to be his or her employer?
Who pays the worker's wages?
Who withholds the worker's Social Security taxes?
Who hired the worker?
Who has the authority to terminate the worker's employment?

People considered independent contractors for other reasons might be considered employees for OSHA record-keeping purposes. If temporary workers are subject to the supervision of the using subcontractor, the temporary help supply service contractor is acting merely as a personnel department for the using subcontractor, and the using subcontractor must keep the records for the personnel supplied by the service. If the temporary workers remain subject primarily to the supervision of the supply service, the records must be kept by the service. In short, the firm should usually keep the records responsible for the day-to-day direction of the employee's activities.

In most situations, the subcontractor supervises the employee's general work activities and is responsible for maintaining the employee's injury and illness records. There are exceptional situations, however, where the subcontractor has no responsibility for supervision of the employee's day-to-day work activities. In these cases, the prime contractor assumes responsibility for recording his or her injury and illness experience on its records; hours worked for this group of employees should also be obtained. Independent truck drivers operating on a contract basis are not generally considered employees of the company for which they are hauling (the using firm).

Workers' Compensation

Workers' compensation data and costs are directly linked to labor operations safety, so the question always comes up in citation defense: What entries, if any, need to be made in instances of employer–OSHA disputes involving state workers' compensation measures to determine the facts related to the alleged violation that lead to the citation? Workers' compensation determinations should not impact the recordability of cases under OSHA. Some cases may be covered by workers' compensation but are not recordable; others may be OSHA-recordable but are not covered by workers' compensation. Cases historically have been evaluated solely on the basis of OSHA requirements.

However, the courts have held that the decision as to whether an injured employee is capable of working must be the employer's. There are often cases in which the employer and the employer's physician feel certain that an employee is perfectly able to perform normal job duties, but the employee and the employee's physician disagrees. If the employer is absolutely certain about the case, it should not be entered on the log, OSHA form 200. If the employer has any doubt about the case, it should be entered on the log and lined out later if it turns out that, in fact, the employee was able to perform his or her job. The employee may file a complaint to OSHA if he disagrees with the employer's decision.

The employer always decides what is recordable. The employer may delegate the responsibility to someone else or may rely on the determination of a doctor, but the responsibility for the decision is ultimately the employer's. And although employers ultimately decide if and how a particular case should be recorded, their decision must not be an arbitrary one. It should be made in accordance with the requirements of the act, the regulations, the instructions on the forms, and these guidelines. Information from medical, hospital, or site supervisors' records should be reviewed along with other pertinent information, and the employee should be interviewed to determine his or her medical condition and ability to perform normal job duties.

Distinguishing Between Injuries and Illnesses

Under the OSH Act, all work-related illnesses must be recorded, while only those injuries that require medical treatment (other than first aid) or involve loss of consciousness, restriction of work or motion, or transfer to another job are recordable. The distinction between injuries and illnesses, therefore, has significant record-keeping implications.

Whether a case involves an injury or illness is determined by the nature of the original event or exposure that caused the case, not by the resulting condition of the affected employee. Injuries are caused by instantaneous events in the work environment. Cases resulting from anything other than instantaneous events are considered illnesses. This concept of illness includes acute illnesses that result from exposures of relatively short duration. An occupational injury is defined on the back of the log and summary form, OSHA form 200, as follows: "*Occupational injury* is an injury such as a cut, fracture, sprain, or amputation that results from a work accident or from an exposure involving a single incident in the work environment." *Note*. Conditions resulting from animal bites, such as insect or snakebites, or from one-time exposure to chemicals are considered to be injuries. A single incident involving an *instantaneous* exposure to chemicals is classified as an injury.

An occupational illness is defined on the back of the log and summary form, OSHA form 200, as follows:

> *Occupational illness* of an employee is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to environmental factor's associated with employment. It includes acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact.

Some conditions may be classified as either an injury or an illness (but not both), depending on the nature of the event that produced the condition. For example, a loss of hearing resulting from an explosion (an instantaneous event) is classified as an injury; the same condition arising from exposure to industrial noise over a period of time would be classified as an occupational illness. Similarly, irritation of the throat from exposure to chlorine gas fumes could be classified as either an injury or an illness. If the exposure was instantaneous and occurred when a cylinder of gas ruptured, the case would be considered an injury. The case would be considered an illness if the employee was exposed to the agent over time, such as by working in an area where chlorine fumes from a bleaching process were present.

This method for recording certain types of cases has its foundation in industrial safety practice. The safety measures required to avoid instantaneous events are considered fundamentally different from those required to prevent exposures over a period of time which result in conditions of ill health. The classification of a case as an injury or an illness is intended to reflect this distinction.

Case defense is built around the basic definition of an occupational injury and includes those cases that result from a work accident or from an exposure involving a *single instantaneous incident* in the work environment. Contact with a hot surface or a caustic chemical that produces a burn in a single instantaneous moment of contact is an injury. Sunburn or welding flash burns that result from prolonged or repeated exposure to sunrays or welding flashes are considered illnesses. Similarly, a one-time blow that damages the tendons of the hand is considered an injury, while repeated trauma or repetitious movement that produces tenosynovitis is considered an illness.

The court has held that the basic determinant is the single-incident concept. If the case resulted from something that happened in one instant, it is classified as an injury. If the case resulted from something that was not instantaneous, such as prolonged exposure to hazardous substances or other environmental factors, it is considered an illness.

Recordability Defense

This section presents guidelines for determining whether a case must be recorded under the record-keeping requirements of the OSH Act and 29 CFR Part 1904, as well as how to classify recorded cases. These requirements should not be confused with record-keeping requirements of various workers' compensation systems, internal industrial safety and health monitoring systems, the ANSI Z.16 standards for recording and measuring work injury and illness experience, and private insurance company rating systems. Reporting a case on the OSHA records should not affect record-keeping determinations under these or other systems, and vice versa. Recording an injury or illness under the OSHA system does not necessarily imply that management was at fault, that the worker was at fault, that a violation of an OSHA standard has occurred, or that the injury or illness is compensable under workers' compensation or other systems.

At the outset, it should be noted that the scope of recordability of the defending against citations system detailed in this chapter might be broader and more inclusive than that of most other record-keeping systems. Some injuries and illnesses are included that may not be compensable in the workers' compensation context, or recordable under individual company safety and health record-keeping systems. These cases were included to make the system as equitable as possible and consistent with the language and intent of the OSH Act and regulations.

The alternative of developing a detailed list of exceptions for not recording specific injuries and illnesses was felt to impose far greater administrative and reporting burdens on most employers than requiring that a relatively small number of borderline cases be recorded. The OSH Act provides a basic description of which cases are to be recorded. The record-keeping regulations in 29 CFR Part 1904 provide specific recording and reporting requirements that comprise the framework of the OSHA record-keeping system. The regulations also expand upon the basic definition of recordability in the act.

In some citation defense situations, the criteria of the regulations or the related guidelines listed in this book may seem inappropriate. However, it would be virtually impossible to enact legislation, draft regulations, or issue guidelines that address every possible record-keeping situation. The required record keeping is done by different systems currently encompassing over 7 million workplaces throughout the United States. Wide variations exist in the training of individuals, making record-keeping determinations and the resources that firms can allocate to the record-keeping process.

Record-keeping criteria must be sufficient to meet the needs of the law. Safety and health professionals maintain complex programs, but the system must also remain comprehensible to those maintaining records without the benefit of specialized safety and health training (such as some employers with small-sized establishments) and the approximately 75 million employees involved in the record-keeping process through the posting and access provisions of the regulations. Although generally well intentioned, employers or trade associations are discouraged from formulating their own guidelines for recordability that differ in substance from these guidelines or deviate from the OSHA regulations.

If employers follow different guidelines, differences in interpretation might be injected into the system that could jeopardize the uniformity of the records and the validity of the statistical data. The OSHA guidelines represent official agency interpretations of employer record-keeping requirements. They provide record-keeping principles that were developed through a cooperative effort between government, business, and labor prior to and following the implementation of the act. The guidelines provide the Department of Labor's interpretation of the requirements of the OSH Act and regulations. They are supplemental instructions to the record-keeping forms.

METHOD USED FOR CASE ANALYSIS

Sections 8 (c)(2) and 24 (a) of the OSH Act provide the basic definition of the types of cases to be recorded: "... work-related deaths, injuries and illnesses other than minor injuries requiring only first aid treatment and which do not involve medical treatment, loss of consciousness, restriction of work or motion, or transfer to another job."

Part 1904.12 (c) of the CFR contains a definition of recordable injuries and illnesses, which follows this language and incorporates criteria for determining the extent or outcome of these cases. Under this part, injuries and illnesses are classified as deaths, lost-time cases, or non-lost-time cases.

The definition of a recordable case in the heading of the log (OSHA form 200) reflects the language of the regulations:

> RECORDABLE CASES: You are required to record information about every occupational death; every nonfatal occupational illness, and those *nonfatal occupational injuries* which involve one or more of the following: loss of consciousness, restriction of work or motion, transfer to another job, or medical treatment (other than first aid).

This definition provides sufficient guidance for the analysis of the vast majority of cases under the OSHA record-keeping system. Only a very small proportion of the cases requires additional criteria to determine recordability.

FAULT

Fault plays no role in the OSHA record-keeping system. Occupational injury and illness statistics produced by such a system would not accurately reflect overall worker experience (i.e., it would be missing those cases reported for which employers are not at fault) and consequently would not satisfy the coverage requirements of the OSH Act. Section 2 (b)(12) of the act states that one of its purposes is to provide for appropriate reporting procedures "... which will accurately describe the nature of the occupational safety and health problem." Sections 8 (c)(2) and 24 (a) of the act specifically define what is a recordable injury.

OSHA makes no distinction between incidents that are compensable under state workers' compensation laws, incidents caused by employer neglect, incidents that are preventable, or the random incidents that seem to happen when no one is at fault. The concept of fault has never been a consideration in any record-keeping system of the U.S. Department of Labor, nor has it been incorporated into various state workers' compensation systems or statistical systems of other agencies and organizations such as the ANSI.

In addition, there would be serious practical limitations. Recording cases on the basis of fault would necessitate the introduction of extremely complex recording criteria to be evaluated by both employers and employees. And whose judgment would prevail as to who was at fault in causing the injury or illness? Such determinations would almost certainly result in employers and employees contesting a significant number of record-keeping decisions.

For a case to be recordable, the worker must have been an employee of the firm at the time of the injury. Workers are considered employees while in pay status. In this context, pay status refers to the overall employment relationship whereby the worker is receiving wages or some other form of compensation from the employer for services rendered. It does not mean that the worker must be involved in some specific job task at the time of the injury or illness exposure for the case to be recordable, or that cases are recordable only if they occur during hours for which wages are paid.

10

Project Scheduling Contingencies

SCHEDULE ACCELERATION

Acceleration of the work is usually the result of an attempt by the prime contractor to apply whatever means and take whatever measures are necessary to complete the work sooner than would normally be expected for a given project under stated contract conditions. Or schedule acceleration is an attempt by the prime contractor to take extra measures to make up for delays (whatever the cause is) by utilizing whatever means are at the contractor's disposal to accomplish that objective. There are two primary types of schedule acceleration: directed acceleration and constructive acceleration

A directed acceleration occurs when the owner or architect, at the owner's direction and authority, orders a contractor to speed up the work. The owner is definitely in this legal position if it advanced the contractor's finish date. The necessary elements of a constructive acceleration claim have been outlined by the U.S. District Court as follows:

> Constructive acceleration is present when:
>
> 1. The contractor encountered an excusable delay entitling it to a time extension;
> 2. The contractor requested an extension of duration time;
> 3. The request was refused;
> 4. The contractor was ordered to accelerate its work, that is, to finish the project as scheduled despite the excused delays; and
> 5. The contractor actually accelerated the work.

In considering the liability of project schedule acceleration, the court's first consideration is whether the acceleration is the result of an order from the owner to a contractor who is behind schedule to get back onto schedule, or an order from the owner to the contractor requiring that the contractor, either directly or constructively, to complete the work prior to the scheduled completion date.

If the contractor is behind schedule and the owner requires the contractor to get back on schedule, it is sometimes necessary to direct the contractor to take whatever means are necessary to assure completion by the originally scheduled completion date. Herein lies an administrative risk for the project scheduler and the owner (or its agent). If an order is issued to the contractor directing it to accelerate the work so as to catch up or make up for delays or lost time, the risk is that the contractor will perform as directed, then submit a claim for directed acceleration. This is an old poker game tactic in the business; it goes like this: The contractor would argue that although it appeared from the original schedule that it would not complete on time, there was originally no risk of failing to complete on time. The contractor would state that in the absence of the acceleration order it would have finished on time anyway and is now due more money claim for directed acceleration from the owner.

The proper handling of this type of situation is not to issue an acceleration order (even though acceleration is justified or needed), but to send a registered letter to the contractor calling attention to the fact that completion by the scheduled date will be required. And that "according to the schedule it appears that the contractor will be unable to complete the activity by the completion date indicated in the contract. A revised schedule shows how the contractor plans to complete the activity by the scheduled date." This leaves the means and methods to the contractor, as well as responsibility.

Often the problem starts in the architect's design office. Project completion dates or time available to complete is frequently established by an architect or design professional who has had little field experience, and thus is not qualified to properly establish the real-world time duration needed to complete all the activities of the project. Typically you will see examples of this in activity durations that are too long or too short.

If insufficient time is allotted to the completion of a project, all the bidders will be forced to bid the job as accelerated work, thus increasing the costs materially. One indication that this may be happening comes when all the bids are in and, although they are grouped close together (a good sign of competent documents), they are all considerably in excess of the architect's estimated project cost. This can be evidence that all the bidders are bidding on the job as accelerated work. This will increase the cost of construction above that for the same job completed within a normal CPM schedule.

Another risk in project scheduling contingencies surfaces here as well. After figuring a bid for a job as being all accelerated work, a bidder may look in the contract documents to determine how much liquidated damages are being assessed in case of a completion delay. Upon finding daily liquidated damages to be assessed, the bidder refigures the bid to include that amount.

In the foregoing example, let us assume that we plan to build a project that on a normal CPM schedule should take 16 months to complete, but the contract documents actually indicate the completion must be within 14 months, including 2 months' acceleration of work. Then the bidder will most certainly check the amount of liquidated damages called for in the contract documents. Let us presume the amount of liquidated damages was only $500 per day. An enterprising bidder will now go back to its 14-month bid and refigure the costs for completion in 16 months instead of the required 14 months. Then the bidder will determine that the owner allowed that the difference in time for completion versus the time that a job such as that should normally take was 2 months, or 44 working days. The bidder now multiplies 44 times $500 per day and adds the amount of liquidated damages to its total bid for doing the work in 16 months, and submits it as its bid price.

The problem here is that the cost of liquidated damages (at $500 per day) is considerably less than the daily cost of acceleration to the contractor. Thus, the bidder submits a bid claiming that it will complete on time, when in fact it planned from the very beginning to complete the work two months late and pay liquidated damages costs. The owner and architect turn out to be the only persons who were unaware that the project was destined to be late before it was even started. Generally speaking, any job that has a resident project manager operating out of an on-site field office can justify in excess of $1000 per day of liquidated damages without difficulty. Typically in commercial construction in California, this figure starts at $2500 per day and goes upward. Only these types of amounts serve as a deterrent to the contractor for finishing late.

A related condition called "deceleration" can also be experienced on a project's schedule. This occurs when a contractor is directed in writing or constructively to slow down its job progress. Many of the same considerations that apply to acceleration also apply to deceleration. In preparing for a claim for acceleration or deceleration, keep in mind that the costs to the contractor for going into premium time, such as working an extended workweek, cannot be computed simply as including the added hourly costs multiplied by the additional hours. Studies have shown that, as the workweek is extended, there is an accompanying drop in productivity. As extended overtime continues, the productivity rate continues to drop.

PROJECT SCHEDULE PRODUCTIVITY LOSSES

Scheduled overtime is not often seen on competitively bid lump sum contracts, as most contractors are well aware of the negative effects of overtime on cost and productivity. Simple arithmetic shows that premium pay for double time or time-and-one-half makes overtime work much more expensive.

However, people who insist on overtime seldom realize that other costs associated with overtime may be even more significant than premium pay. Premium pay affects only overtime hours, but continuing of scheduled overtime drastically affects costs of all hours. All available research indicates a serious inverse ratio between the amount and duration of scheduled construction overtime and the labor productivity achieved during both regular and overtime hours.

Studies have shown that, in the first few weeks of scheduled overtime, total productivity per person is normally greater than in a standard 40-hour workweek, but not as high as it should be considering the number of additional work hours. After 7 to 9 consecutive 50- or 60-hour workweeks, the total weekly productivity is likely to be no more than that attainable by the same workforce in a standard 40-hour workweek. Productivity will continue to diminish as the overtime schedule continues.

After another eight weeks or so of scheduled overtime, the substandard productivity of later weeks can be expected to cancel out the costly gains made in the early weeks of the project's overtime schedule. This means that the total work accomplished during the entire period over which weekly overtime was worked will be no greater, or possibly even less, than if no overtime had been worked at all.

When the loss of productivity is combined with the higher wage cost (including premium pay), productive value per wage dollar paid after several weeks of scheduled overtime, drops to less than 75% for five 10-hour days. And less than 62% for six 10-hour days, and less than 40% for seven 12-hour days. When an overtime schedule is discontinued, it has been found that there was a dramatic jump in productivity per hour after returning to a 40-hour workweek.

Construction delay claims involving acceleration of the work usually include claims for loss of productivity, which often exceed all other claimed amounts. The following breakdown of a claim on a public works job illustrates the relative magnitude of the claim for loss of productivity, as compared with the other issues shown:

1.	Extended project overhead	$ 1,019,099
2.	Unabsorbed home office overhead	227,620
3.	Labor escalation	142,430

4.	Material escalation	148,329
5.	Labor loss of productivity	2,442,409
6.	Subcontractor claims	920,407
	SUBTOTAL	$ 4,900,284
7.	Profit and overhead on items 1 to 5	1,298,575
8.	Unresolved changes	157,993
9.	Interest on money	1,073,897
10.	Additional bond premium	11,844
	TOTAL CLAIM	$ 7,442,593

Suspension of the Project Schedule

For any of several reasons, the owner can usually suspend the work on a project. In each case, the owner or its agent should keep detailed cost isolation records of all activities affected by the suspension. It should be kept in mind that suspension of the work for any amount of time, such that the completion date is extended, may impact the contractors' costs through unabsorbed home office overhead and the real possibility of missing other projects due to the delay.

The contractors may also claim the effect upon their organizations of the costs related to demobilization, direct costs, settlement expenses, escalation costs, prior commitments, post-termination continuing costs, unabsorbed overhead, unexpired leases, severance pay, implied agreements, restoration of work, utility cutoffs, inventory, replacement costs, and all other allocable costs. On suspensions of the work, be certain that all such orders are in writing and that a careful, detailed record is kept of its total effect on each contractor's time and costs.

CHANGE ORDER PRICING

One of the most common causes of contractor claims occurs during attempts to price change orders. Typically, owner change orders contain a waiver clause that requires the contractor to guarantee that the price and time named in each individual change order represents the total cost to the owner for that change, and the contractor waives any rights to impact costs.

This, unfortunately, leaves the contractor only one recourse: the claims litigation process. The claims courts have traditionally held that an owner may not force a contractor to "forward price" its impact costs when pricing an owner-directed change. The court has written:

> While it might be good contract administration on the part of the owner to attempt to resolve all matters relating to a contract

modification (change order) during the negotiation of the modification, use of a clause which imposes an obligation on the contractor to submit a price breakdown required to cover all work involved in the modification cannot be used to deprive the contractor from its right to file claims.

