Construction & Evaluation

Study Guide
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WELCOME

Thank you for choosing Brightwood Architecture Education for your ARE study needs. We wish you the best of luck in your pursuit of licensure.

ARE OVERVIEW

Since the State of Illinois first pioneered the practice of licensing architects in 1897, architectural licensing has been increasingly adopted as a means to protect the public health, safety, and welfare. Today, the United States and Canadian provinces require licensing for individuals practicing architecture. Licensing requirements vary by jurisdiction; however, the minimum requirements are uniform and in all cases include passing the Architect Registration Exam (ARE). This makes the ARE a required rite of passage for all those entering the profession, and you should be congratulated on undertaking this challenging endeavor.

Developed by the National Council of Architectural Registration Boards (NCARB), the ARE is the only exam by which architecture candidates can become registered in the United States or Canada. The ARE assesses candidates’ knowledge, skills, and abilities in six different areas of professional practice, including a candidate’s competency in decision making and knowledge of various areas of the profession. The exam also tests competence in fulfilling an architect’s responsibilities and in coordinating the activities of others while working with a team of design and construction specialists. In all jurisdictions, candidates must pass the six divisions of the exam to become registered.

The ARE is designed and prepared by architects, making it a practice-based exam. It is generally not a test of academic knowledge, but rather a means to test decision-making ability as it relates to the responsibilities of the architectural profession. For example, the exam does not expect candidates to memorize specific details of the building code, but it requires them to understand a model code’s general requirements, scope, and purpose and to know the architect’s responsibilities related to that code. As such, there is no substitute for a well-rounded internship to help prepare for the ARE.

Exam Format

The six ARE 5.0 divisions are outlined in the table below.

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The exam presents multiple-choice questions, new hotspots, and drag-and-place, as well as incorporating case studies. Candidates may answer questions, skip questions, or mark questions for further review. Candidates may also move backward or forward within the exam using simple on-screen icons.

Appointment times for taking the exam are slightly longer than the actual exam time, allowing candidates to check in and out of the testing center. All ARE candidates are encouraged to review NCARB’s ARE 5.0 Guidelines.
for further detail about the exam format. These guidelines are available via free download at NCARB’s website (www.ncarb.org).

**EXAM PREPARATION**

**Overview**

There is little argument that preparation is key to passing the ARE. With this in mind, Brightwood has developed a learning system for each exam division, including study guides, QBanks, and flashcards. The study guides offer a condensed course of study and will best prepare you for the exam when utilized along with the other tools in the learning system. The system is designed to provide you with the general background needed to pass the exam and to provide an indication of specific content areas that demand additional attention.

In addition to the Brightwood learning system, materials from industry-standard documents may prove useful for the various divisions.

**Preparation Basics**

The first step in preparation should be a review of the exam specifications and reference materials published by NCARB. The ARE 5.0 Handbook is available for download at www.ncarb.org.

Though no two people will have exactly the same ARE experience, the following are recommended best practices to adopt in your studies and should serve as a guide.

*Set aside scheduled study time.*

Establish a routine and adopt study strategies that reflect your strengths and mirror your approach in other successful academic pursuits. Most importantly, set aside a definite amount of study time each week, just as if you were taking a lecture course, and carefully read all of the material.

*Take—and retake—quizzes.*

After studying each lesson in the study guide, take the quiz found at its conclusion. The quiz questions are intended to be straightforward and objective. Answers and explanations can be found at the back of the book. If you answer a question incorrectly, see if you can determine why the correct answer is correct before reading the explanation. Retake the quiz until you answer every question correctly and understand why the correct answers are correct.

*Identify areas for improvement.*

The quizzes allow you the opportunity to pinpoint areas where you need improvement. Reread and take note of the sections that cover these areas and seek additional information from other sources. Use the question-and-answer handbook and online test bank as a final tune-up for the exam.

*Take the final exam.*

A final exam designed to simulate the ARE follows the last lesson of each study guide. Answers and explanations can be found on the pages following the exam. As with the lesson quizzes, retake the final exam until you answer every question correctly and understand why the correct answers are correct.

*Use the flashcards.*

If you’ve purchased the flashcards, go through them once and set aside any terms you know at first glance. Carry the rest with you throughout the day, reviewing them on the train, over lunch, or before bed. Remove cards as you
become familiar with their terms until you know all the terms. Review all the cards a final time before taking the exam.

Supplementary Study Materials

In addition to the Brightwood learning system, materials from industry-standard sources may prove useful in your studies. Candidates should consult the list of exam references in the NCARB guidelines for the council’s recommendations and pay particular attention to the following publications, which are essential to successfully completing this exam:

- International Code Council (ICC)
  - International Building Code

- National Fire Protection Association
  - Life Safety Code (NFPA 101)

Test-Taking Advice

Preparation for the exam should include a review of successful test-taking procedures—especially for those who have been out of the classroom for some time. Following is advice to aid in your success.