PROJECT SCHEDULE CONFLICTS

This is an often-misunderstood area in contractor claims against the project. However, the probability of recovery by the contractor as the direct result of such conflicts is good, insofar as the settlement is limited to the cost difference between the project cost as the plans and the owner or architect and the contractor interpret specifications.

Public works contracts are called *contracts of adhesion*, which is a term applied to contract documents that are drawn by one party and offered to the other party on a take-it-or-leave-it basis, where there can be no discussion of terms nor contract modification by the other party. The contractor, however, does have one advantage. In case of ambiguity, the court will interpret the contract in the contractor's favor. This does not relieve the contractor from the obligation of building the work in accordance with the interpretation of the architect or design professional, but only assures that the contractor be paid.

Frequently, the contractor will find that outdated standards are specified or that products are named that no longer exist. Often, the specification will contain references stating that, wherever codes or commercial standards are specified the contractor is obligated to use the latest issue of that standard existing at the time the project went to bid. Unfortunately, in many cases the designers considered the fact that the design was based on an old standard that existed in their files or on a standard that was current during the design phase but that later may have been updated by the sponsoring agency without the designer's knowledge.

Occasionally, serious difficulties arise from such practices, and the contractor has the legal right to assess the project cost difference resulting from the error. Perfect specifications are hard to find, so the contractor must make a reasonable interpretation at the time of bidding the job and will then be in a good position for recovery if a variance exists. The contractor's interpretation must be based on what a reasonable person would interpret the documents to mean; then the contractor will have the court on its side.

A contractor should never attempt to construct any questionable area, or change, without first submitting to the owner or architect a request for clarification, or notifying them of an error. This is known as an RFI (request for information) or an RFC (request for clarification). In most contract forms, failure to do this may bar full recovery of contractor costs.

Other problems that often come up in project scheduling are directly related to the conduct of the owner's representatives on the job, such as the project manager's or site supervisor's issuing changes in the work that are of such magnitude as to constitute a major change that creates a breach of contract. Or, on a lesser scale but indirectly related, where one activity subcontractor may negligently delay another, which may result in the owner's seeking recovery from the negligent contractor to pay the contractor that was harmed. Some of the types of scheduling problems that fall into this category include the following:

Damage to work by other prime contractors in fast-track scheduling
Breach of contract
Cardinal changes
Beneficial use of the entire project before completion
Work beyond contract scope
Partial utilization of the project before completion
Owner nondisclosure of site-related information
Owner's failure to make payments when due

Scheduling techniques, such as CPM or other network scheduling systems and their associated computer-generated printout sorts, also have compounded problems between the project team and the work contractors. Often the owner is swamped with stacks of computer printouts that he either does not want or does not know how to read. Yet somewhere in that stack of paper may well be the key defense against claims being made against the project and the owner. The question of scheduling methods of operation, and the impact of deviating from the anticipated schedule, requires a careful analysis to determine the reasonableness of the originally anticipated schedule in conjunction with the planned methods of operation.

The analysis of every schedule-related problem is unique, and every such analysis should include a review of the anticipated sequence and schedule together with a review of the actual progress of the work. The review must include an analysis of any delays and impacts caused by all parties to the progress of the project. It is in the presentation of the sorts, containing cost data and their supporting documentation, that most construction claims are the weakest. A carefully detailed reconstruction of all construction activities and their related costs must be made and presented so that they can be clearly identified for use in negotiating affirmatively or defensively. Construction-related organizations are reported to be poor in their cost record-keeping systems (or lack of systems), and they traditionally lack the ability to assign costs to possible claims areas.

An accounting firm is not the answer either, because often those cost items relating to an accounting firm does not identify potential claims. Most accounting firms are not familiar with the cost-control procedures for construction contracts. A project scheduler who realizes this, and takes steps to structure and run cost-tracking and audit-trail sorts, will provide his or her clients with the best form of protection against claims. Remember that records are the owner's first line of defense in construction litigation documentation; if not by the accountant, then by the project team. The responsibility may get assigned to the project scheduler for computer recordation and tracking. The accounting operations must cover all the necessary payroll functions, and the following employment laws must have tracking:

1. All wages earned by any person working for an activity subcontractor for hourly wages on the project are due and payable at least twice during each calendar month. Labor performed between the 1st and 15th days must be paid for between the 16th and 26th day of the month. Work performed on the project between the 16th and the last day of the month must be paid between the 1st and 10th day of the following month. However, the salaries of administrative or salaried management employees may be paid monthly.
2. In a case of dispute over wages, the activity subcontractor must pay all wages conceded by him to be due, leaving the employee the right to dispute the remaining amount.
3. Every activity subcontractor employer must keep posted conspicuously at its place of work a notice specifying the regular pay days and the time and place of payment.
4. In the event of a labor strike, the unpaid wages earned by the striking employees must become due and payable on the next regular payday.
5. No activity subcontractor must issue in payment of wages due any check or draft unless it is negotiable and payable in cash upon demand.
6. No activity subcontractor must issue script, coupons, or other things redeemable in merchandise as payment for wages.
7. An activity subcontractor may not withhold from any employee any part of the wages unless required by the government.
8. No activity subcontractor must charge a prospective employee for any pre-employment medical or physical exam or charge an employee of the same.
9. Every activity subcontractor must, semimonthly, at the time of each payment of wages, furnish each employee, either with a detached part of the check paying the employee's wages, or separately, and an itemized statement in writing showing:

Gross wages earned plus deductions (SDI, FICA, state, and federal taxes)
Net wages earned

Dates of work period
Name of employee or Social Security number
Name and address of employer

10. Every activity subcontractor who pays wages in cash must, semimonthly or at the time of each payment of wages, furnish each employee an itemized statement in writing, showing all deductions, dates of work period, name of employee and Social Security number, and the name and address of the activity subcontractor.

11. Whenever an activity subcontractor has agreed with any employee to make payments to a health or welfare fund, pension fund, or vacation fund, it is unlawful for the activity subcontractor to willfully or with intent to defraud or fail to make the payments required by the terms of any such agreement.

12. No activity subcontractor must demand or require an applicant for employment or any employee to submit to or take a polygraph or lie detector test as a condition of employment or continued employment.

13. No activity subcontractor must require any prospective employee or any employee to disclose any arrest record that did not result in conviction.

14. Eight hours of labor constitutes a day's work, unless stipulated expressly by the parties to a contract. No employee must be required to work more than 8 hours per day or more than 40 hours a week unless time and one-half is paid.

15. Each person employed is entitled to one day's rest in seven. Violation of this law is considered a misdemeanor.

16. Labor laws usually apply to those hours exceeding 30 hours a week. Employment that does not exceed 30 hours in one week or 6 hours in one day is considered part-time and is not protected by the same laws.

17. No activity subcontractor must force any employee to join or not join a labor union.

18. An activity subcontractor who seeks to replace employees on strike or not working due to a lockout must be permitted to advertise for replacements if such advertisement plainly mentions that a labor dispute is in progress.

19. A strike means an act of more than 50% of the employees to lawfully refuse to perform work.

20. A lockout means any refusal by an activity subcontractor to permit any group of five or more to work as a result of a dispute over wages, hours, or condition of employment.

21. A jurisdictional strike means a concerted refusal to perform work for an employer arising out of a controversy between two or more labor

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unions as to which of the unions has or should have the right to bargain collectively with an employer. This type of strike is illegal in most state courts.

22. The Labor Commissioner may issue a citation to any activity subcontractor disobeying these labor laws. The activity subcontractor has, upon receipt of the citation, 10 days to request a hearing of contestment.

23. A collective bargaining agreement is an agreement between management and labor to which they have collectively agreed following a period of bargaining. These agreements are enforceable in most state courts.

24. Where a collective bargaining agreement contains a successor clause, such an agreement must be binding upon any successor activity subcontractor who purchases the contracting activity subcontractor's business until expiration of the agreement or three years, whichever is less.

25. Professional strikebreaker means any person who repeatedly offers himself for hire to two or more employers during a labor dispute for the purpose of replacing an employee involved in a strike or lockout.

26. A minor under 16 years of age is forbidden to (1) Work on any job power-activated machines or power tools; (2) work on scaffolds; (3) work on excavation work; (4) drive vehicles; (5) work with dangerous or poisonous acids; (6) work in tunnels or other types of excavation.

27. No discrimination must be made by any activity subcontractor in the employment of persons because of race, religion, color, national origin, ancestry, physical handicap, medical condition, marital status, or gender.

28. Nothing must prohibit an activity subcontractor from refusing to hire or from discharging a physically handicapped person unable to perform duties or whose performance would endanger his health or the health or safety of others.

29. It is unlawful for an activity subcontractor to refuse to hire or employ, discharge, dismiss, suspend, or demote any individual over the age of 40 on the grounds of age unless the person fails to meet the bona-fide requirements for the job. This must not limit the right of an activity subcontractor to select or refer the better-qualified person from among all applicants for the job.

30. Activity subcontractors must keep all payroll records, showing the hours worked daily, wages paid, etc. for at least two years.

31. No activity subcontractor must knowingly employ any nonresident individual who is not entitled to lawful residence in the United States if such employment would have an adverse effect on lawful resident workers.

32. No deduction from the wages of an employee on account of his coming late to work must be made by the activity subcontractor in excess of the proportionate wage that would have been earned. For a loss of time of less than 30 minutes, one-half hour may be deducted.

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33. Every activity subcontractor having one or more employees is subject to the Social Security laws of the Internal Revenue Service.

34. Each activity subcontractor must secure an employer's identification number from the Internal Revenue Service or from the Social Security Administration.

35. Each activity subcontractor must ascertain each employee's correct Social Security account number and copy it directly from the employee's Social Security number card when he or she starts work.

36. Every activity subcontractor who has one or more employees in his employ and pays wages in excess of $100 or more during a calendar quarter becomes an employer under the Unemployment Insurance Code and is subject to its provisions. Everyone who becomes an employer is required to register within 15 days with its state's Employment Development Department.

PREDICTABLE PERILS

Contractual financial penalties for late completion of a contractor's activity are liquidated damages that are daily cash *penalties*, which start in the thousands of dollars per day and go ballistic from there. On the other side of the coin, delays of the contractor's work schedule due to owner, architect, or project team fault are back-chargeable to the project in the form of *claims*. Lost time, lost project profits, lost use of the project in terms of unrecoverable capital income loss to the owner, liquidated damages charged to the general contractor, probable litigation among all parties, and poor-quality workmanship are all results from overruns in network scheduling. Because of the amount of money involved, vested parties and contractors frequently run into expensive disputes. Usually, both parties throw away even more money by hiring lawyers and expert witnesses and going into all-out litigation warfare.

These problems can usually be traced to inadequate float assigned within the critical path(s). This condition always burns up the allowable total float in the project at the first sign of trouble, and any further float necessary later on in the project must be "borrowed" from the remaining activities. I use the term "borrowed" because that is how it is defined in the trade. However, in reality, what does not exist cannot be borrowed. That's the truth of project scheduling, pure and simple—although the truth is rarely pure and never simple.

Disputes among the chain of command during the course of your project's production will be commonplace. Stuff happens all the time. Court dockets are full of construction litigation suits. Construction management professionals are currently hired by lawyers and legal referral systems at a prevailing rate of $300 to 500 per hour and upwards, plus all expenses, to appear as expert witnesses. In three of the cases I have sat in on, the project schedulers as well as the project managers were subpoenaed and/or depositioned. All but one of them were intimidated by the proceedings and made a weak showing of the strength of their project's CPM schedule's audit trail and accompanying backup documentation.

Requiring the prime contractor to construct and maintain a CPM project schedule has at least three advantages that should be utilized fully. First, a CPM schedule requires the contractor to work more efficiently. Second, it gives the owner notice of the actual progress of the work. Third, from a litigation standpoint, requiring the contractor to maintain a CPM schedule helps prove or disprove construction claims and helps to quantify the impact of an owner-caused delay.

Many contractors do not usually have high-degree sophisticated software in their computer programs, and the odds are against a contractor's efficiently scheduling a large CPM network showing 10 different critical paths with the same duration. Invariably, this type of scenario results in unforeseen change orders and claims that typically go to litigation. This situation can often be foreseen in a contractor's network CPM schedule, while the same situation will not show up in project phase scheduling.

CLAIMS

Contractors using their own CPM network scheduling can circumvent the general conditions and specifications of the contract by the use of claims. The contractor anticipates that the owner will delay at least two of the critical paths (on a multiple critical path network) that make up the project's production schedule, thus allowing the contractor to file claims against the owner. Claims are monetary reimbursements, usually in cash or canceling off certain punch-list items chargeable to the contractor, that are levied against the owner for delaying the contractor's work schedule. This results in cost overruns and blowing the budget. The tactic of eliminating as much float as possible from the network puts the owner at a cost disadvantage in network analysis, and smart contractors know this.

So, the experienced owner may try to nullify this contractors' claims technique through clauses in the schedule specification that direct the contractor to redraw the network any time it is behind schedule on any specified critical path. In the accompanying project scheduling software, this condition is shown on the Sort by Total Float file in the Negative Float column whenever an activity falls behind schedule. The owner's project team will attempt to resolve these and other scheduling problems and will always move to gain management control over claims.

Usually, the project manager will make the stipulation in the contract for one or more of the several network scheduling techniques currently available. Such specifications would be written with the intent to boilerplate (cover all bases for) the owner's protection. With a combination of appropriate general conditions and supplemental general conditions, such specifications can be quite complex.

One can easily see that the whole process can, and often does, wind up in claims and litigation. Many court decisions have been rendered on such claims, but none seems to have solved the problem. Now that you see both perspectives, you can understand how, in project scheduling, your use (or nonuse) of different types of float in your phase scheduling can benefit either the owner or the contractor (whichever is your client).

This is how we do it. To prevent creation of artificial networks by the contractor, those schedules traversed by more than one critical path should require a contractual agreement between the owner and the contractor prior to the start of the work or any change in work's scope. To prevent manipulation of activity duration by the owner, networks with several near-critical paths should be subject to resource (labor hours, equipment hours, dollars, etc.) and quantity (permanent material) analysis with respect to activity duration.

Owners and contractors should be required to review and approve such analyses prior to the start of work or the start of change-of-scope work. In today's business combat, control in this area is another profit maker for the modern project scheduler. Such performance analyses should consider the following:

1. Budgeted rate of quantity installation as a function of time
2. Budgeted rate of resource usage as a function of time
3. Budgeted consumption of resource usage as a function of quantity, type, and time

All parties should agree upon the results of these calculations (or other performance calculations) to each activity under potential dispute prior to performing the work. To prevent improper consumption of float by either party, distributed float calculations can be used. Distributed float allocates float to each and every activity. Using such a targeted approach will always predetermine who gets what float. Relative to who has hired you, you now know how to swing the scales on their behalf.

AIA Document A201, Section 4.3.1, delineates the parameters of acceptable and enforceable delay claims submitted by the contractor. These requirements can make it difficult for a contractor who does not keep detailed weather records to claim a time extension for adverse weather conditions. They reflect a belief by the AIA that weather generally is a risk assumed by the contractor and that only in extraordinary circumstances should weather be the basis for a time extension. The legal documents used by the courts to determine judgments in weather-related claims are a daily inspection report (DIR) and a quality assurance report (QAR). If the contractor or owner is unaware of these documents, then certainly you, the project scheduler, should be. And you should implement them on your client's behalf (whoever that may be) to protect its interests.

Another reason for not granting a time extension is the single-contract system's objective of centralizing administration and responsibility in the prime contractor. Only if subcontractor-caused delay is specifically included should it excuse the prime contractor. This needs to be stated within the contract specifications to protect your client from the schedule's default through circumstances beyond your control. The independent contractor rule, though subject to many exceptions, relieves the employer of an independent contractor for the losses wrongfully caused by the latter.

Prime contractors sometimes assert that the subcontractor is an independent contractor, inasmuch as the subcontractor is usually an independent business entity and can, to a large extent, control the details of how the work is performed. Even so, the independent contractor rule does not relieve the employer of an independent contractor when an independent contractor has been hired to perform a contract obligation, and the party who suffers the loss caused by the independent contractor is whom the contract obligation is owed. In the construction contract context, the owner usually permits the prime contractor to perform obligations through subcontractors. This does not usually mean that the prime contractor is relieved of its obligation to the owner, unless the owner specifically agrees to exonerate the prime contractor. The residuary power of agency granted to the architect to grant time extensions has been criticized as leading to a deterioration of any fixed completion date. It does have the virtue of not forcing the architect to think of every possible event and include it in the contract specifications as a "catalog of events" justifying a time extension.

Another portion of contract law affects the project schedule, and that is AIA Document A201, Sections 4.3.3 and 4.3.8.1, which cover time extensions in construction contracts. These usually provide a mechanism under which the contractor will receive a time extension if it is delayed by the owner or by designated events such as those described in the contract specifications. Increasingly, contractors make large claims for delay damages. As a result, it is becoming even more common for clauses in the contracts, particularly public contracts and private ones drafted with the interests of the owner in mind, to attempt to make the contractor assume the risk of owner-caused delay.

Public entities are often limited by appropriations and bond issues. As a result, they must know in advance the ultimate cost of a construction project. Thus, many public entities use the disclaimer system for unforeseen subsurface conditions. Similarly, they wish to avoid having claims made at the end of the project, based on allegations that they have delayed completion or required the contractor to perform its work out-of-sequence. These public works and awarding authority entities recognize that barring claims may cause higher bids, but they would prefer to see bidders increase their bids to take this risk into account rather than to face claims at the end of the job.

Preparing for the troublesome question of the validity of no-damage clauses is not within the parameters of the project scheduler, but lies instead with the owner and/or the project team, so I will not delve further into this issue other than to make you aware of alternatives so that you (as the project's production scheduler) will have viable options to propose. One method used to eliminate or reduce the likelihood of such claims and delays to your schedule is to have the contract specify that the owner has the right to delay the contractor and that such interference is not a contract breach.

Another technique is to contend that any time-extension mechanism is the exclusive remedy. Generally, the availability and use of the time-extension mechanism does not imply precluded delay damages. The AIA's time-extension mechanism specifically states that it does not bar the contractor from recovering delay damages.

An indirect technique for limiting delay claims is to require written notice by the contractor, to the owner or the project team, if events have occurred that later will be asserted as justifying delay damages. This is the method that is currently taking preference nationwide in the construction industry, because it warns of potential claims in time to resolve the situation at the activity stage. Typically, this notice is stated to be a condition precedent to any right to delay damages. Historically, courts have not looked favorably on such clauses. Noncompliance with a notice provision can be the basis for barring a claim for delay damages and, as a contractual obligation, can "bulletproof" the situation as well as is currently possible without undue and unjustifiable constraint on the contractor.

Another common method to deny the delay damage problem outright by not setting up notice conditions or specifying what can be recovered is to configure the contract with no-damage or no-pay-for-delay clauses. Such clauses attempt to place the entire risk for delay damages on the contractor and to limit the contractor to time extensions. Generally, such clauses are upheld but are not looked on favorably by the courts and much less by contractors. A current modification on the "no-pay" or "no-damage" pro-

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vision clauses is to provide that the contractor can recover delay damages only after a designated number of days' delay by the owner.

A newer technique is to have contract clauses that permit some delay damages but avoid large claims for diminished productivity by an open-ended, total-cost formula. The method provides that the contractor can recover delay damages, but only for premiums paid on its bond and for wages and salaries of workers needed to maintain the work, the plant, and the equipment during the delay. California courts, however, have held that such clauses will not be enforced if there is affirmative or positive interference or a failure to act in some manner essential to the prosecution of the work.

These clauses have functions and ramifications that go deeper and are beyond the scope of this book. Whether such clauses should be included in a construction contract depends both on the likelihood of their being enforced in a legal case and on the willingness of the owner to take "front-loaded" costs (at the front end of the contract) rather than through claims at the end of the work. However, the use of these clauses in a highly competitive construction market will protect the project schedule somewhat by encouraging bidders to bid low and take their chances.

DISPUTE RESOLUTION

Velocity network diagram scheduling systems were originally developed as production management and cost-control tools in Europe, but like everything else efficient at making money, velocity network diagram scheduling has evolved significantly. Project schedulers learned how the system could be abused for their own advantage. Some developers and project teams have even used CPM scheduling as a litigation weapon, to secure as much profit as possible through denial of claims by contractors.

Conversely, prime contractors and subcontractors have been known to employ professional project schedulers to devise ways to give their particular business an edge on float in activity events, especially those on multiple critical paths. Modern computer network-based management systems that run a construction project like a mathematical clock can also create biased documents to support the originator's right to claims and extra work orders. Those who are familiar with software spreadsheets will nod in agreement with me here as I inform you that anyone can make wrong data look right in charts if it's presented with enough spreadsheet manipulation and corresponding bar graphs.

On the one hand, a contractor might create an artificial network with multiple critical paths. The contractor's intent would be to present claims if the owner caused delay on any of the paths. On the other hand, the owner might plan the project duration and then shorten it. The owner's intent would be to obtain a bid on the shortened duration and then hold the contractor to the time limit. Obviously, these practices reduce an otherwise effective management tool to a weapon for justifying or denying claims. The result has been more litigation over more claims.

Contractors and owners view the problem differently. A contractor might question whether an owner has a right to direct starts or delays for specific purposes. Owners, trying to manage project costs and overall scheduling, might ask whether they have the right to force the contractor to start an activity before an established late-start date. Too many of these late starts could cause problems toward the end of the job. For the owner, a week's slippage in a power plant's commercial operation date translates into a loss of several hundred thousand dollars. At the same time, improper or premature activity starts can cause serious hardship for a contractor, who may incur additional expense for equipment, material, labor, and other resources.

Very little float is in a network velocity diagram, and the owner is subject to claims at any time that it delays the prime contractor on any one of the multiple critical paths. This technique invariably gets the prime contractor off on the wrong foot when he submits the claims. The owner's project team will then resent the owner's implication that they were not smart enough to see through the contractor's ploy, and an adversarial relationship will be set up that will last for the duration of the contract. When requiring a CPM project schedule submittal from a contractor, it is wise to follow the Associated General Contractors guide specifications, which recommend that the network be comprised of individual work activities, each of which does not exceed 10 days' duration.

However, remember, information is power. These tactics are the domain of the professional project scheduler, and professional trade secrets should not be confided to others on less than a need-to-know basis. As Shakespeare wrote, "Once the deed is done, 'tis done forever and cannot be undone." Your prowess in these matters may or may not be something you wish others to know about. It's therefore recommended that your knowledge of manipulation techniques in network velocity diagramming be kept close to your vest.

Here's how we do it. Dispute resolution should be a contractual obligation appearing within the specifications. The order of precedence of resolution steps should be: mediation, arbitration, litigation . . . specifically, and in that order. Arbitration should be further specified as binding arbitration. In this manner, precedence is already established for resolving the inevitable arguments that will occur throughout the project's production.

Mediation

Mediation means that all parties try to iron it out among themselves, with no outside consultants or lawyers becoming involved. If the contract is written with the above precedence for dispute resolution, and if the dispute cannot be

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resolved at the mediation level, all parties must proceed to arbitration before leaping into litigation.

Arbitration

Arbitration proceedings are much more informal than court litigation proceedings. Arbitrations are generally held in conference rooms in private locations. Arbitration is usually heard before a retired judge or member of the Bar Association, and no lawyers are allowed. Arbitration is a lot less expensive than going to court. It is also a means to a quicker solution. I have always advised my clients to include a binding arbitration clause in all contracts.

If this clause is included, all parties are forced to arbitrate. The downside to arbitration is that although arbitration is cheaper and quicker than court litigation, if your side loses it is almost impossible to appeal the judgment decision in arbitration. Proceedings are arranged and conducted by the American Arbitration Association. However, the actual proceedings are left to the arbitrator's discretion. Meeting considerations, such as time, location, and agenda, are worked out among both parties and the arbitrator.

Arbitration expenses can sometimes be substantial, although typically less so than litigation. In arbitration cases lasting only one or two days, the arbitrator charges no fee. On the third day, the arbitrator begins to charge a fee that will be comparable to other legal professionals in the area (which will usually average three digits an hour), and proceedings will begin to get costly. Additionally, the filing fee for arbitration is based on the size of the claim. The winning party can usually recover the fees from the losing party. These fees can be split between both parties as part of the final award, at the discretion of the arbitrator.

Arbitration is typically faster than a court suit. Court litigation (especially in California) usually takes up to a year and a half to get to the first court date. The arbitration process, which includes the filing process, arbitrator selection, and calendar date, usually takes only a month to schedule. The entire arbitration settlement can take up to six months, typically one third of the time required for litigation cases.

Litigation

Lengthy court battle, exorbitant costs, 10 cents on the dollar return, and nobody wins but the lawyers.

TYPICAL CASE HISTORY

A contractor hired a professional project scheduler and, using the scheduler's CPM network, constructed a $9 million commercial building exactly per approved plans, only to find out during inspection that the structure did not meet code compliance due to an error by the building inspector. Who was liable for the cost overruns? This case scenario appears in many stories about planning or building departments being liable for mistakes they have caused or overlooked. Here are some facts based on previous court cases. Let's first deal with building officials. In several cases, such as *Chaplis v. County of Monterey*, the court held that, while the building official issued a permit in violation of a county ordinance, the county and its employees were immune from liability.

However, when the trial court in a construction-defect case dismissed a complaint against a building department official in Mammoth Lakes, the appellate court reversed the decision and held that the plaintiff stated a good cause if the representations made by the building official were shown to be false. So you see, it could go either way. Courts have traditionally held that building departments and their employees are immune from liability and that errors in design that are carried through the construction process revert to the architect or design professionals, who are held to be liable because they are supposed to be experts and are held to a "higher level of responsibility and accountability," and should be informed enough to spot an error before or during construction.

A contractor on a $12 million civil construction project submitted a CPM network schedule that had been meticulously prepared. Its court deposition stated that the only objective of the CPM schedule was to get the project done as quickly and cost-effectively as possible. Due to a public works department-caused delay, the contractor fell behind schedule. Later, the contractor submitted a claim for additional money and a 45-day extension. The awarding authority's engineers analyzed the contractor's network and showed that the contractor's succeeding activity event on the next major milestone on the critical path was delayed only 20 days. The awarding authority contended that 20 days' delay was all the contractor was entitled to. The contractor stated it was only through its diligence in accelerating its work that the delay was held to only 20 days, and the contractor should be entitled to the full 45 days.

The final court judgment was that the contractor could not support its 45-day claim because of improper schedule monitoring. The awarding authority's engineers had been able to do a better job of network analysis than had the contractor, and the contractor had to settle for the expenses he could prove. Despite the fact that it was public works' delay, the contractor was, in effect, financially penalized for maintaining the schedule because of its activities improper schedule monitoring by public works.

In *Miller v. Delcon Development Corporation*, Mr. Miller was a subcontractor who complained to the project owner, Delcon Corp., that the prime contractor had failed to pay him for his time and materials. The owner wrote a letter to Mr. Miller requesting that Miller send them a stop notice. Mr. Miller never did, but he did file a preliminary notice in a timely manner. The court held that if a subcontractor in a CPM network contract does not respond to a letter such as the one written by the owner, he loses his lien rights and stop notice rights. The final judgment was that Mr. Miller had lost his lien rights as a result of not giving the owner a stop notice. His only recourse was to sue for liquidated damages in civil court, which he tried and lost.

MULTIPLE CRITICAL PATH

A prime contractor on a $14 million industrial building project submitted a CPM project schedule in compliance with the owner's specifications. There were four zero-float paths and seven critical paths. The prime contractor later stated that he was anticipating that the project team would delay one or more of the seven activities that were a part of the critical paths, thus allowing the contractor to file claims against the owner, which the contacting company did at project completion.

This type of bid getting is known in the trades as "low-balling." During mediation, the owner's project team cited the seven critical paths as an unrealistic approach. The contractor responded that it was the contractor's plan of work and the owner did not have any right to alter it once the contract had been signed. The mediation went unresolved into arbitration and later into litigation.

What had the contractor done to his network, and what was achieved? First, he increased the duration of routine concrete pours to three times their normal duration. If requested to shorten this duration, he planned to request payment for accelerated work. To prevent this, the owner had, as stated in the contract specifications, the right to use CPM and other standard planning tools, such as estimating guidebooks, to determine reasonable durations of all activities. Exceptions were to be negotiated between them both. The contractor used "policy or management constraints" (preferred way of doing work) to consume float. These constraints prevent activities from starting until preceding activities are sufficiently complete. On detailed analysis, this appeared illogical; however, the contractor was asked to apply workaround techniques, and he countered by saying that the changes to his plan of work would result in extra work, and therefore more claims against the owner.

An owner should have the right to demand that constraints of this type are removed, and the work be replanned when the constraints threatened the critical path. Difficulties such as those just described might be overcome with adequate specifications. However, one can hardly hope to anticipate all the problems that can arise, particularly if the specifications writer has a limited knowledge of all the tricks that can be used.

The specifications should protect both the owner and the contractor. But it should be remembered that the owner pays for the scheduling system and is entitled to get what he pays for. The specifications should set forth restrictions on falsifying networks to eliminate float. They should spell out what rights the owner has to utilize float to his advantage. They should clarify areas where the owner has the right to apply standard estimating techniques to activities for which contractors have obviously set over-long durations to eliminate float.

CONTRACT CHANGE ORDERS

A contract change order is an authorization of additional work in addition to, but pertaining to, the original contract. The courts have typically held that a change order is a contract in itself, and since it amends the original contract, it must be reflected in the network schedule and filed with the original contract documents. The legal sequence that must be observed regarding change orders is that, if the network schedule requires numerous changes during the course of the project, the contractors must bill the owner after the changes have been completed.

This is important to know, because to do otherwise is to allow your project schedule to become sidetracked or derailed. If you, through the project manager and prime contractor, have to play hardball with the subcontractors to keep your schedule on track, so be it. The law says that a contractor may collect (in progress payments) only what he has provided in labor and materials to date. If, on Monday, the contractor performs additional work that amounts to $5000, the contractor can amend (through a contract change order) the next progress payment to include that amount. However, the work must be done first.

Contractors have a right to collect extras as long as they amend their contract and/or use change orders indicating when extras are being added and when they are to be paid for. This means that contractors cannot suspend activities for extra work payments and that your schedule cannot be brought to a halt over contract change orders. The primary objective of any project schedule is to complete the project as designed, in a systematic, coordinated manner. All this must be accomplished in the shortest time consistent with material and personnel constraints, thereby maintaining a good profit.

Today's construction management professionals recognize that change orders are a normal part of the construction process. Every project manager, site superintendent, and project developer knows that, in all probability, changes will occur on the project that will affect the final duration. If they can be handled competently and in stride, the effects on the project might still be felt, but accountability for them will remain where it belongs.

Project schedules that are constructed and updated in a clear, consistent manner with complete, thorough notes and references can accomplish this. If the schedules are managed so that the information in them can be easily extrapolated, categorized, and supported (or denied) in the event of a worst-case scenario, their strength will actually minimize serious disputes. A good production schedule will easily provide significant, visible comparisons and convincing proof of damages, including delay, acceleration, suspension of work, inefficiencies, disruption, interference, and demobilization.

In dealing with change orders in your project schedule, remember: Contract law does not allow the prime contractor or subcontractors to make any changes to an existing contract. An addendum in specified work requires the contractor to write up a contract change order and then seek written approval from the owner. The owner is not obligated to sign a change order, but the owner's approval is absolutely necessary to avoid litigation problems. The owner cannot be forced to pay for work that he did not authorize. Contract law specifies that "all changes to the original contract must be in writing and signed by both the property owner and contractor."

These following six fundamentals form the basis for presentable evidence in a court of law for project schedules and will, in turn, establish the basis of good recordation, clear accountability, and effective presentation:

1. The project schedule must be the same one that was actually used to build the project. Even if a schedule that is substantially different from the one under consideration had been formally submitted and approved by the owner and/or the design professional, the schedule that was actually used and depended on by the various trades will generally be considered to be the contract document.

2. The project schedule must be periodically revised. It is generally recognized that project scheduling, however exact or inexact, is nothing more than a plan to construct what can reasonably be construed from the contract documents, considering that there may be several ways to build the same project. Although contingencies may be included to allow for imprecisely defined variables, there probably has never been a schedule that anticipated every problem, coordinated every piece of work, and required no modifications to make it work. Changes to, or corrections of, the plan are inevitable. The schedule, therefore, must be updated periodically to maintain a current and accurate representation of reality.

3. The periodic updates of the project schedule must show all positive and negative influences by all parties. None must be singled out; none must be absent for convenience. If all updates, for example, only indicate delays

caused by the owner and fail to delineate other known problems caused by other parties, it won't be very difficult for your opponent to demonstrate that bias has been built into the document. Failing to recognize all significant events will bring into question the validity of the entire project schedule presentation.

4. The project schedule must include realistic construction logic and activity durations to demonstrate the professional ability of the planning and scheduling team. Illogical sequences or the lack of consideration of critical variables (such as indicating the installation of commercial HVAC units in a building with no overhead doors, to occur before the roof is constructed) will only demonstrate that the constraints in the project schedule were unrealistic to begin with.

5. The project schedule must fairly represent the actual method planned to build the project. If, for example, the project schedule had been prepared primarily to cater to progress payments, or was otherwise unrelated to actual construction of the project, it would become clear that, as a tool for managing the project, its value was marginal at best.

6. The project schedule updates and analyses must be realistic and in perspective. An overly aggressive computation of damages might hurt the validity of the entire analysis. Direct cause–effect relationships must be shown.

In addition to the foregoing, the project scheduler must be sure that all notes and references are correlated with the more detailed, chronological project correspondence on the sort by correspondence transmittals. Have all field notes, claims, commitments, deadlines, and promises detailed in the schedule documents. Include the dates and the names of the individuals in those organizations supplying information. Pin it down.

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11

Software Program

INSTALLATION

This book is bundled with accompanying CD-ROM software configured to run on the PC spreadsheet program MS Excel™ '97 or higher, on a Windows™ platform, version 3.1 or higher. Boot up the computer, open the spreadsheet program, insert the disk, and switch to that drive to begin the program. Install the files to your Excel™ spreadsheet application hard drive directory and run program from there. This method will produce greater speed in compilations of summary sorts because operating memory will not be restricted to RAM. For the purposes of clarity in instruction within this section, commands are shown in text as bold with underlining.

The underlining represents the command keys if you're entering commands through the keyboard, or the bolded letter you would point to and click if you are using a mouse. Link absolute cells and chain-link macro the spreadsheets according to your spreadsheet application's instructions. Set up the spreadsheet formulas to do the range statistics calculations for you. Spread your databases over many ranges, and remember to leave a blank row or column between each database for additional safety in data retrieval.

Cell ranges within each sort that have data in italic are for your company and project data input. Areas of format layout are protected against overwriting, as is the tabulation programming. The format is to make the data entry process bulletproof, because I make mistakes just like everybody else. I still wipe out cells of work from going too fast and overrunning a range select inadvertently during data transfer. (You know what I'm talking about. . . .

When you do something so stupid, you look around the room to see if anyone saw you acting dumber than a box of rocks.) So the accompanying CD-ROM is designed with protected ranges of cells that will keep the master sort formats from being erased accidentally. Only your data input cells can be messed up, and you're not going to lose the master by experimenting with the program spreadsheets, so relax. Do some playing with it and see how your activities integrate through the different sorts.

DATA ENTRY

To enter data in any sort spreadsheet, move to the cell in the spreadsheet you wish to input the information and type in the data. Press **E**nter. As you type, the entry appears on the edit line. As you press **E**nter, the data entry inputs to the current cell. If you enter data in a cell that already had information in it, the old data will be deleted and replaced with the new input data.

If you need to input data into more than one cell address at a time, you do not need to repeat the data entry process in each cell individually. Instead, to increase the speed of multiple data entry, you can select blocks of cells called ranges, make information or layout changes, then press **E**nter. The selected range will accept the command. This is called a *range command*, because it affects the entire selected range within the spreadsheet. By selecting groups of ranges, you can step up to the macroactivity of data entry, called *global commands*, which are data entry commands that affect the entire spreadsheet at once.

You can press a directional key such as Tab, Page Down, Page Up, or Arrow, and move to the data entry cell with one keystroke, enter data, then lock in the entry for automatic computation by pressing **E**nter. Activities are laid out in the vertical axis of columns, and number figures are laid out in the horizontal axis of rows. Each row and column is integrated, and the two or more data entries made on each activity will automatically compute to the subtotal cell address in each column. These subtotal column cell addresses are further integrated to the master total cells for total computation of all activities in each phase. These phases are preset as you see them, in a typical commercial project sequence.

For residential projects, simply use the activities that are relevant to your project and leave the others blank. Data will automatically wash through the blank cells. You may add or delete activities as you wish; however, it is recommended that you save your new spreadsheet sorts under a new file or to a separate disk, leaving the master format for future projects.

The software is formatted in WYSIWYG (What You See Is What You Get), and the data that appear as you enter it is what the finished and printed product will look like. You can create two kinds of cell entries for different kinds of data entry: *values* for the number figures and *labels* for your word processing data. A label is configured solely as a text entry, whereas a value is a number or formula the computer uses for computation. The computer recognizes which type of data entry is being used in the cell by the first character in the entry. If the character is a number, the computer will use the data for numerical computation factoring.

If the first character is a letter, the computer then recognizes the entry as a label. You can interlink text entry activity names with their relative values by the use of activity numbers. You then further link those numbers globally in the spreadsheet in groups of phases by their *i–j* numbers. This in turn produces the sequential linkage necessary for the computer to produce the program logic.

Labels make the numbers and formulas in the spreadsheet anchor the related data specifically to that activity. As a text entry, a label can be a string of up to 512 characters, or bytes. Labels include headings, titles, explanations, and notes; basically, any word processing that will explain, clarify, or add information to the description of that activity. When you enter a label, the software adds that data entry to the relative cell address and the computer then recognizes that cell as a label. When you enter a label, the program, by default, will left-align your entry in the cell. You can change the format of the label by typing one of the following label character prefixes before typing the data:

’ Left-aligned (default setting)
" Right-aligned
ˆ Centered
\ Repeating

A vertical bar (|) entered as a label prefix notifies the computer not to print the contents of the cell. Column headings should be aligned with the data in the columns. This provides instantaneous orientation to the human eye of data with text. When an entry fills the cell width, the entry can be centered, right-aligned, or left to the default setting of left-aligned. Standard spreadsheet format requires that labels be centered when the column heading is narrower than the data in the column. Repeating labels will fill the width of the cell and, if you change the width of the column, will automatically repeat more to refill the new column width. To use a label prefix as the first character of a label, first type the label prefix if you wish to change to from the default setting of left-aligned. If no change in label alignment is desired, simply type in the data and the computer will automatically align the data with a left justification.