Pace yourself.

Each division allows candidates at least one minute per question. You should be able to comfortably read and reread each question and fully understand what is being asked before answering. Each vignette allows candidates ample time to complete a solution within the time allotted.

Read carefully.

Begin each question by reading it carefully and fully reviewing the choices, eliminating those that are obviously incorrect. Interpret language literally, and keep an eye out for negatively worded questions.

Guess.

All unanswered questions are considered incorrect, so answer every question. If you are unsure of the correct answer, select your best guess or mark the question for later review. If you continue to be unsure of the answer after returning the question a second time, it is usually best to stick with your first guess.

Review difficult questions.

The exam allows candidates to review and change answers within the time limit. Use this feature to mark troubling questions for review upon completing the rest of the exam.

Choose the best answer.

Many candidates fall victim to questions seeking the “best” answer. In these cases, it may appear at first glance as though several choices are correct. Remember the importance of reviewing the question carefully and interpreting the language literally. Consider the following example.

1. Which of these cities is located on the east coast of the United States?
   A. Boston
   B. Philadelphia
   C. Washington, D.C.
   D. Atlanta

At first glance, it may appear that all of the cities could be correct answers. However, if you interpret the question literally, you’ll identify the critical phrase as “on the east coast.” Although each of the cities listed is arguably an “eastern” city, only Boston sits on the Atlantic coast. All the other choices are located in the eastern part of the country but are not coastal cities.
ABOUT BRIGHTWOOD

Thank you for choosing Brightwood Architecture Education as your source for ARE preparation materials. Brightwood brings its experience and history to the world of architectural education, pairing unparalleled resources with acknowledged experts in ARE content areas to bring you the very best in licensure study materials.

Only Brightwood Architecture offers a complete catalog of individual products and integrated learning systems to help you pass all six divisions of the ARE. Brightwood’s ARE materials include study guides, QBanks, and flashcards. Products may be purchased individually or in division-specific learning systems to suit your needs. These systems are designed to help you better focus on essential information for each division, provide flexibility in how you study, and save you money.

To order, please visit www.brightwoodarchitecture.com or call 877.523.8208.
INTRODUCTION
This division will test the candidate’s understanding of how to “manage the build.” Topic areas will include bidding, construction contract administration, and post-occupancy analyses. The candidate should be knowledgeable about the procedures of managing the project development from concept to close-out.

DESIGN SCHEDULING
Establishing a Schedule
In furnishing professional services, an architect must prepare a time schedule that encompasses all phases of production, from initial conceptual planning to the start of construction. The architect must plan the judicious and efficient use of manpower and resources to achieve an economical, functional, and harmonious design, executed within a reasonable period of time, and with an efficient utilization of personnel. The managerial skills required for such planning and scheduling are based on experience and judgment.

To organize the schedule, the architect first separates the design effort into phases, which
generally correspond to phases of the AIA standard owner-architect agreements as follows:

1. **Schematic design**, consisting of schematic drawings and other documents that describe the general relationships and space requirements of the project, along with a cost estimate.

2. **Design development**, consisting of preliminary drawings, outline specifications, and other documents that describe the form, size, and materials of a project, and the structural, mechanical, and electrical systems to be utilized. A preliminary cost estimate is also prepared during this phase.

3. **Construction documents**, consisting of working drawings, final specifications, and a final cost estimate.

4. **Bidding or negotiation**, which includes the receipt and evaluation of bids or negotiated proposals. It may also include preparing addenda to the contract.

5. **Construction administration**, consisting of the services rendered by the architect after bidding or negotiation to assure that the structure is built in accordance with the construction documents. In this phase the architect may issue change orders, approve shop drawings, choose or approve materials and colors, and issue payment approvals.

In complex projects, the five phases described may not be adequate. For example, schematic design may be divided into conceptual design and schematic design. Similarly, the construction documents phase may be organized into several subdivisions, so that work on one subdivision may be completed and bid before the next phase is begun.

The architect must estimate the time required for each phase of the work. The schematic design phase is the most difficult to estimate, since it has the greatest amount of variability.

This phase of the work is usually done by a small design team, generally headed by a chief designer, and possibly including an engineer and other specialists. The design concept must be developed out of the skill and experience of the design team working closely with the client and each other. Among the factors affecting the time required for schematic design are:

1. *The size and complexity of the project,* complexity generally being more critical than size.

2. *The quality and completeness of the program information supplied by the client.* If the architect does not have an adequate statement of the client’s requirements—a conclusive program—then it will be necessary to prepare one, or to improve what exists. In contrast, an experienced client will often furnish the architect with a thorough and reliable catalog of needs, thereby enabling the architect to begin work immediately. Such a client may provide the architect with information such as project goals, area requirements, functional relationships, zoning information, a site survey, and a budget.