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If the cell entry data are numeric, you must first type a label character as a prefix. This is done because, without a label prefix, the computer will mistake the entry as a number or formula for computation and will begin to compute the data as soon as you hit **E**nter. The classic example of this data entry technique is a telephone number. If we were to enter the phone number 555-702-1995, the computer would instantly mistake this data entry as a mathematical formula and begin subtracting 1995 from 702, and the remainder then would be subtracted from 555. We would end up with a bizarre negative number in a cell where the client's phone number was supposed to appear. Computers are, after all, just dumb boxes that record data. The program cannot think for you or anticipate your intentions, and it is restricted to observing whatever format the program is configured with in dealing with your data entry. A simple oversight of label prefixes or typographical errors will result in what is called a *syntax error*, which is the inability of the computer to read your data, or even worse, sending that information off to do something other than what you had intended.

Another classic example that serves as an illustration of this data entry fundamental is entry of dates. If we were to enter 7-15-95 as the date, we might recognize that as a date but the computer recognizes that entry, again, as a mathematical formula and, instead of the date appearing in the cell, the answer resulting from subtracting 95 from 15 from 7 would appear. Therefore, to retain a numerical entry as such and not signal the computer to use the entry for computation, you must use a label character as a prefix. A telephone number would be preceded by an opening parenthesis followed by a closing parenthesis at the end (555-702-1995). Here the opening parenthesis serves as a label character before the figures and signals the computer to treat this data as a label and not to use it for computation functions. Similarly, a date entry can be handled with either of two techniques. The first is by using the @Date function of the software program; the second is by entering the date data as 7/15/95, which the computer recognizes as a date label and not a formula function.

If a label is accidentally evaluated as a formula, press F2, (**E**dit), then press **H**ome, then type the label prefix, and press **E**nter. Should the program place you in the edit mode, press **H**ome, type the label prefix at the formatted insertion point, and press **E**nter. If the label characters string is longer than the cell's width, the label will automatically scroll across and through the cells to the right if there are no data in those cells. If data are already in those cells, the program will cut off the display of the current cell data entry at the right border of that cell. The computer, however, still stores the complete data string and will display the entire cell entry on the current edit line when the cell is selected. To display the entire label in the spreadsheet, you can insert new columns to the right of the current cell containing the long label, or you can widen the column sufficiently to contain the entire label's characters string.

ENTERING NUMBERS

To enter a valid number in the spreadsheet, you can type any of the standard numerical characters (0 through 9) and certain other characters that will serve as formula prefixes. The following are the numerical entry procedures for this software configuration:

You can start the numerical entry with a plus sign (+). The plus sign is not stored when you press Enter. +555 is stored and displayed as 555.

You can start the numerical entry with a minus sign (−). The number is stored as a negative number. 555 is stored and displayed as −555.

You can include one decimal point. .555 is stored as displayed as 0.555.

You can place the numerical entry in parentheses. The number is stored as a negative number. The computer will automatically drop the parentheses and install a minus sign prefix to the number. (555) is stored as displayed as −555.

You can begin the number with a dollar sign ($). Unless the cell is formatted as Automatic or Currency, the dollar sign will be dropped and will not be stored to memory when you press Enter. $555 is stored and displayed as 555 in an unformatted cell. If the cell is formatted in either Automatic or Currency, $555 is stored and displayed as $555 (with no decimal places unless you also format the cell to display decimal places). Three digits must follow each comma you include. Unless you format the cell as Automatic or Comma, commas are not stored in memory when you press Enter. 123,456 is stored and displayed as 123456 in an unformatted cell. 123,456 is stored as 123456 and displayed as 123,456 in a cell formatted as Automatic or Comma (with 0 decimal places).

You can enter the number in scientific notation. A number is stored as scientific notation only if it requires more than 20 digits. 555E3 is stored and displayed as 555000. 5.55E30 is stored as 5.55E+30 and displayed as 5.5E+30. 555E-4 is stored and displayed as 0.0555. 5.55E-40 is stored as 5.55E-30 and displayed as 5.5E-40.

You can type the number with a percent sign (%) at the end. Unless the cell is formatted as Automatic or Percent, the computer will divide the number by 100 and the percent sign is dropped. 555% is stored and displayed as 5.55 in an unformatted cell. 555% is stored as 5.55 and displayed as 555% in a cell formatted as Automatic or Percent (with 0 decimal places).

You can enter a number with more than 18 digits. When the computer has read 18 digits, the number is rounded off and ends with one or more zeros. 123456789987654321123456 is stored as 12345678998765432100 and is displayed as 1.2E + 19. If the number is too long to display in the cell, the computer will display as much of the number as will fit within the cell borders. If the cell data input is done using the **G**eneral default setting, and if the integer part of the number does not fit into the cell, the program will display the number in scientific notation. If the cell's data entry is with a format other than **G**eneral or if the cell is too narrow for the number to be displayed in scientific notation, the number will be stored in its entirety but will be displayed as asterisks.

ENTERING FORMULAS

The real power in the accompanying CD-ROM software comes from building a chain-linked macro (follow your Help Icon's instructions for linking your spreadsheets with formula summary computation) to "wash through" one sort to another. Formulas are integrated through the sorts to provide computerized interlinkage for assembling CPM sorts. You enter the numbers and formulas in the sorts spreadsheets, and the program calculates the results of all the formulas.

The real beauty of this type of system is that, as you add or change data, you do not need to recalculate the effects of the changes throughout the entire spreadsheet. . .the program will automatically do this for you. This is how we run "what-if" scenarios, by changing a factor here or there to see what the end results would be if certain changes were undertaken without upsetting or revising the entire spreadsheet. If the changes are acceptable, they can be introduced into the specific sort you are working in or globally to the entire network schedule.

You can enter formulas that operate on labels, numbers, and other cells in the spreadsheet. Like a label, formulas can contain up to 512 characters. A formula can include text, numbers, operators, cell and range addresses, range names, and functions. A formula cannot contain spaces except within a range name or text string. You can create four types of formulas: numeric, string, logical, and function. Numeric formulas work with numbers, other numeric formulas, or string functions. Logic formulas are true or false tests for numeric or string values. Formulas can operate on numbers in cells. The formula 2 + 10 uses the calculator within your program to compute the answer.

A much more useful formula involves using cell references in the calculation. The current cell shows the formula you've input and, by interlinking the formula to different cell addresses, the spreadsheet shows the result of the calculations throughout all the assigned cells. The resulting computations will change if you change any number in the other cells. This instant recalculation is the real power behind CPM programs, because it allows you to change paths and their related data on the computer first, to analyze the moves before actually making them in the field production.

Formulas consist mainly of operators and cell references. You can type each, or you can use a better way to enter the cell addresses. When the program requires a cell address as a source or target reference cell, use the directional keys to move to the cell or type the cell address, and then press **E**nter. The preferred method is to move to the cell directly as opposed to typing the cell address, because a simple mistake in typing the cell address will result in that data going to the wrong cell.

One error will lead to multiple errors when the data are calculated through to other cells. The error will not show up on the display, and the project scheduler may not catch the mistakes carried throughout calculations within the master spreadsheet. Errors of this nature are common and will show up when the schedule is cooked in number totals that seem unreasonable compared to estimated figures or historical data. Backtracking the error usually confirms that the data entry was being sent to a wrong cell address.

Formulas that interlink between files are usually very long and complicated. Accordingly, standard operating procedure is that the target file you are transferring data to should be open behind the current file you're working in. This allows you to specify the target file by selecting cells or ranges instead of typing the cell or range address (and thereby incurring the risk of error from a typo in data entry). In formulas, data entry can be done in one of two ways. A cell address in a formula is known as a *cell reference*. Usually, when you use the **E**dit **C**opy command to copy a formula from one cell to another, the cell references are adjusted by default. If you copy the cell formula in your source cell, once transferred, the cell references change by default in your target cell(s). This adjustment is known as *relative addressing*.

An *absolute address* in a formula, on the other hand, does not change when you copy the formula to another cell. You specify an absolute address in a formula by typing a dollar sign ($) before the column and row addresses. For example, +$A:$A$1 is an absolute address. If this address were in cell B5 and you copied it to cell G10, the cell reference would still be +$A:$A$1. To specify an absolute cell address in the select mode, press F4 (**A**bs). In addition to using relative and absolute cell addresses, you can use mixed cell addresses.

In a mixed cell address, part of the cell address is relative and part of the address is absolute. If we were to change our above example to read +A$1, this would now be a mixed address because one factor is relative (+A), and the other factor ($1) is fixed as an absolute address by the use of the dollar sign. Whether a cell reference is relative, absolute, or mixed has no effect on how the computer calculates the formula. The computer will differentiate between them when you copy the formula from the source cell address to the target cell address.

LOGIC FORMULAS

Logic formulas are true/false computations based on the formula within the cell. A logical formula compares two values and returns the number 1 if the formula computes to be true, and 0 if the formula computes to be false. This kind of formula is used mainly in establishing database criteria ranges.

As an example, Table 11.1 shows typical logic formulas, how the computer reads them, and how the program then computes them. Note the difference in results from similar formulas simply from the syntax of data entry. This points out to the project scheduler the importance of avoiding typos in data entry. The trick to accurate data entry is to take time to double-check your numbers.

USING STRING OPERATORS

A formula is a mathematical instruction to the computer to perform a calculation or series of calculations. We use *operators* to specify the calculations to be performed, and their order of precedence or sequence. The software uses operators in numeric, string, and logical formulas. Just as ranges are the macroactivity of cells, operators are the macroactivity of formulas. You begin to see now how our building blocks work. We are structuring circles within circles. In this way, our network schedule will have all levels of data from the minute tasks and work items right on up to the major phases of activities, which gives the computer the factoring linkage necessary for program logic. Time manipulation is achieved in the network schedule through the use of tools such as string operators.

Numeric operators are used for the four basic mathematical functions of addition, subtraction, multiplication, and division, as well as *exponential factoring* (raising a number to a power). The simplest numeric formula uses

TABLE 11.1 Logic Formulas

Formula	Computation	Result
5+3*2	(5+(3*2))	11
(5+3)*2	(5+3)*2	16
5+4*8/4−3	5+(4*(8/4))−3	10
5+4*8/(4−3)	5+((4*8)/(4−3))	37
(5+4)*8/(4−3)	(5+4)*8/(4−3)	72
(5+4)*8/4−3	(5+4)*(8/4)−3	15
5+3*4^2/6−2*3^4	5+(3*(4^2)/6)(2*3^4))	−149
−3^2*2	−3(3^2)*2	−18
−3^(2*2)	−(3^(2*2))	−32

just the plus sign (+) to repeat the value in another cell. The most complicated can involve all the above four standard numeric functions, as well as exponential factoring of any or all integers in the formula, in differing sequence or precedence, all together or individually. This is a very powerful function that provides fast, error-free data quicker than any human being could.

To transfer string operator formulas from source cells to target cells or ranges, you can select the target cells or ranges (which is the recommended method), or you can enter the following commands by using double angle brackets: ≪ Source range ≫ A:B3 + ≪ Target range ≫ .

Any length of formula or string command can appear where the example formula of A:B3 + appears. If the data transfer is to go to another sort, you must include the entire command path, which is fundamental in DOS operations. For example: ≪ C:\Filename\data\target file.doc ≫ .

If a formula is entered using an operator shown in Table 11.2, the program calculates the data by following the order of precedence noted in the following table.

Using operators in string formulas differs from regular numeric formula entry in that a string is a label or a string formula. Only two string formulas exist. You can repeat another string, or you can combine two or more strings. The simplest string formula uses only the plus sign (+) to repeat the string in another cell. The formula to repeat a string cell is the same as repeating a numeric cell. A formula is considered a numeric formula because the formulas

TABLE 11.2 String Operators

Operator	Operation	Precedence
10^{10}	Exponentiation	1
− (prefix)	Negative value	2
+ (prefix)	Positive value	2
*	Multiplication	3
/	Division	3
+	Addition	4
−	Subtraction	4
< >	Less than, greater than	5
< =	Less than or equal to	5
> =	Greater than or equal to	5
=	Equal to	5
#NOT#	Logical NOT	6
#AND#	Logical AND	7
#OR#	Logical OR	7
&	String formula	7

refer to cells that contain numbers. A string operator is considered a string formula because the formulas refer to cells that contain string formulas. The operator for combining strings is the ampersand (&).

The first operator in a string formula is the plus sign, then all sequential operators in the formula must be ampersands. The program assumes a value of zero for a cell containing a label. If you do not use the ampersand but instead use any of the numeric operators, the computer will compute the data as a numeric formula. By inserting an ampersand, the computer now treats the data as a string formula. If you insert any other numeric operator after the prefix plus sign at the beginning of the entry, the formula will result in a syntax error, and ERR will be displayed. The string formulas +A1&B2+C3 and +A1+B2&C3 will both result in syntax error due to the additional numeric operator inserted in the formula.

If you make an error during data entry that will not compute through the system, an audible beep will come from your CPU, which is signaling you that an invalid formula has been input. Common errors that make a formula invalid are extra or missing parentheses in the formula where the program encountered an error, incorrect precedence or arguments in the formula, and misspelled function names (syntax error). The following is a list of the most commonly encountered types of scheduling data entry errors:

+A1/(2-A3	Missing right parenthesis
@SIM(A1..A6)	Misspelled @SUM function
@IF(A1>200,200)	Missing argument in function

MENU COMMANDS

To issue a command with the keyboard, you activate the main menu by pressing the **A**lt key or the **M**enu (F10) key. Use the arrow keys to move the menu pointer to the name of the command you wish to select, and then press **E**nter; or type the underlined letter of the menu option. If you are using a GUI system with a mouse, just point to the command you wish to choose and click the mouse that serves as **E**nter. This GUI command automatically activates the menu and chooses the command. As you choose a menu option from the main menu, the next set of commands appears in a pull-down menu. All of the main menu commands lead to pull-down menus, which provide further detailed task commands within the larger main menu option, which holds the main directories.

In Windows™ applications, if the pull-down menu option has another level of commands, the commands appear in a *cascade menu*. A solid triangular marker usually follows pull-down menu options that lead to a cascade menu, depending on which type of processing program your system is running on. If you make a mistake while choosing menu commands, press Esc to return to the preceding menu. If you press Esc at the main menu, you deactivate the menu and return to the Ready mode. When using menus, pressing Ctrl + Break is equivalent to using the Esc key.

When you make changes to the master format provided, all the work exists only in the computer's working memory (RAM). If you do not save new spreadsheets or changes before you quit the program, you will lose all work done. Before exiting the program, save all new work or changes in a separate file or save to C, your hard disk, or to a backup disk in either the A or B drive. If you save your changes on the master format, the information existing previous to your changes will be unrecoverable. This will be another of those outstanding moments in computer applications history when you'll want to drag your computer outside and shoot it right between the running lights.

SAVING YOUR WORK

When you have created a sort on the master format, the data and information will have to be saved on either your hard disk or a floppy disk. When a sort is keyed in for the first time and is displayed on the screen, it is in RAM and is only temporary. If you turn the computer off or if the power goes off, you will lose the data and information and have to re-enter it. Only when you save a sort to a disk is it saved permanently. Every time you load the CD on your spreadsheet program, you will be able to bring up a saved sort back to the screen.

To save a sort you must execute a save command. The software provides four methods for doing this:

1. Using the toolbar
2. Using the menu bar with the mouse
3. Using the menu bar with the keyboard
4. Using speed commands

The software contains two commands used to save sorts. One is the Save As command, and the other is the Save command. When you begin creating a sort, it does not yet have a filename. You assign it a name when you save the file. The first time you save the file, you may choose either the Save or Save As command. The software gives you the opportunity to assign the file a name of your choosing. After the first time you save a sort, however, you should use the Save command to continue saving changes to your sort. The software automatically uses the same filename when the sort is saved by using the Save command. The Save As command is used to save changes to an existing file under a different filename.

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Speed commands are executed by pressing either one or two keys on the keyboard in conjunction with a function key, or by pressing a function key alone. In some cases, there is more than one speed command for the same function. For example, to save a sort file for the first time, you can press either Shift + F12 or Alt + Shift + F2. Either method executes the Save command. To save a file using toolbar, complete the following steps:

1. Click on the Save icon.
2. At the Save As dialog box, key in the name of the sort.
3. Click on OK or press Enter.
4. At the Summary Info dialog box, click on OK or press Enter.

To save a sort file using the menu bar with the mouse, complete the following steps:

1. Click on File, then Save.
2. At the Save As dialog box, key in the name of the file.
3. Click on OK or press Enter.
4. At the Summary Info dialog box, click on OK or press Enter.

To save a sort file using the menu bar with the keyboard, complete the following steps:

1. Press the Alt key, key in the letter **F** for File, then the letter **S** for Save.
2. At the Save As dialog box, key in the name of the file.
3. Click on OK or press Enter.
4. At the Summary Info dialog box, click on OK or press Enter.

PROCEDURES

To begin, enter into the Activities Sort and begin building your schedule by adding activities and creating links between them. Add an activity, fill in its duration and other details in the activity form, and connect the activity to its predecessors and successors. Create activities linkages by connecting set of dates (early and late start and finish events). Compare today's schedule dates to the plan for each activity by varying their events and end points for completion. Switch to each sort and enter data to define the data columns that appear in each sort, along with specific time-scale data to be programmed into the rows. This configuration will give you computation factoring on all the data on each activity and work item.

Once data entry is complete, begin organizing and summarizing the sorts. Activities that share a common attribute, such as a subcontractor or responsibility, can be grouped into collective blocks known as *ranges*. Activities can be grouped into bands based on activity codes, such as project team member responsibility or related assigned subcontractors. You can also group activities by resource, cost accounts, dates, calendar milestones, or the work breakdown structure of the project.

To integrate data from other applications, use **O**bject **L**inking and **E**mbedding (**OLE**) within that application to originate the transfer. Use source application attachment tools to link text, graphics, spreadsheets, and drawings. Plan resource usage and financial budgets for the duration of the project by allocating, analyzing, and tracking resources and costs by activity. Sort by activities costs will show when required resources are exceeding normal availability, and another column will show when required resources are exceeding maximum availability.

CHANGING DATA

After you have built the data within the spreadsheet, you may want to change the data in specific cell locations or input new data for a new project. You can change an existing entry in two ways. First, you can replace the entire contents of a cell by typing in a new entry and pressing **E**nter. Second, you can change part of a cell's contents by selectively editing only the portion of the data that you wish to change, by inserting the cursor ahead of the data to be changed. Make the changes, delete the old data, and press **E**nter to store and display the new data. To replace the entire contents of a cell, move to the cell you want to change and press **E**nter to select that cell. You can either press **D**elete to empty the cell and input the new data or simply type the new data, and press **E**nter to store and display the new data. To selectively edit certain portions of a formula or string within a cell, move the cursor to the cell and press F2 (**E**dit) to enter the edit mode.

If you press **E**sc while in the **E**dit mode, you clear the edit area. If you press **E**nter in a blank edit area, you do not erase the cell contents, and you return to the **E**dit mode. Should you make an error in your data changes, you can reverse the changes to the original data by the **U**ndo function (**A**lt + **B**ackspace), or select the **E**dit **U**ndo command to return the original data to the cell. If you type over an existing entry, you can undo the new entry and restore the old one. The **U**ndo function undoes only the last action performed, whether it involved entering data, using a command to completion, or running a macro. When **U**ndo is enabled, the computer must retain the most recent action in RAM. This feature requires a great deal of computer memory. Accordingly, the bigger your RAM, the faster the command entries will respond.

How much memory is used up in RAM depends on the different actions involved. If you run low on memory, you can disable the **U**ndo function by selecting **T**ools/**U**ser **S**etup and deselecting the **E**nable/**E**dit **U**ndo feature. If you run out of memory while the program is undoing an action, the program will suspend the operations and save the data currently in RAM. The **U**ndo function is very powerful and also tricky, so you must use this function carefully. To use **U**ndo properly, you must understand what the computer considers a change. A change occurs between the time when the program is in the ready mode, data are entered, and the next time the program is in the ready mode.

This is the extent of data entry change that will reside in RAM for recovery. Let's take a practical example to illustrate this point. Suppose that you press F2 (**E**dit) to go into the **E**dit mode to change a cell. You can make any number of changes in the cell, press **E**nter to save and display the changes, and return to the **R**eady mode. If you were to press **U**ndo at this point, the computer would return the spreadsheet to the original data condition the spreadsheet was in during the last **R**eady mode. The cell returns to the previous data existing before you performed the edit. You can change a range or group of cells at one time or even erase everything in RAM with just one command. The **U**ndo command is powerful enough to cancel all the effects of the command.

On the other side of the coin, some functions cannot be canceled, including the **U**ndo command. When used by mistake, **U**ndo cannot be canceled. If you press **U**ndo (**A**lt + **B**ackspace) at the wrong time in data entry and cancel an entry, you cannot recover the entry. If you are not in the habit of saving your work every 15 minutes, then this will be the first time you've lost four hours of work on a pilot error glitch. Really stinks, huh? Wait, wait! It gets worse! Just wait until it dawns on you that you've another four hours to go to reconstruct your work all over again just to get back to where you started. Then you're going to go ballistic. Moral of story: Hit the **S**ave button every 15 minutes and discipline yourself to do it automatically, forever. Fifteen minutes of lost work can be caught up on with only a couple of choice swear words, instead of missing your dinner for another four hours in a manic-depressive state. Other commands that cannot be canceled include

- The **G**raph commands (although you can cancel these commands by using the **E**dit commands in the **G**raph tool)
- All commands on the **C**ontrol menus
- All commands that affect an outside source but have no effect on the current spreadsheet sort
- Actions that move the cell pointer or scroll the spreadsheet, including **G**o**T**o (F5) and **W**indow (F6)
- Formula recalculations that result when you press **C**alc (F9)

DATABASE TERMINOLOGY

A *data table* is an on-screen view of information in a column format, with the field names at the top. A data table contains the results of a Data What-if Table command, plus some or all of the information that was used to generate the results. A *data table range* is a spreadsheet range that contains a data table. A *variable* is a formula component whose value can change. An *input cell* is a spreadsheet cell used by the computer for temporary storage during calculation of a data table. One input cell is required for each variable in the data table formula.

The cell addresses of the formula variables are the same as the input cells. An input cell can be a blank cell anywhere on the spreadsheet. The preferred procedure is to identify the input cell by entering its title with an appropriate label either above the input cell or immediately to the left. An *input value* is a specific value the computer uses for a variable during the data table calculations. The *results area* is the portion of the data table where the calculation results are placed. One result is generated for each combination of input values.

The results area of a data table must be unprotected, or the data will not write to the area. The formulas used in data tables can contain values, strings, cell addresses, and functions. You should not use logic formulas in a results area, because this type of formula always evaluates to either 0 or 1. Although using a logic formula in a data table does not cause computer error, the results are usually meaningless.

USING DATABASES

A database is a directory of related information, organized so that the end user can sort, list out, or search through the data to find desired information. A database may contain any information pertaining to the project, grouped into whatever divisions make the data retrieval more convenient for the end user. In the software program, the computer recognizes a database as a range of cells that spans at least one column and more than one row. Because a database is a data list, its manner of configuration and organization of data make it distinct from ordinary label cells. Just as an information list must be organized to be useful, a database must be organized for the computer to access the data within the database parameters.

The software program has three types of database organization. The simplest database organization is a single database contained within a single spreadsheet sort. In real-world applications, this is the most common and frequently used type of database organization. The next step is organizing groups of multiple databases from these single database organizations.

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The software uses program logic to integrate multiple single-database organizations with others occupying a different portion of the same spreadsheet sort. This second level of database organization can be precedence-linked or nonsequential, according to your needs in programming the data retrieval.

The last type of database organization involves integrating multiple databases in two or more spreadsheet sorts. Remember, however, that a single database table cannot span different spreadsheet levels. In order to accomplish this third type of database organization, you must relate databases that are different spreadsheet levels, and the computer will then interlink them to produce a more efficient overall database structure.

Any of these database organizations is similar to any other group of label cells. The computer separates them from label addresses by specifying the two components of a database system, *fields* and *records*. A field is the smallest unit in a database, made up of a single data item (datum). An example would be a client record that includes separate fields containing a company name, phone number, address, and contact person. A record is a collection of related fields that build an information group. In our example, the four fields noted for each company, when accumulated, would make up one record for one company. In simpler terms, the computer recognizes a field as one cell address and a record as a range of cell addresses within the database.

The functional purpose of building a database is to organize information to expedite data retrieval for the end user. In operating with a database, data retrieval involves searching in *key fields*. A database key field is any field on which you base a list, sort, or search operation. In a key field search operation you can use a search operator, such as an address, as a key field to sort the data in the company database and to assign the information retrieval according to geographic areas.

It is important that you do not intermix database tables with data tables, as this will result in computer data search syntax error. The computer will compute data tables through its precedence configuration, which is the menu function **D**ata **W**hat-if **T**able command. In database tables, however, the computer searches multiple ranges used with relational databases, because a single database may contain several tables of related information.

BUILDING A DATABASE

You can create a database as a new spreadsheet file or as part of one of the master sorts existing within the program. If you decide to build a new database as part of an existing spreadsheet, be certain there is sufficient room to store and retrieve a spreadsheet database that resides within the spreadsheet's row-and-column format. Labels or field names that describe the data items contained within the record or field appear as column headings. Information about each specific data item (field) is entered in a cell in the appropriate column.

Theoretically, the maximum number of records you can input in a database corresponds to the maximum number of rows in the spreadsheet sort. This program is configured with 8191 rows for your benefit in scheduling larger commercial projects. Residential projects will not need that depth of database volume, but this software was programmed with that data entry ability in case you should need it. Realistically, however, the number of records in a specific database is limited by the amount of memory in your computer. The actual amount of memory equals the internal working memory (RAM) plus disk storage for virtual memory, less the room needed within the database to hold data extracted by the **D**ata **Q**uery commands. When you estimate the maximum database size you can use on your computer equipment, be sure to include enough blank rows to accommodate the maximum output you expect from data extract operations.

A working technique I use on small systems that run short of memory is to split a large database into separate database tables on different spreadsheet levels if all the data do not have to be sorted or searched as a unit. For example, you may be able to separate a telephone list database by name such as A through M in one file and N through Z in another file, or perhaps sort by area codes. Create a database as a new spreadsheet or as part of an existing spreadsheet. If you decide to build a database as part of an existing spreadsheet, chose a sort area that is not needed for other data. This area needs to be large enough to accommodate the number of records you plan to enter during the current data entry session and for future data entry in that sort.

When interlinking separate sort spreadsheets, make sure that the spreadsheets do not interfere with one another with respect to available target file room for data. The easiest way of doing this is to use the **G**lobal **S**ettings command to make certain **G**roup mode is not selected. This will prevent the data from overwriting the existing data inadvertently. This also prevents the column width and row height settings, as well as the insertion and deletion settings, from transferring through from your source spreadsheet to your target spreadsheet. Overlooking this will cause you all kinds of aggravation when you see how the target spreadsheet has been re-edited with the new settings. Reconstructing the previous spreadsheet format will be equally hard and time-consuming.

After you have determined the data entry area in the target spreadsheet, you create a database by specifying field names across a row and entering data in cells as you would with standard data entry. The mechanics of entering data into a database are simple: The most critical step in creating a useful database

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is identifying the fields properly. Database retrieval techniques work by locating the data by field names. When you are ready to enter the data into the database, you must specify the following for each datum to be entered:

A field name
The column width
Type of data entry

In determining these steps, you first need to choose the level of detail needed for each item of information. This is the same type of critical analysis you did in the chapter regarding levels of specificity for your network schedule. Once the data have been organized in the manner you wish to retrieve it in, select the appropriate column width, and determine whether to enter the data as a label or number. If you enter the database content from a standard source document, you can increase the speed of data entry by setting up the field names in the same order as that of the corresponding data items on the source document. Remember here to plan the target database carefully before establishing field names and transferring data. The software program is configured with 256 fields, which is the number of columns available in any single sort.

Field names must be input as labels even if they are numeric labels. If that is the case, use a label prefix as previously discussed. You can use more than one row for the labels; however, the program will only read the values that appear in the bottom row as the field names. Insert blank columns between fields to prevent fields from crowding and overwriting data. When deciding on the database title, remember that all field names must be unique. Any duplication of similar names will confuse the computer and cause computation string error. The format of the database includes the title, date, labels, or numbers, and all these affect how the computer sorts and searches the data.

SORTING DATABASES

To sort the database, you start by designing a **D**ata **R**ange. This range must include all records to be sorted and must wide enough to include all the fields in each record. If you do not include all fields when sorting, you destroy the integrity of the database because parts of one record end up with parts of other records. Having to reconstruct your database after committing this type of entry error will cause an immediate rise in your blood pressure. Also, be sure that the data range does not include the field name row. If you make this error, the field name row is considered as one of the records to be sorted and the database may be destroyed. The data range does not necessarily have to include the entire database. If part of the database already has the database

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organization you want, or if you do not want to sort all the records, you can selectively sort only a portion of the database.

USING KEY SORTS

After choosing the **D**ata range, specify the key for the database sort. The field with the highest precedence is assigned to the Primary key, and the field with the next-highest precedence is assigned to the Secondary key. You must set a Primary key, but the use of a Secondary key is optional. Once you have specified the range to sort, specify the sort keys(s) on which to base the reordering of the records, indicate whether the sort order (based on the sort key) is ascending or descending, and then press **E**nter to execute the command. Again, make sure you use **F**ile **S**ave before sorting the database, in case you later need to restore the database to its original order.

The simplest type of database sort is the single-key database, the Primary key method. Data entered are usually sequentially or alphabetically sorted. To arrange your database sorting capability to reorder records alphabetically, first select the **D**ata range, then select **D**ata **S**ort, and fill in the fields with the data entry. Select a Primary key, and then type the cell address in the column containing the Primary key field. Now enter a sort order (**A**scending or **D**escending) to tell the computer the sequence in which you want the data sorted.

You can add a record to a sorted database without having to insert a row manually to place the new record in the proper position. Simply add the new record to the bottom of the current database, expand the **D**ata range, and then sort the database again by using the Primary sort key.

DOUBLE-KEY SORT

A double-key sort uses both a Primary key and a Secondary key. The classic example of a double-key sort is the database sort used in your phone book. In the telephone book's yellow pages, records are sorted first according to business type (the primary key) and then by business name (the secondary key). To see how the double-key method can work in your databases by first sorting with one key and then another key within the first sort order, you can add a new record to the end of the Clients Companies database and then reorder it first by state and then by the city within the state.

EXTRA KEYS SORT

The extra keys sort option allows you to specify as many as 253 sort keys to be used in addition to the Primary and Secondary key fields. These extra keys are numbered 1 through 253 and are sequenced by the computer in this prece-

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dence: Extra key 2 is used to break ties in Extra key field 1; Extra key 3 is used to break ties in Extra key 2; and so on. You assign an Extra key the same way that you assign Primary and Secondary keys. Select Extra key from the **D**ata **S**ort menu, and then enter the field (column) to be used for the extra key, followed by the sort order (**A**scending or **D**escending). Hit enter twice to sort the database. An example of how an Extra keys sort works would be our previous example of the Clients Companies database. Suppose that as the database grew, several of the records were tied in their city and state fields. You could sort this database on the city and state fields, specifying "company" as an Extra key to break the ties. To remove an extra sort key, assign its number to the data field being used by a higher sort key. For example, to cancel Extra keys 2, select **D**ata **S**ort Extra keys, type **2**, and specify the column being used by Extra keys 1.

DATA TABLES

In many situations in construction project scheduling, the variables in activity durations are known quantities that can be researched from company historical data. Previous project data can provide summary reports with current project variables whose exact values are already known. The results of calculations performed by using those values contain no uncertainties. Other situations, of course, will involve variables whose exact values are unknown. Spreadsheet sorts for milestone events usually fall into the first category, and sorts for delay durations often fall into the last category.

Data tables enable the project scheduler to work with variables whose values are not known. With the **D**ata **W**hat-if **T**able commands, you can create tables that show how the results of formula calculations vary as the variables used in the formulas change. This extremely helpful computer forecasting function is enhanced by another function of the **D**ata **W**hat-if **T**able commands that creates *cross-tabulation tables*. A cross-tabulation table provides summary information categorized by unique information in two fields such as the total amount of delay expected between two or more long-lead items in two or more activities.

DATA TABLE RANGE

The data table range is a rectangular spreadsheet area that can be any number of columns or rows, in either a horizontal or vertical configuration that can be placed in any empty spreadsheet location. The size of the data table range is calculated by the following two factors:

1. The range has one more row than the number of input values being evaluated.

2. The range has one more column than the number of formulas being evaluated.

The **R**ange command affects a single cell address or groups of individual cells that make up the data table range. Some range commands control the way data in certain cells appears on-screen and the way data prints out to the hard-copy sorts. For example, you can change the way numbers and formulas are displayed, or justify the margin of a block of text that spans many rows of the spreadsheet.

You can further determine how data will appear in column or row format. Using the range commands, you can protect certain areas of the spreadsheet from being written over with new data so that you, or other users, do not accidentally change or erase data within any sort.

Another very useful function of the range command is to assign a name to a single cell or range of cells. By naming a column of numbers, you can create a formula that totals the numbers within the column. You can do this operation by entering the function @SUM, then entering in parentheses the range name of the column. The typical format for a data table range follows this structure:

1. The input values to be plugged into the formulas are entered down the first column.
2. The top left cell in the data table range is empty.
3. The formulas to be evaluated are entered across the first row. Each formula must refer to the input cell.
4. After the data table is calculated, each cell in the results range contains the result obtained evaluating the formula at the top of that column, with the input value at the left of that row.

The size of the data table range depends on the number of values of each variable you want to evaluate. The cells below the formula contain the various input values for one variable. These values are used for input cell number one. The cells to the right of the formula contain the various input values for the other variable. These values are used for input cell two.

Be sure that the formula refers correctly to the two input cells so that the proper input values get plugged into the correct part of the formula. After the data table is calculated, each cell in the results range contains the result of evaluating the formula with the input values in that cell's row and column.

USING WHAT-IF

The software is programmed to remember the relationships among the cells does not calculate values unless instructed to do so. Therefore, you can change the value in a cell and see what happens when your formulas are recalculated with new factors. This is an extremely powerful feature for the project scheduler, as it allows many type of analysis.

For example, you can analyze the effect of an expected delay in delivery of a long-lead item, examine the effects of changing one date or more in one cell, and the results will wash through all related cells. You can then determine what kind of workaround is needed in every analysis evaluation. Situations yet to unfold can have contingency planning already developed on the computer for variables within the project schedule.

To set up and solve what-if problems, enter the necessary data, numbers, and formulas into the spreadsheet, then change various numbers along the factors path until you achieve the desired end results. The program uses numeric equivalency analysis to wash through your new data change in the individual cell to all connected cells, instantly showing you the results of total change in all cells from changing the factors in one cell.

DIRECTORIES/SORT REPORTS

The software has an extensive directory of sorts, each of which is configured with different summary reports. Enter relative data into the appropriate sort, and the program automatically integrates the data and computations throughout the other related summary sorts. Time-scale computations done by the program are factored from your calendar timeline entries in the network timeline sort. The summary report sorts include the following sorts:

Sort by Activities

This is the main sort of the program and the heart of a network schedule. See Fig. 7.1 on p. 128.

Sort by Events

In the Sort by Events, we see the different structuring of the program computation factors by event dates. See Fig. 7.2 on p. 135.

Sort by *I–J* Numbers

In the Sort by *I–J* Numbers, events are logged as the exact day an activity starts or finishes. See Fig. 7.3 on p. 142.

Sort by Job Logic

The logical sequence of the project's construction activities, adjusted by local limitations, is factored here in the Sort by Job Logic. See Fig. 7.4 on p. 149.

Sort by Total Float/Late Start

Total float is shown on the Sort by Total Float/Late Start as the amount of time an activity can be delayed without delaying the late-finish event for the project completion. See Fig. 7.5 on p. 156.

Cost by Activity Number

The crucial tasks of monitoring the project field service costs as separate and distinct from the architect's design costs are handled by the cost by activity number sort. See Fig. 7.6 on p. 166.

Schedule of Anticipated Earnings

The computer uses the schedule of anticipated earnings data to provide calculations under the What-If pull-down menu. See Fig. 7.7 on p. 170.

Sort by Early Starts

The Sort by Early Starts is concerned with *time* use. See Fig. 7.8 on p. 177.

Daily Field Reports

The Daily Field Report is the fundamental sort that records actual job progress, together with all conditions that affect the work. See Fig. 7.9 on p. 183.

Bar Chart by Early Start

By making a separate bar chart from the master Bar Chart by Early Start in the software for any daily or weekly tracking for contract documents and then making a related calendar entry in a the master network timeline sort, then saving both to a separate file, you create synchronicity between the two sorts in each distinct and dedicated file. See Fig. 7.10 on p. 185.

Network Timeline

This is the time-scale directory that establishes the data the computer uses for factoring time computations throughout the integrated sorts. See Fig. 7.11 on p. 193.

Shop Drawings Log

The Shop Drawings Log should be started prior to commencement so that when the shop drawings start arriving from subcontractors and suppliers, each drawing can be properly logged into the computer for tracking. See Fig. 7.12 on p. 204.

Submittal Items Tracking

The Submittal Items Tracking sort is used on all long-lead and fabricated items' procurement tracking. See Fig. 7.13 on p. 205.

Correspondence Transmittals

Much of the actual day-to-day work of a project involves correspondence of schedules, unforeseen problems, and changes. See Fig. 7.14 on p. 206.

Change Order Tracking

Interlocking the activity number, type, and description with the status and value does change order tracking. See Fig. 7.15 on p. 207.

Audit-Trail Tracking

The Audit-Trail Tracking sort factors its summary report by the computer database computed from the activity's assigned *i–j* number, the activity description, the item number, the date it was linked to procurement, who sent it and to whom, and who's responsible for authorization and procurement. See Fig. 7.16 on p. 208.

Contract Purchase Order Summary

This sort provides a summary report by the computer database computed from the purchase order's (P.O.) assigned number, the activity description, the date it was issued, who's responsible for authorization, who sent it, and to whom. Tracking is done by the original date, the revised date, and the status. See Fig. 7.17 on p. 209.

SAVING OR CANCELING COMMANDS

When you have created a sort on the master format, the data and information will have to be saved on either your hard disk or a floppy disk. When a sort is keyed in for the first time and is displayed on the screen, it is in RAM and is only temporary. If you turn the computer off or if the power goes off, you will lose the data and information and have to re-enter it. Only when you save a sort to a disk is it saved permanently. Every time you load the software on your spreadsheet program, you will be able bring a saved sort back to the screen.

To save a sort, you must execute a save command. The software provides four methods for doing this:

1. Using the toolbar
2. Using the menu bar with the mouse

3. Using the menu bar with the keyboard
4. Using speed commands

The software contains two commands used to save sorts: the Save As command and the Save command. When you begin creating a sort, it does not yet have a filename. You assign it a name when you save the file. The first time you save the file, you may choose either the Save or the Save As command. The software gives you the opportunity to assign the file a name of your choice. After you first save a sort, however, you should use the Save command to continue saving changes. The software automatically uses the same filename when you save it by using the Save command. The Save As command is used to save changes to an existing file under a different filename.

Speed commands are executed by pressing either one or two keys on the keyboard in conjunction with a function key, or by pressing a function key alone. In some cases, more than one speed command exists for the same function. For example, to save a sort file for the first time, you can press either Shift + F12 or Alt + Shift + F2. Either method executes the Save command.

To save a file using the toolbar, complete the following steps:

1. Click on the Save icon.
2. At the Save As dialog box, key in the name of the sort.
3. Click on OK or press Enter.
4. At the Summary Info dialog box, click on OK or press Enter.

To save a sort file using the menu bar with the mouse, complete the following steps:

1. Click on File, then Save.
2. At the Save As dialog box, key in the name of the file.
3. Click on OK or press Enter.
4. At the Summary Info dialog box, click on OK or press Enter.

To save a sort file using the menu bar with the keyboard, complete the following steps:

1. Press the Alt key, key in the letter **F** for File, then the letter **S** for Save.
2. At the Save As dialog box, key in the name of the file.
3. Click on OK or press Enter.
4. At the Summary Info dialog box, click on OK or press Enter.

Canceling a command begins by pressing the Alt key, which moves the cursor to the menu bar at the top of the screen. Pressing the Alt key again, or the Esc key, moves the cursor back to the sort screen. You can also move the mouse cursor to the sort screen and click the left button to move the cursor back to the sort screen. If a menu is displayed, position the mouse cursor anywhere on the sort screen outside the menu and click the left button to remove the menu without executing a command. If you are not using a mouse, press the Alt or Esc key to remove the menu without executing a command.

To remove a dialog box from the screen without executing a command, press the Esc key. This removes the dialog box and returns the cursor to the sort screen. To close a dialog box with the mouse without executing a command, click on Cancel.

OPENING OR CLOSING A SORT

Once a sort has been saved, you may want to remove it from the screen. Removing a sort from the screen does not delete the sort from the disk. To close a sort and remove it from the screen, choose **F**ile, then **C**lose, or press Ctrl + F4. You can also close a sort by positioning the mouse cursor on the window's close button (the lower button in the upper right corner of the screen), clicking the left button, and choosing **C**lose in the menu that is displayed. This will close the sort and remove it from the screen.

When you close a sort, the software displays a clear screen. If you want to key in a new sort, you need to display a sort screen. To do this, complete the following steps:

1. Choose **F**ile, then **N**ew.
2. At the new dialog box, choose OK (or press **E**nter).

To open a previously saved sort, complete the following steps at a clear screen:

1. Choose **F**ile, then **O**pen, or press Ctrl + F12.
2. Move the mouse cursor to the sort to be opened and click the left button. If you are not using a mouse, press the down arrow key to move the cursor to the list of files, and then position the cursor on the sort to be opened.
3. Choose OK by moving the mouse cursor to OK and clicking the left button, or by pressing **E**nter. (You can also double-click the mouse button while the mouse cursor is located on the sort name.)

You can also choose the Open icon on the toolbar to access the Open dialog box. The Open icon is the first icon from the left on the toolbar. The sort is brought to the screen, where you can make revisions. Whenever changes are made to a sort, save the sort again to save the changes. If you do not, you will lose all your changes.

DELETING CELLS, ROWS, AND COLUMNS

Remember that, when working in the software, if you select the contents of a cell, row, or column, and press Delete or Backspace, only the text is deleted. In order to remove the entire cell, row, or column, you must use the commands in either the Table menu or the Edit menu. To delete a row of cells, complete the following steps:

1. Select the row to be deleted.
2. Choose Edit, then Delete Rows.

Or

1. Locate the cursor anywhere within the row to be deleted.
2. Choose Edit, then Delete Cells.
3. Choose Delete Entire Row in the Delete Cells dialog box.
4. Choose OK (or press Enter).

To delete a column within a sort, complete the following steps:

1. Select the column to be deleted.
2. Choose Edit or Table, then Delete Columns.

Or

1. Locate the cursor anywhere within the column to be deleted.
2. Choose Edit, then Delete Cells.
3. Choose Delete Entire Column in the Delete Cells dialog box.
4. Choose OK (or press Enter).

To delete a cell or group of cells within a sort, complete the following steps:

1. Select the cells to be deleted.
2. Choose Edit, then Delete Cells.
3. In the Insert Cells dialog box, specify how you want the remaining cells shifted (up or left), then choose OK (or press Enter).

You could also select an entire row or column and then use the Cut command in the Edit menu. However, if you have selected a group of cells within a row or column and you access the Cut command, only the text within the cells will be deleted.

MERGING AND SPLITTING CELLS

On numerous occasions, while working within different sorts, you will want to combine data by merging a group of cells in a row together to create one large

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cell. This is especially useful in creating a subheading that spans the width of a sort, for example. Using the Merge Cells command in the Edit menu, you can merge cells within the same row together.

When you merge a group of cells together within the sort, each original cell becomes a new line in the merged cell. Therefore, if you merge four cells together, you will have one cell that is four lines in height. You should merge cells before entering text in them. Otherwise, when the cells are merged, the text within the original cells will be merged into a series of lines in the merged cell.

In the software, only cells within the same row can be merged. You cannot merge cells from different rows together. For example, to merge all the cells in the top row of a sort to contain a title or subheading, complete the following steps:

1. Select the entire first row of the target row you wish to expand.
2. Choose Edit, then Merge Cells.

You do not have to merge all the cells in a row together; sometimes you may want to merge only some of the cells within a row. To do this, select those cells that you want to merge, then access the Merge Cells command in the Edit menu. If you make a mistake in merging cells together and wish to undo the merge, access the Undo Merge Cells command in the Edit menu immediately after merging the cells. You can also split cells that have been merged back into their original configuration by accessing the Split Cells command in the Edit menu. To do this, complete the following steps:

1. Select the cell to be split.
2. Choose Edit, then Split Cells.

The Split Cells command is not always visible in the Edit menu; the Merge Cells and Split Cells commands are toggle commands (they switch back and forth in the menu). If the Split Cells command is not visible, it means that you have not selected a cell that was previously merged (and you cannot split cells that were not previously merged).

CHANGING COLUMN WIDTHS

When a sort is created within the software, the columns are the same width by program default. The width of the columns depends on the number of columns as well as the spreadsheet margins. In some sorts, you may want to change the width of certain columns to accommodate more or less text. There are three ways to change the column width in the software:

1. Use the mouse to drag the column borders to the desired location.

2. Use the mouse to drag the column markers to the desired location.
3. Use the Column **W**idth command in the **E**dit menu.

To change the column width with the column borders, complete the following steps:

1. Position the mouse cursor on the column border to be moved. When the mouse cursor is positioned directly on a column border, it changes to a double-pointed arrow with vertical lines in between.
2. Hold down the left mouse button, then drag the border to the right or left to widen or shorten the column. (As you drag the border, the column border in the original location displays in blue, and the column border being moved displays as a faint gray line.)
3. When the column border is in the new location, release the mouse button.

When you move a column border in this manner, any column borders to the right move the same distance in the same direction. In this way, the columns to the right of the border you are shifting remain their original widths. If you want to move a column border without moving the columns to the right, hold down the Shift key while dragging the column border to its new location. In this way, the location of the columns to the right is not changed, but the width of the column immediately to the right is resized. Any other columns to the right of the border you have shifted remain their original widths. If you want to move a column border without moving the columns to the right, but want those columns to be resized proportionately, hold down the Ctrl key while dragging the column border to its new location.

You can also use the Column **W**idth command to determine the measurement of a particular column in a data table. To do so, position the cursor in any cell within the appropriate column and access the Column Width dialog box. The current measurement for the column width appears in the appropriate text box. With the Column Width dialog box displayed on the screen, you can also enter specifications for the previous column and the next column by clicking on these buttons first, then entering the appropriate specifications.

CHANGING ROW HEIGHT

The amount of text in a cell and its point size determine the height of a cell. The height adjusts automatically as the text wraps around from one line to the next within the same cell. The tallest cell in the row determines the height of an entire row; all cells adjust to be the same as the tallest cell.

In some cases, you may want to establish a minimum row height, independent of the amount of text contained in the cells. You can create a variety of special effects by varying the row height. For example, you might want to add more blank space between the title of a data table and the surrounding border, or separate one row of cells from another by changing the row height of one of the rows. To change the row height, you must locate the cursor in the row you wish to change, then access the Row Height command in the Edit menu. When you access this command, the Row Height dialog box appears, allowing you to set the row height to your desired setting.

CHANGING CELL ALIGNMENT

When you initially create a sort, the alignment is pre-established in the software by default. If the cursor was located in a text line, paragraph, or data table that was centered when you inserted the data into the sort, each cell in the text line, paragraph, or data table will use center alignment. In this case, the end-of-cell markers appear in the center of each cell.

To change the alignment of cells, select the cells, then choose the desired alignment button on the toolbar, or access the paragraph command in the Format menu. Different alignment options can be applied to different cells.

OPENING A WINDOW

The maximum number of windows you can have open at one time is nine. Therefore, you can work on up to nine different sorts at one time. When you open a new window, it is placed on top of the original or preceding window. Once multiple windows are opened, however, you can resize the windows to see all or a portion of them at one time on the screen. There are three ways to open a new window:

1. Use the New Window command from the Window menu. This command opens a new window, which is placed upon the original window.
2. Use the New command from the File menu. This opens a totally new window.
3. Open another file (sort) with the Open command from the File menu. Use this command to open a different file (sort). The new file will be contained in a new window, placed on top of the original window.

At the bottom of the Window menu is a list of all open windows. The name with the checkmark next to it indicates the activity window being used (the one in which the cursor is located).

MOVING WINDOWS

Once you have multiple windows open, you can move them around on the screen without changing their size. This is particularly helpful when working with several different small windows at once. To move a window, you can use the **M**ove command in the Document Control menu, or use the mouse to drag the window to the desired location. To move a window, complete the following steps:

1. Choose the Document Control menu, then **M**ove. If you are using the keyboard, press Alt, O, M; or use the speed command Ctrl + F7. (If the Move command is unavailable, choose **W**indow, then **A**rrange All first.)
2. Press the arrow keys continuously to position the window in the desired location.
3. Press **E**nter to confirm the move.

If you are using a mouse, you can move a window easily by positioning the mouse cursor on the title bar of the window you want to move, and then hold down the left mouse button as you drag the window to the desired location.

MOVING BETWEEN WINDOWS

Once you have opened a second window, the original window is hidden behind the new window. To move back and forth between windows, you can choose one of the following methods:

1. Press Ctrl + F6 for the next window, or Shift + Ctrl + F6 for the previous window.
2. Choose Next Widow in the Document Control menu.
3. Access the **W**indow menu, and select the appropriate filename on the menu.
4. Click on the title bar of the appropriate window (when it is visible).

When you move back and forth between windows in this manner, the cursor in each window remains in the same location as when you last worked with it.

COPYING WHILE MOVING BETWEEN WINDOWS

The most common use of multiple windows is moving or copying text and formulas between windows. To do this, use the range operation explained in Data Range commands, together with the information presented in this

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chapter. For example, to move text or formulas from one window containing one sort to another window containing a different sort, complete the following steps:

1. Select the text or formulas you wish to copy or move.
2. Choose **E**dit, then **C**ut (or Copy), or use one of the other methods for transferring data to the clipboard.
3. Open the sort (file) in which you wish to insert the text (or locate the cursor in the appropriate window).
4. Position the cursor in the desired location.
5. Choose **E**dit, then **P**aste, or use one of the other methods for pasting information from the clipboard.

The steps are almost the same as when moving and copying information within the same sort. The advantage of working with multiple windows, however, is that you can transfer information *between* sorts very easily. If you are using Excel '97 or higher, the steps involved in transferring information from one window to another can also be used to transfer information from one pane to another in a split window.

USING MULTIPLE WINDOWS

The software operates on your Excel spreadsheet program within the Windows environment created by the created by the Windows operating platform. However, when you work with the software, the term *window* refers to the screen, excluding the menu bar, status bar, and message bar. A window therefore contains the portion of the screen where you enter or edit text, formulas, the title bar, and the scroll bars.

The Windows program creates an environment in which various software programs are used with menu bars, scroll bars, and icons to represent programs and files. With the Windows program, you can work on several different software programs at one time. Similarly, using the windows options in the software, you can work on several different sorts at one time.

With multiple windows open, you can work on several sorts or on two different parts of the same sort at once. You can copy or move information from one window to another, or compare the contents of several different windows. The software's windows feature is very useful for

- Looking up information in one part of a sort while working on another part of the sort
- Copying or moving text or formulas between different sorts or between different parts of the same sort
- Comparing the contents of several different sorts at once

CLOSING WINDOWS

The software offers several different methods for closing windows. To close an open window individually, you can do any of the following:

> Choose File, then Close.
> Choose the Document Control menu, then Close.
> Press Ctrl + F4.
> Double-click the Document Control box at the left side of the title bar.

If you access the Close command in the File menu when you have more than one window open that contains the same sort (if you selected the New Window command in the Window menu), all windows containing that sort are closed at once. If you have not saved your changes before closing a window, the software prompts you to do so.

You can also close all open windows and exit the software program at the same time. To do this, access the Close command in the Applications Control menu (represented by the gray box at the left side of the application title bar) by pressing Alt, space bar, Close, or by pressing Alt + F4.

PRINTING

When a sort is created in the computer, gridlines display on the screen identifying individual cells within the sort. These gridlines will not print when the sort is printed unless you choose to do so by selecting Grid Lines in Print Preview. This is the default setting in the software; however, the network timeline and S-charts should always be printed with the gridlines to provide easy visual alignment of the multiple dates.

In printing the sorts, remember the software is programmed in PostScript fonts and will reproduce best with a laser or ink-jet printer. Acceptable sort copies can be printed on a dot matrix printer, but some of the finer text and data on the sorts will not print legibly with dot matrix printers.

MAINTAINING SCHEDULE SORTS

Every project schedule maintains a filing system. The system may consist of documents, folders, and filing cabinets, or it may be a computerized filing system where information is stored on disks. Whatever kind of filing system a project uses, the daily maintenance of files is important to the project schedule's successful completion. Learning how to maintain sorts saves a great deal of time in searching for particular information and avoids costly mistakes from accidentally deleting or writing over existing files.

Because the software operates from a computer's hard disk, it saves information automatically to that hard disk unless you specify another drive. Effective file maintenance is particularly important on a hard disk; however, it also applies to floppy disks. Maintaining files on a disk usually includes such activities as deleting unnecessary documents and files, copying important documents and files so that you have a backup available, and establishing a logical way of organizing where files are stored.

A computer's hard disk is usually divided into several different subdirectories. You can think of subdirectories as file folders. File folders contain documents that have something in common; so do subdirectories. There are many different ways of organizing computer files into subdirectories. Some of these include

By the program in which they were created
By the name of the person who generated the files
By the name of the person who input the files
By the type of file (sorts, memos, letters, etc.)

Subdirectories are most commonly found on hard disks. However, a floppy disk can be divided into various subdirectories also. To choose a different subdirectory in the Open dialog box, access the Directories option, then select the appropriate directory from the list box. To choose a different drive, access the Drives option, then select the appropriate drive from the drop-down list that displays. To open a sort that is stored in a subdirectory on the C drive, complete the following steps:

1. Choose **F**ile, then **O**pen.
2. Choose **D**irectories, then select the root directory (C:\) in the Directories list box, and choose **OK** (or press **E**nter). (If you are using the mouse, you can double-click on the C:\ at the top of the Directories list box.)
3. Select the desired subdirectory in the Directories list box, and choose OK (or press **E**nter). If you are using the mouse, you can double-click on the desired subdirectory instead.
4. Choose File Name, then select the sort or file you wish to access in the file list box, then choose **OK** (or press **E**nter). If you are using the mouse, you can double-click on the sort or filename instead.

Opening the same sort or file from a floppy disk is a somewhat simpler procedure, since you would not normally need to specify a subdirectory on a floppy disk. To open the desired sort or file from the disk in drive A, complete the following steps:

1. Choose **F**ile, then **O**pen.

2. Choose **Drives**, then select a: in the drop-down list that displays, and choose OK (or press **Enter**). If you are using the mouse, you can double-click on a: instead.
3. Choose File **Name**, then select the desired sort or file from the file list box, and choose OK (or press **Enter**). If you are using the mouse, you double-click on the sort or filename instead.

EXITING THE SOFTWARE

When you are finished working with the software and have saved all necessary data and information, exit the software by choosing **File**, then **Exit** or by pressing Alt + F4. You can also exit the software by positioning the mouse cursor on the Control-menu box (the upper box with a dash in it in the upper left corner of the screen), clicking the button once, and choosing **Close** in the menu that displays. After exiting the software for Excel, you must exit the Excel spreadsheet program.

When you exit the software, the program group window appears on top of the program manager window. You should always close the software before exiting from the spreadsheet platform. To do so, click on the Control-menu box in the upper left corner of the program group window, then choose **Close** in the menu that displays on the screen, or press Crtl + F4. If the software is running on your Excel platform in Windows, you exit Windows by completing the following steps:

1. Choose **File**, then **Exit** Windows or press Alt + F4.
2. At the Exit Windows dialog box, choose OK (or press **Enter**).

If you are using Windows 3.0 or higher, the Exit Windows dialog box contains the **Save Changes** option. By default, this option should have an X in the check box. With this option selected, Windows is exited, and any changes made to the layout of the program manger are saved.

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Appendix A

Project Production Abbreviations

Contract documents, which include the project's schedule, are governed by AIA specifications. These AIA acronyms and abbreviations are typical and commonly used. You will note some of these abbreviations have periods while some don't. This is not a typo; this is the way they appear in use. Don't ask me hy, because I don't know why. Neither does anyone else at the AIA headquarters office. It's just the way it is. Probably one of those things that tradition has passed on to us just to drive people nuts when they try to learn the system.

You will see many of these in production documents. Make sure you understand all acronyms and abbreviations that come to your production scheduling. You will note by examining these that there are subtleties that go with the periods, such as PCC stands for "point of compound curve" whereas P.C.C. stands for "Portland Cement Concrete." As always, pay attention to details in looking at abbreviations, especially in your long-lead items. Remember the scheduler's credo, "Check twice, schedule once."

A	area
AASHO	American Assn. of State Highway Officials
A.B.	anchor bolt
A.B.	aggregate base
ABS	acrylonitrile butadiene styrene (plastic sewer pipe)
AC	alternating current
A.C.	asphalt concrete

ACI	American Concrete Institute (concrete specs for concrete production)
ACP	asbestos cement pipe
ACST	acoustic
ACST PLAS	acoustical plastic
ACU	air conditioning unit
AD	area drain
ADD	addition
ADJ	adjustable
AFF	above finish floor (elevation)
AGG.	aggregate
AH	air handling unit
AIA	American Institute of Architects (contracts and design specs)
AISC	American Institute of Steel Construction (structural steel specs)
ALT	alternate
AMT	amount
ANGL	angle
ANGL DF	angle of deflection (intersecting angle)
APP	ataxic polypropylene
APPX	approximate
APT	apartment
ARCH	architect(s) or architectural
ASA	American Standards Association
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASPH	asphalt
ASSEM	assemble
ASSOC	Associate
ASTM	American Society of Testing Materials
AT	acoustical tile
AUTO	automatic
AVG	average
AWPA	American Wood Products Association (wood standards)
AWS	American Welding Society (steel specs standards)
AWWA	American Water Work Association (water standards)
Ba	bay
BB	bond beam
BC	begin horizontal curve
BF	bottom of footing
BHP	boiler horsepower

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BITUM	bituminous
BLDG	building
BLKG	blocking
BM	benchmark
BOT	bottom
B.O.W.	back of walk
BP	blueprint (refer to plans)
BRG	bearing (load bearing)
BRG PL	bearing plate
BRK	brick
BRKT	bracket(s)
BTR	better
>BTR	better than
BTU	British thermal unit
BU	Bureau of Standards
BVC	begin vertical curve
C	thermal conductive
C.	one hundred (100)
CATV	cable television
CB	catch basin
CC	center to center
CEM	cement
CF	cubic foot
CFM	cubic feet per minute
C&G	curb and gutter
CC	center to center
CL	center line
CLR.	clear
CMU	concrete masonry units (masonry blocks)
CMP	corrugated metal pipe
CND	conduit
CO	company
CONC	concrete
CONF	conform
CONST.	construct
CONT.	contours or continuous
CONTR	contractor
CP	concrete pipe
CPM	critical path method, critical path management
CPM	cycles per minute
CS	cast steel
CS	commercial standards (as in "up to")
CSF	100 square feet
CSI	Construction Specifications Institute (construction specs)

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CTR	contract (as in "per")
CU FT	cubic foot
CU IN	cubic inch
CU YD	cubic yard
D	drain
D	depth
DC	direct current
DEG	degree
DEPT	department
DET.	detail
DF	Douglas fir (construction grade lumber)
D.I.	drain inlet
DIA.	diameter
DIAG	diagram
DIP	ductile iron pipe
DISC	disconnect
DIV	division
DL	dead load
DN	down
DP	duplicate
DPG	damp proofing
DSB	double-strength B grade glass
D4S	dressed and matched on four sides
DU	double strength
DWG.	drawing D/W driveway
DWV	drain, waste, vent piping
DX	duplex
E	east
EA.	each
E to E	end to end
EC	end horizontal curve
EL, ELEV.	elevation
EJ	expansion joint
ENCL	enclosure
ELEC	electric
ELVR	elevator
EMER	emergency
EMT	electrical metallic tubing (conduit)
ENGR	engineer
ENT	entrance
EP	electrical panel
EQ	equal
EQUIP	equipment
EST	estimate
ETE	end to end

EWC	electric water cooling
EXC	excavate
EXCL	exclude
EXH	exhaust
EXIST	existing
EXP	expansion
EXR JT	expansion Joint
EXP	exposure
EXPO	exposed
EXST	existing
EXT	exterior
EXTN	extension
E.P.	edge of pavement
EQ	equal
EVC	end vertical curve
EX.,EXIST	existing
F	Fahrenheit
FA	fire alarm
F&I	furnish and install
FAB	fabricate
FAO	finish all over
FB	flat bar
FBM	foot board measure
FD	floor drain
FD	found
FDN	foundation (East Coast)
FE	fire extinguisher
FEC	fire extinguisher cabinet
FED	federal
FED SPEC	federal specification
FG	finish grade
FH	fire hose
FHC	fire hose cabinet
FICA	Social Security tax
FIG	figure
F.L.	flowline
FIN	finish
FIN CEIL	finish ceiling (elevation)
FIN FL	finish floor (elevation)
FIX	fixture(s)
FL	flashing
FL	floor
FLASH	roof flashing
FLG	flooring (type)
FLNG	flange

FLUOR	fluorescent
FND	foundation (West Coast)
FOB	free on board
FOC	face of concrete
FOF	face of finish
FOS	face of studs
FP	fireplace
FPM	feet per minute
FPRF	fireproof
FPS	feet per second
FR	frame
FRG	furring
FRP	fiberglass reinforced plastic
FS	full size
FT	foot
FT^3	cubic feet
FTG	footing
FTG	fitting
FUT	future (use)
FUTA	Federal Unemployment Tax
FWH	frostproof
FX WDW	fixed window
G	gas
GA	gauge
GAL	gallon
GALV	galvanized
GB	grade beam
G.B.	grade break
GFI	ground-fault interrupter
GFCI	ground-fault circuit interrupter
GI	galvanized iron
GL	glazed (glass)
GND	ground
GOVT	government
GPH	gallons per hour
GPM	gallons per minute
GR	grade
GR	grate
GRAN	granular
GRD	ground
GRTG	grating
GYP	gypsum
GYP BD	gypsum board (sheetrock drywall)
HA	hot air
HB	hose bib

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HC	heating coil
HD	head
HDP	head pressure
HDW	hardware
HDWD	hardwood
HEX	hexagonal
HGT	height
HM	hollow metal
HOR, HORZ	horizontal
HP	horsepower
HR	hour
HSE	house
HTR	heater
HU	humidifier
HV	heating and ventilation unit(s)
HVAC	heating, ventilation, and air conditioning
HW	hot water
HWH	hot water heater
HWR	hot water return
Hz	Hertz
I	I beam
I	iron
ID	inside diameter
IF	inside face
IMC	intermediate metal conduit
IN	inch
IN^3	cubic inch
INC	incorporate(d)
INCAND	incandescent
INCL	include(d)
INCR	increaser
INS	insulate
INT	interior
INV	invert (flow line)
INV.	invert
I.P.	iron pipe
J	junction
JAN	janitor
JB	junction box
JB	jamb
JP	joist and plank
JST	joist
J.B.	junction box
K	kilo (1000)
KAL	kalamein

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KD	kiln dried
Km	kilometer
KP	kick plate
KVA	kilo volt amperes
KW	kilowatt
L	left
L	lumen
L	length
LAB	laboratory
LAM	laminated
LAT	lateral
LAU	laundry
LAV	lavatory
LB	light beam
LB	pound
LBR	lumber
L.C.	length of curve
LDG	landing
LEV	level
LF	linoleum floor
L.F.	linear foot
LG	long
LH	left hand
LHR	left hand reversed
LIN FT	linear feet
LL	live load
LOA	length overall
L&PP	light and power panel
LP	low point
LPG	liquefied petroleum gas
LR	living room
LS	lump sum (contract)
LT	light (pane of glass)
LTH	lath
LVR	louver
LW	light weight
M	bending moment (force)
M	meter
M	thousand
MAGN	magnesium
MAS	masonry
MATL	material
MAV	manual air vent
MAX	maximum
MBF	thousand board feet

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MBtu	thousand British thermal units
MBR	master bedroom
M&D	matched and dressed
MDO	medium-density overlaid
MDP	main distribution panel
MECH	mechanical
MED	medium
MET	metal
MFD	manufactured
MFG	manufacture
MH	manhour
MH	manhole
MI	mile
MIN	minute
MIN	minimum
MISC	miscellaneous
MIX	mixture
MK	mark
ML	metal lath
MLF	thousand linear feet
MDG	molding
mm	millimeter
MN	main
MN	mean (average)
Mo	month
MO	motor-operated
MOD	modular
MOR	mortar
MS	manual starter
MSF	thousand square feet
MTD	mounted
N	north
NATL	national
NBS	National Bureau of Standards
NEMA	National Electrical Manufacturers Association
NF	near face
NFPA	National Fire Protection Association
NIC	not in contact
No	number
NOM	nominal
NOR	normal
NRC	noise reduction coefficient
NTS	not to scale
O to O	out to out
OA	overall

OBS	obscure
OC	on center
O.C.	on center
OCT	octagonal
OD	outside diameter
OF	outside face
OFF	office
OPNG	opening
OPP	opposite
OS	outside
OUT	outlet
OVHD	overhead
OZ	ounce
P	plumb
PAR	parallel
PART	partition
PASS	passageway
PAV	paving
PCC	point of compound curve
P.C.C.	Portland cement concrete
PCR	point of curb return
PCS	pieces
PERF	perforated
PERIM	perimeter
PERP	perpendicular
PG	page
PH	phase
PL	pilot light
PL	plate
PL	property line
PLAS	plaster
PLAT	platform
PLBG	plumbing
PLGL	plate glass
PL HT	plate height
PLMB	plumb
PLY	plywood
PNL	panel
PPM	parts per minute
PRCST	precast
PR	pair
PRC	point of reverse curve
PREFAB	prefabrication
PRESS	pressure
PRI	primary

PROP	property
PROP	proposed
PRV	pressure-reducing (regulating) valve
PS	pull switch
PSI	pounds per square inch
PT	point
P.T.	pressure-treated
P.U.E.	public utility easement
PVC	polyvinyl chloride (plastic water pipe)
P.V.I.	point of vertical intersection
PVMT	pavement
QT	quarry tile
QT	quart
QTY	quantity
R	radius
R	thermal resistance
(R)	radial
RA	return air
RAD	radius
R.C.	relative compaction
RCP	reinforced concrete pipe
RD	round
RDM	random
REC	recessed
RECP	receptacle
REF	reference
REFL	reflective
REFR	refrigeration
REG	register
REM	remove
REINF	reinforcing
REP	repair
REQ	required
RESIL	resilient
RETG	retaining
REV	revision
RF	roof
RFG	roofing
RGH	rough
RGH OPNG	rough opening
RH	right hand
RHR	right hand reversed
RHW	heat- and moisture-resistant rubber
RIO	rough-in opening
RIV	rivet

R/L	random lengths
R/W/L	random widths and lengths
RM	room
RO	rough opening
RPM	revolutions per minute
RST	rigid steel conduit
RT	rubber tile
RT	right
RV	relief valve
RDW	redwood
RWL	rain water leader
s	slope in feet per foot
S	south
SA	supply air
SAD	supply air defuser
SAF	safety
SAN	sanitary
SC	scale
SC	self-closing
SC	solid core
SCHED	schedule
SCT	sewer clay tile
SCUP	scupper
SD	storm drain
SDMH	storm drain manhole
SEC	second
SEC	secondary
SECT	section
SER	service
SEW	sewer
SFCA	square feet of form in contact with concrete
SHLP	shiplap
SHT.	sheet
SHTG	sheathing
SIM	similar
SJ	steel joist
SM	sheet metal
SOV	shut-off valve
SPEC	specification
Sq	hundred square feet
SQ	square
SQ FT	square foot
SQ YD	square yard
SR	supply register (air)
SS	sanitary sewer

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SSB	single-strength B grade glass
SSG	single-strength glass
SSMH	sanitary sewer manhole
SST	stainless steel
STA.	station
Std	standard
STD	stud
STL	steel
STR	straight
STRL	structural
STRUC	structural
SUB	substitute
SUPP	supplement
SUR	surface
SUSP	suspended
SV	safety valve
S/W, SW	sidewalk
SWG	standard wire gauge
SY	square yard
SYM	symbol
SYM	symmetrical
S2E	surfaced on two edges
S2S	surfaced on two sides
S4S	surfaced on four sides
T	thick
T	threaded
T	thermostat
TAN	tangent
TB	top of beam
T&B	top and bottom
TBM	temporary benchmark
TC	top of concrete
TC	top of curb
TEL	telephone
TEMP	temporary
TEMPL	template
TERM	terminal
TF	top of footing
TG	top of grate
T&G	tongue and groove
TH	threshold
THK	thickness
TM	top of masonry
TOF	top of footing
TP	top of pier

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TRANS	transformer
TS	tensile strength
TS	time switch
TS	top of slab
TV	television
TW	top of wall
TYP	typical
U	up
UBC	uniform building code
UG	underground
UH	unit heater
UL	Underwriters Laboratory (electrical fixture specs)
UNEX	unexcavated
UNF	unfinished
UON	unless otherwise noted
UR	utility room
USS	United States standard
V	valve
V	vent
V	volts
VAC	vacuum line
VD	vent duct
VAP PRF	vapor proof
VC	vitrified clay
VEN	veneer
VENT	ventilate
VERT	vertical
VEST	vestibule
VI	central valve (as numbered)
VLF	vertical linear feet
VOL	volume
VP	vitreous pipe
VS	vent stack
VT	vertical tangent
VT&G	vertical tongue and groove
VTR	vent through roof
W	west
W	width
W	water
W/	with
WC	water closet
WD	wood
WDW	window
WF	water fountain
WGL	wire glass (reinforced)

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WH	water heater
WHR	watt meter hour
WI	wrought iron
WM	water meter
WP	waterproof
WP	weather-proof
WR BD	weather-resistant board
WS	weather stripping
WS	water service
WSCT	wainscot
WT	weight
WV	water valve
WWF	welded wire fabric
X	by (multiplied by, as in 2×4)
X SECT	cross section (blueprint view)
XT	temporary marker
YD	yard
YD^3	cubic yard
YP	yellow pine
Z	zinc

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Appendix B

Industry Associations

The following associations are important resource centers for the professional project scheduler. Most have information brochures, literature, and advice that they will forward at no cost.

American Institute of Architects
1735 New York Ave.
Washington, DC 20006
202/626-7300

American Standards Institute
11 W. 42nd Street
New York, NY 10036
212/642-4900

American Transportation Assn.
1916 Race St.
Washington, DC 20024
202/488-2722

American Society of Civil Engineers
345 E. 47th St.
New York, NY 10017
212/705-7496

American Institute of Constructors
9887 N. Gandy, Ste. 104
St. Petersburg, FL 33702
813/578-0317

American Public Works Association
1313 E. 60th Street
Chicago, IL 60637
312/667-2200

American Society Testing Materials (ASTM)
501 School St., SW, 8th Floor
Philadelphia, PA
215/299-5400

American Society Home Inspectors
1735 N. Lynn St., Ste. 950
Arlington, VA 22209
800/296-2744

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American Subcontractors
Assn.
1004 Duke St.
Alexandria, VA 22314
703/684-3450

Associated Builders &
Constructors
729 15th St., NW
Washington, DC 20005
202/637-8800

Associated General Contractors
1957 E St., NW
Washington, DC 20006
202/393-2040

Building Officials Administrators
4051 W. Flossmoor Rd.
Country Club Hills, IL 60478
708/799-2300

Building Research
Board
2101 Constitution Ave., NW
Washington, DC 20418
202/334-3376

Construction Management
Institute
P.O. Box 1001
Soquel, CA 95073
408/462-0147

Construction Specifications
Institute
601 Madison St.
Alexandria, VA 22314
703/684-0300

Society of Professional
Engineers
1420 King St.
Alexandria, VA 22314
703/684-2800

Scaffolding Institute, Inc.
1300 Sumner Ave.
Cleveland, OH 44115
216/241-7333

Assn. of Geoscience Engineering
8811 Colesville Rd.
Silver Spring, MD 20907
301/565-2733

American Concrete Institute
22400 W. Seven Mile Rd.
Detroit, MI 48219
313/532-2600

Portland Cement Association
5420 Old Orchard Rd.
Stokie, IL 60077
708/966-6200

Wire Reinforcement Institute
1101 Connecticut Ave., NW
Washington, DC 20036
202/429-4303

Concrete Reinforcing Institute
933 N Plum Grove Rd.
Schaumberg, IL 60173
708/517-1200

National Precast Concrete
Institute
825 E. 64th St.
Indianapolis, IN 46220
317/253-0486

Prestressed Concrete
Institute
175 W. Jackson Blvd., Ste. 1859
Chicago, IL 60604
312/786-0300

Tilt-Up Concrete Association
2431 W. Cummings Wood Lane

International Masonry Institute
823 15th St., NW

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Hendersonville, NC 28739
704/891-9578

Masonry Institute of America
2550 Beverly Blvd.
Los Angeles, CA 90057
213/388-0472

Building Stone Institute
P.O. Box 5047
White Plains, NY 10602
914/232-5725

Limestone Institute of America
Stone City Bank Bldg., Ste. 400
Bedford, IN 47421
812/275-4426

Marble Institute of America
33505 State St.
Farmington, MI 48335
313/476-5558

American Steel Construction
1 E. Wacker Dr., Ste. 3100
Chicago, IL 60601
312/670-2400

Copper Development Association
Greenwich Oce Park 2
Greenwich, CT 06836
203/625-8210

National Metal Manufacturers
600 S. Federal St., Ste. 400
Chicago, IL 60606
312/922-6222

Steel Joist Institute
1205 48th Ave., N, Ste. A
Myrtle Beach, SC 29577
803/449-0487

Southern Forest Products Assn.
P.O. Box 52468

Washington, DC 20005
202/783-3908

Brick Institute of America
11490 Commerce Park Dr.
Reston, VA 22091
703/620-0010

Cast Stone Institute
Greentree Pavilons, Ste. 408
Marlton, NJ 08053
609/858-0271

Marble Center Assn.
499 Park Ave.
New York, NY 10022
212/980-1500

Aluminum Association
900 19th St., NW, Ste. 300
Washington, DC 20006
202/862-5100

American Iron & Steel Institute
1133 15th St., NW
Washington, DC 20005
202/452-7100

Lath/Steel Framing Association
600 S. Federal St., Ste. 400
Chicago, IL 60606
312/922-6222

Steel Structures Council
4400 5th Ave.
Pittsburgh, PA 15213
412/268-3327

Steel Deck Institute
P.O. Box 9506
Canton, OH 44711
216/493-7866

Western Wood Products Assn.
522 SW 5th Ave.

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270 Madison Avenue, New York, New York 10016

New Orleans, LA 70152
504/443-4464

American Timber Construction
11818 SE Mill Plain Blvd.
Vancouver, WA 98684
206/254-9132

Architectural Woodwork Institute
P.O. Box 1170
Centerville, VA 22020
703/222-1100

American Wood Preservers Assn.
P.O. Box 5283
Springfield, VA 22150
703/339-6660

Laminate Products Association
600 S. Federal St., Ste. 400
Chicago, IL 60606
312/922-6222

Sealant & Waterproofing Assn.
3101 Broadway, Ste. 585
Kansas, MO 64111
816/561-8230

Perlite Institute
88 New Dorp Plaza
Staten Island, NY 10306
718/351-5723

Exterior Insulation Association
2759 State Rd. 580, Ste. 112
Clearwater, FL 34621
813/231-6477

Cedar Shake & Shingle Assn.
515 116th Ave. NE, Ste. 275
Bellevue, WA 98004
206/453-1323

American Architectural Assn.
1540 E. Dundee Rd., Ste. 310

Portland, OR 97204
503/224-3930

American Plywood Association
P.O. Box 11700
Tacoma, WA 98411
206/565-6600

National Particleboard Association
2310 S. Walter Reed Dr.
Gaithersburg, MD 20879
301/670-0604

Cultured Marble Institute
435 N. Michigan Ave.
Chicago, IL 60611
312/644-0828

Institute of Roofing
4242 Kircho Rd.
Rolling Meadows, IL 60008
708/991-9292

Insulation Manufacturers Assn.
1420 King St., Ste 410
Alexandria, VA 22314
703/684-0084

Polyisocyanurate Insulation Assn.
1001 Pennsylvania Ave. NW
Washington, DC 20004
202/624-2709

Asphalt Roofing Association
6288 Montrose Rd.
Rockville, MD 20852
301/231-9050

Single Ply Roofing Institute
104 Wilmot Rd., Ste. 201
Deerfield, IL 60015
708/940-8800

National Wood Assn.
1400 E. Touhy Ave.

Palatine, IL 60067
708/202-1350

Vinyl Window & Door Institute
355 Lexington Ave.
New York, NY 10017
212/351-5400

Door & Hardware Institute
7711 Old Springhouse Rd.
McLean, VA 22102
703/556-3990

National Glass Association
8200 Greensboro Dr.
McLean, VA 22102
703/543-7456

Gypsum Association
810 1st St., Ste. 510
Washington, DC 20002
202/289-5440

Tile Council of America
P.O. Box 326
Princeton, NJ 08542
609/921-7050

Acoustical Society of America
500 Sunnyside Blvd.
Woodbury, NY 11797
516/349-7800

National Wood Flooring Assn.
11046 Manchester Rd.
St. Louis, MO 63122
800/422-4556

National Coatings Association
1500 Rhode Island Ave.
Washington, DC 20005
202/462-6272

Plumbing Manufacturers Institute
800 Roosevelt Rd.
Des Plaines, IL 60018
708/299-5200

Steel Window Institute
1621 Euclid St.
Cleveland, OH 44115
216/241-7333

Steel Door Institute
30200 Detroit Rd.
Cleveland, OH 44145
216/899-0010

International Institute of Plaster
820 Transfer Rd.
St. Paul, MN 55111
818/256-9980

Ceramic Tile Institute
700 North Virgil Ave.
Los Angeles, CA 90029
213/660-1911

National Mosaic Tile Assn.
3166 Des Plaines Ave.
Des Plaines, IL 60018
708/635-7744

Interior Systems Association
104 Wilmot Rd.
Deerfield, IL 60015
708/940-8800

Resilient Floor Institute
966 Hungerford Dr.
Rockville, MD 20850
301/340-8580

Wallcovering Manufacturers Assn.
355 Lexington Ave.
New York, NY 10017
212/661-4261

Air Diffusion Council
111 E. Wacker Dr., Ste. 200

Glen Ellyn, IL 60137
708/858-9172

Cooling Tower Institute
P.O. Box 73373
Houston, TX 77272
713/583-4087

Institute of Heating & Air Conditioning (IHACI)
606 Larchmont Blvd., Ste. 4A
Los Angeles, CA 90004
213/467-1158

Edison Electric Institute
701 Pennsylvania Ave. NW
Washington, DC 20004
202/508-5000

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
1791 Tullie Circle NE
Atlanta, GA 30329
404/636-8400

Chicago, IL 60601
312/616-0800

Air Movement Control Assn.
30 W. University Dr.
Arlington Heights, IL 60004
703/394-0150

Lighting Research Center
Polytechnic Institute, Bldg. No. 115
Troy, NY 12180
518/276-8716

National Elect. Contractors Assn
7315 Wisconsin Ave.
Bethesda, MD 20814
301/657-3110

Appendix C

EJCDC Table of Contract Standards

The following appendix contains the table of standards set for general conditions of the construction contract that is prepared by the Engineers Joint Contract Documents Committee, recognized nationwide as the authoritative industry standard for construction contracts. Your project schedule will operate within the parameters of these standards. Use this table to locate the contracting and scheduling precedence of the item you seek when and if there's a contract dispute delaying your schedule. Even if the project owner doesn't know this, you should. This table is of the current 2001 edition of the Standard General Conditions of the Construction Contract, prepared by the EJCDC.

Article	Division	Title	Page number
1.1	Contract Definitions	Addenda	13
1.2	Contract Definitions	Agreement	13
1.3	Contract Definitions	Payment Application	13
1.4	Contract Definitions	Asbestos	13
1.5	Contract Definitions	Bid	13
1.6	Contract Definitions	Bid Documents	13
1.7	Contract Definitions	Bid Requirements	13
1.8	Contract Definitions	Bonds	13
1.9	Contract Definitions	Change Order	13
1.10	Contract Definitions	Contract Documents	13
1.11	Contract Definitions	Contract Price	13

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

1.12	Contract Definitions	Contract Times	13
1.13	Contract Definitions	Contractor	13
1.14	Contract Definitions	Defective Work	13
1.15	Contract Definitions	Drawings	13
1.16	Contract Definitions	Eective Agreement Date	13
1.17	Contract Definitions	Engineer	13
1.18	Contract Definitions	Engineer's Consultant	13
1.19	Contract Definitions	Field Order	13
1.20	Contract Definitions	General Requirements	14
1.21	Contract Definitions	Hazardous Waste	14
1.22	Contract Definitions	Laws and Regulations	14
1.23	Contract Definitions	Liens	14
1.24	Contract Definitions	Milestones	14
1.25	Contract Definitions	Notice of Award	14
1.26	Contract Definitions	Notice to Proceed	14
1.27	Contract Definitions	Owner	14
1.28	Contract Definitions	Partial Utilization	14
1.29	Contract Definitions	PCBs	14
1.30	Contract Definitions	Petroleum	14
1.31	Contract Definitions	Project	14
1.32	Contract Definitions	Radioactive Material	14
1.33	Contract Definitions	Resident Representative	14
1.34	Contract Definitions	Samples	14
1.35	Contract Definitions	Shop Drawings	14
1.36	Contract Definitions	Specifications	14
1.37	Contract Definitions	Subcontractor	14
1.38	Contract Definitions	Substantial Completion	14
1.39	Contract Definitions	Supplementary Conditions	14
1.40	Contract Definitions	Supplier	14
1.41	Contract Definitions	Underground Facilities	14
1.42	Contract Definitions	Unit Price Work	14
1.43	Contract Definitions	Work	15
1.44	Contract Definitions	Work Change Directive	15
1.45	Contract Definitions	Written Amendment	15
2.0	Preliminary Matters	Delivery of Bonds	15
2.1	Preliminary Matters	Copies of Documents	15
2.2	Preliminary Matters	Contract Commencement	15
2.4	Preliminary Matters	Starting Work	15
2.5	Preliminary Matters	Preliminary Schedule	15
2.7	Preliminary Matters	Preconstruction Conference	15
2.9	Preliminary Matters	Accepted Schedules	16
3.0	Contract Documents	Standards	16
3.1,2	Contract Documents	Intent	16
3.3	Contract Documents	Specifications	16
3.4	Contract Documents	Terms & Adjectives	17

3.5	Contract Documents	Amending	17
3.6	Contract Documents	Supplementing Documents	17
3.7	Contract Documents	Reuse of Documents	17
4.0	Physical Conditions	Reference Points	17
4.1	Physical Conditions	Land Availability	17
4.2	Physical Conditions	Subsurface Conditions	17
4.2.1	Physical Conditions	Reports & Drawings	17
4.2.2	Physical Conditions	Reliance by Contractor	18
4.2.3	Physical Conditions	Differing Conditions Notice	18
4.2.4	Physical Conditions	Engineer's Review	18
4.2.5	Physical Conditions	Possible Contract Change	18
4.2.6	Physical Conditions	Possible Price Change	18
4.2.8	Physical Conditions	Possible Time Adjustments	18
4.3	Physical Conditions	Underground Facilities	18
4.3.1	Physical Conditions	Shown or Indicated	18
4.3.2	Physical Conditions	Not Shown or Indicated	19
4.4	Physical Conditions	Reference Points	19
4.5	Physical Conditions	Hazardous Materials	19
5.0	Bonds & Insurance	Bonds	20
5.1	Bonds & Insurance	Payment Bonds	20
5.2	Bonds & Insurance	Performance Bonds	20
5.3	Bonds & Insurance	Sureties	20
5.4	Bonds & Insurance	Contractor's Insurance	20
5.5	Bonds & Insurance	Owner's Insurance	21
5.6	Bonds & Insurance	Property Insurance	21
5.7	Bonds & Insurance	Machinery & Equipment	21
5.8	Bonds & Insurance	Notice of Cancellation	21
5.9	Bonds & Insurance	Contractor's Responsibility	22
5.10	Bonds & Insurance	Special Insurance	22
5.11	Bonds & Insurance	Waiver of Rights	22
5.13	Bonds & Insurance	Application & Receipt	22
5.14	Bonds & Insurance	Acceptance of Bonds	22
5.15	Bonds & Insurance	Partial Utilization	23
6.0	GC Responsibility	Supervision	23
6.1	GC Responsibility	Superintendence	23
6.4	GC Responsibility	Labor & Materials	23
6.5	GC Responsibility	Equipment	23
6.6	GC Responsibility	Progress Schedule	23
6.7	GC Responsibility	Item Substitutes	23
6.8	GC Responsibility	Engineer's Evaluation	23
6.11	GC Responsibility	Subcontractors	24
6.12	GC Responsibility	Fees	24
6.13	GC Responsibility	Permits	25
6.14	GC Responsibility	Laws & Regulations	25
6.15	GC Responsibility	Taxes	25

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

10.2	Work Changed	Adjustment Claim	32
10.3	Work Changed	Work Not Required	32
10.4	Work Changed	Change Orders	32
10.5	Work Changed	Surety Notification	32
11.0	Contract Changes	Price	32
11.2	Contract Changes	Claim for Adjustment	32
11.4	Contract Changes	Cost of Work	33
11.5	Contract Changes	Exclusions	34
11.6	Contract Changes	Contractor's Fee	34
11.7	Contract Changes	Cost Records	34
11.8	Contract Changes	Cash Allowances	35
11.9	Contract Changes	Unit Price Work	35
12.0	Changes in Times	Contract Time	35
12.1	Changes in Times	Claim for Adjustment	35
12.2	Changes in Times	Time of the Essence	35
12.3	Changes in Times	Contractor Delay	35
12.4	Changes in Times	Owner Delay	35
13.0	Tests & Inspections	Acceptance	36
13.1	Tests & Inspections	Notice of Defects	36
13.2	Tests & Inspections	Access to the Work	36
13.3	Tests & Inspections	Contractor Cooperation	36
13.4	Tests & Inspections	Owner Responsibility	36
13.5	Tests & Inspections	Contractor Responsibility	36
13.7	Tests & Inspections	Covering Work	36
13.9	Tests & Inspections	Uncovering Work	36
13.10	Tests & Inspections	Owner Stop Work	36
13.11	Tests & Inspections	Correction of Work	37
13.12	Tests & Inspections	Correction Period	37
13.13	Tests & Inspections	Acceptance of Work	37
13.14	Tests & Inspections	Owner Correction	37
14.0	Payments	To Contractor	37
14.1	Payments	Schedule of Values	37
14.2	Payments	Progress Payments	38
14.3	Payments	Contractor's Warranty	38
14.4-7	Payments	Review of Payments	39
14.8	Payments	Substantial Completion	39
14.10	Payments	Partial Utilization	39
14.11	Payments	Final Inspection	39
14.12	Payments	Final Application	40
14.14	Payments	Final Payment	40
14.15	Payments	Payment Acceptance	40
14.16	Payments	Waiver of Claim	40
15.0	Work Suspension	Termination	40
15.1	Work Suspension	Owner Suspension	40
15.2-4	Work Suspension	Owner Termination	40

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

15.5	Work Suspension	Contractor Termination	41
16.0-9	Dispute Resolution	Precedence	41
17.0	Miscellaneous	Extras	42
17.1	Miscellaneous	Giving Notice	42
17.3	Miscellaneous	Time Computation	42
17.4	Miscellaneous	Notice of Claim	42
17.5	Miscellaneous	Cumulative Remedies	42
17.6	Miscellaneous	Professional Fees	42
17.18	Miscellaneous	Court Costs	42
18.0	Acceptance	Bonds & Insurance	43
18.1	Acceptance	Defective Work	43
18.2	Acceptance	Final Payment	43
18.3	Acceptance	Insurance	43
18.4	Acceptance	Other Work	43
18.5	Acceptance	Substitutes	43
18.6	Acceptance	Work By Owner	44
19.0	Access	Lands	44
19.1	Access	Site	44
19.3	Access	Work	44
20.0	Acts/Omissions	Contractor	45
20.1	Acts/Omissions	Engineer	45
20.2	Acts/Omissions	Architect	45
20.3	Acts/Omissions	Owner	45
20.4	Acts/Omissions	Inspector	45
21.0	Addenda	Definition	46
21.1	Addenda	Specifications	46
21.2	Addenda	Insurance	46
21.3	Addenda	Adjustments	46
21.5	Addenda	Prices	46
21.6	Addenda	Contract Times	46
21.7	Addenda	Adjustments	46
21.8	Addenda	Progress	47
21.9	Addenda	Agreement	47
22.0	Amendment	Written	47
22.1	Amendment	General	47
22.2	Amendment	Claims	47
22.3	Amendment	Contractor	47
22.4	Amendment	Owner	47
22.5	Amendment	Architect	48
22.6	Amendment	Engineer	48
22.8	Amendment	Definition	48
22.9	Amendment	Prices	48
23.0	Authorization	Owner	48
23.1	Authorization	Architect	48
23.2	Authorization	Engineer	49

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

23.3	Authorization	Contractor	49
23.4	Authorization	Prior	49
23.5	Authorization	During Construction	49
23.6	Authorization	Change Order	49
23.7	Authorization	Claims	49
24.0	Contract Specs	Documents	50
24.1	Contract Specs	Bidding	50
24.2	Contract Specs	Award	50
24.3	Contract Specs	Recordation	50
24.4	Contract Specs	Bonds & Insurance	50
24.5	Contract Specs	Amendment	50
24.6	Contract Specs	Arbitration	50
24.7	Contract Specs	Changes	51
24.8	Contract Specs	Change Order	51
24.9	Contract Specs	Claims	51
25.0	Certificates	Bonds	51
25.1	Certificates	Insurance	51
25.2	Certificates	Cancellation	51
25.3	Certificates	Cash Allowance	52
25.5	Certificates	Substantial	52
25.6	Certificates	Inspections	52
25.7	Certificates	Final	52
25.8	Certificates	Completion	52
25.9	Certificates	Cancellation	52
26.0	Contractor	Defined	53
26.1	Contractor	Fee	53
26.2	Contractor	Cost of Work	53
26.3	Contractor	General	53
26.4	Contractor	Exclusions	53
26.5	Contractor	Cost Records	53
26.6	Contractor	Lump Sum	53
26.7	Contractor	Unit Price	53
26.8	Contractor	Surety Notify	54
26.9	Contractor	Scope of	54
27.0	Owner	Defined	54
27.1	Owner	General	54
27.2	Owner	Scope of	54
27.3	Owner	Insurance	54
27.4	Owner	Coordination	55
27.5	Owner	Disclosures	55
27.6	Owner	Value of Work	55
27.7	Owner	Schedule	55
27.8	Owner	Testing	55
27.9	Owner	Inspections	55
28.0	Architect	Defined	55

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

28.1	Architect	General	56
28.2	Architect	Scope of	56
28.3	Architect	Coordination	56
28.5	Engineer	Defined	56
28.6	Engineer	General	56
28.7	Engineer	Scope of	56
28.8	Engineer	Coordination	56
29.0	Change Orders	Defined	57
29.1	Change Orders	Acceptance	57
29.2	Change Orders	Amendments	57
29.3	Change Orders	Cash Allowance	57
29.4	Change Orders	Price	57
29.5	Change Orders	Contract Times	57
29.6	Change Orders	Work Changes	57
29.7	Change Orders	Schedule	57
30.0	Work Changes	Responsibilities	58
30.1	Work Changes	Execution of	58
30.2	Work Changes	Indemnification	58
30.3	Work Changes	Insurance	58
30.4	Work Changes	Bonds	58
30.5	Work Changes	Terminate	58
30.6	Work Changes	Recordation	58
30.7	Work Changes	Substitutes	58
30.8	Work Changes	Unit Price	58
30.9	Work Changes	Lump Sum	58
31.0	Claims	Contractor	59
31.1	Claims	Owner	59
31.2	Claims	Architect	59
31.3	Claims	Engineer	59
31.4	Claims	Price Changes	59
31.5	Claims	Contract Times	60
31.6	Claims	Contractor's Fee	60
31.7	Claims	Liability	60
31.8	Claims	Cost of Work	60
31.9	Claims	Adjustments	60
32.0	Disputes	Resolution	61
32.1	Disputes	Agreement	61
32.2	Disputes	Precedence	61
32.3	Disputes	Arbitration	61
32.4	Disputes	Arbitrator	61
33.0	Conditions	Amending	62
33.1	Conditions	Bonds	62
33.2	Conditions	Cash Allowances	62
33.3	Conditions	Price Changes	62
33.4	Conditions	Time Changes	62

33.5	Conditions	Work Changes	62
33.6	Conditions	Clarifications	62
33.7	Conditions	Interpretation	63
33.8	Conditions	Definition	63
33.9	Conditions	Agreement	63
34.0	Contract Price	Bid	63
34.1	Contract Price	Amendments	63
34.2	Contract Price	Adjustments	63
34.3	Contract Price	Change of	63
34.4	Contract Price	Definition of	63
34.5	Contract Price	Acceptance	64
34.6	Contract Price	Cash Allowances	64
34.7	Contract Price	Payment Schedule	64
34.8	Contract Price	Progress Payments	64
34.9	Contract Price	Final Payment	64
35.0	Subcontractor	Defined	65
35.1	Subcontractor	Responsibility	65
35.2	Subcontractor	Schedule	65
35.3	Subcontractor	Communications	65
35.4	Subcontractor	Cooperation	65
35.5	Subcontractor	Continue Work	65
35.6	Subcontractor	Stop Work	65
35.7	Subcontractor	Shop Drawings	65
35.8	Subcontractor	Progress Schedule	66
35.9	Subcontractor	Progress Payment	66
36.0	Work Items	Defined	66
36.1	Work Items	Acceptance	66
36.2	Work Items	Standards	66
36.3	Work Items	Rejection	66
36.4	Work Items	Reinstallation	66
36.5	Work Items	Adjustments	67
36.6	Work Items	Continue Work	67
36.7	Work Items	Procurement	67
36.8	Work Items	Safety	67
36.9	Work Items	Storage	67
37.0	Safety	Defined	67
37.1	Safety	Representative	68
37.2	Safety	Program	68
37.3	Safety	Inspections	68
37.5	Safety	Reports	68
37.6	Safety	Recordation	68
37.7	Safety	Meetings	68
37.8	Safety	Site Cleanliness	68
37.9	Safety	Special Conditions	68
38.0	Cost	Defined	69

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

64.1	Warranties	of Work	82
64.2	Warranties	of Items	82
64.3	Warranties	of Documents	82
64.5	Warranties	of Record	82
64.6	Warranties	Waiver of	82
64.7	Warranties	Utilization	83
64.8	Warranties	Expressed	83
64.9	Warranties	Implied	83
70.0	Work	Defined	84
70.1	Work	General	84
70.2	Work	Access to	84
70.3	Work	by Others	84
70.4	Work	Continuing	84
70.5	Work	Delay	85
70.6	Work	Contractor Stoppage	85
70.6.3	Work	Owner Stoppage	85
70.6.5	Work	Engineer Stoppage	85
70.6.7	Work	Architect Stoppage	85
70.6.8	Work	Inspector Stoppage	85
70.7	Work	Coordination of	86
70.8	Work	Cost of	86
70.8.2	Work	Neglect of	86
70.8.3	Work	Related	86
70.8.5	Work	Variation	86
70.8.6	Work	Commencement	86
70.8.7	Work	Inspections	87
70.8.8	Work	Progress Schedule	87
70.8.9	Work	Final	87
70.9	Work	Completion	87
71.0	Progress	Defined	88
71.1	Progress	General	88
71.2	Progress	Schedule	88
71.3	Progress	Projected	88
71.4	Progress	Variation	88
71.5	Progress	Delay	88
71.6	Progress	Contractor Termination	88
71.7	Progress	Owner Termination	89
71.8	Progress	Weather	89
71.9	Progress	Completion	89

Index

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

MARCEL DEKKER, INC.
270 Madison Avenue, New York, New York 10016

Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

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