3. *The decision-making ability of the client.* If the client has a decisive representative who has the authority to make decisions, schematic design can proceed at a rapid pace. On the other hand, if decisions require committee approval, or if they cannot be made expeditiously, schematic design time will be prolonged, with consequent loss of momentum. If the client and architect do not have an effective communication system, the process is further delayed.

4. *The nature of the design team.* If the team is well balanced, if they work together harmoniously, if they are skilled and experienced, if they are able to work on the project without interruption, and if they...
Lesson One: Preconstruction Activities and Scheduling

can communicate readily with the client, then schematic design time will be kept to a minimum.

These factors illustrate why it is difficult to plan a time schedule for schematic design. For a simple, conventional project, schematic design can often be completed in one or two months. It is not unusual, however, for the schematic design of a complex project to require 12 months or more.

The design development and construction documents phases of the work are much more predictable than schematic design, assuming schematic design has been thorough and there are no program changes. A team of architects and drafters, headed by a project architect and/or job captain, develops the schematic design into preliminary design drawings, which are then developed into working drawings.

If the project is large in scope, staffing must be increased commensurately. The length of time required to produce these drawings may not be directly proportional to the size of the project. A $10,000,000 project, for example, may require only 50 percent more time than a $2,000,000 project. The complexity of a project, rather than its size, determines scheduling and staffing requirements. During the preliminary design and design development phases, close coordination between consultants, client, and designers is vital.

Design development for a typical project takes from two to four months; the construction documents phase may typically require from three to seven months. The bidding or negotiation phase usually requires three to six weeks, regardless of the size of the project.

![Bar Graph for Scheduling of Design](image-url)

**Figure 1.1**
A less obvious factor that may influence the work schedule is project financing. Whether the client is an individual, a partnership, a corporation, or a public agency, money is required to convert a design into reality. Private clients may borrow money from a bank, while a public agency may have to obtain a bond issue. The client may use the time between work phases to obtain a financial commitment and may, in some cases, postpone authorization to the architect to proceed with a successive phase until financing is secured. This may take weeks or months for a private client and even longer for a public agency.

Client review and approval is customary between phases, and the time required for this will depend on the size and complexity of the project, as well as the ability of the client to make decisions.

Some projects require more than one client approval, which may lengthen the review period. For example, many public school projects require the approval of a state department of education as well as a local school district. Client review and approval usually takes between one week and one month, unless complications arise.

The time required for approval of plans by a building department or other public agency varies considerably, depending on the locality and type of project. For example, a state hospital project, which may require approval by a state agency as well as the local building department, may require up to three months for plan checking. In localities where the checking of plans is less critical, a building permit may be obtained within a week.

Application for a building permit requires the filing of construction drawings and specifications; this is often done near the conclusion of the construction documents phase so that the building permit is obtained at about the same time the construction contract is let. This is not always the case, however. Sometimes the application for the building permit is not made until after the bidding period, while in other cases, the permit is obtained before the bidding phase. Whatever order is followed, the time required for plan approval should be considered by the architect in preparing the time schedule.

In completing the time schedule, the architect assembles all the time estimates into a bar graph, as shown on the previous page. The bar graph indicates ranges of time for each phase. In an actual project, however, a specific period of time would be assigned for each phase.

Contingencies

In organizing the architectural production schedule, the architect must consider the possibility of unexpected problems that may arise. There may be delays with the building department, consultants may need additional time because of unique problems inherent in the project, staffing problems may arise in the architect’s office if the work load changes suddenly, or the client may be less decisive than expected. For these and other reasons, it is wise to include a contingency factor in the schedule. If the architect estimates the total required time to be eight months, an additional allowance of at least two to four weeks seems prudent.

The schedule should be flexible and responsive to changing conditions. For example, if the schematic design phase extends beyond its scheduled completion date, it should be possible to reduce the time allotted to design development and construction documents.

Working with a Builder

The preceding discussion assumes a conventional sequence of events in which the con-
construction documents are completed before bidding or negotiation begins. In recent years, however, closer methods of work coordination between the architect-engineer team and the builder have been developed. Many architects now work closely with a contractor from the conceptual phase through the completion of working drawings. A result of this cooperation is often a guarantee of maximum project cost, furnished to the owner by the contractor, upon completion of contract documents. This is referred to as a GMP—a “guaranteed maximum price.”

Working closely with a builder has a significant effect on the architect’s production schedule. More time must be given to schematic design if the architect is to produce a concept that the contractor considers economical. Design development, likewise, may take more time; however, construction documents will probably take the same time. Since the time during which the drawings are being prepared overlaps actual construction, overall project time is generally shortened. But there are risks in this procedure that the building design may not be fully developed or the components fully resolved.

Regardless of the procedure followed, the working drawings and specifications must be complete, clear, and correct. In some cases where the architect works closely with the contractor who will construct the project, the documents may be less specific, allowing the contractor leeway in procedures, details, and materials. This practice can be risky for both, and hence, should be restricted to common or repetitive projects. With close architect/builder cooperation, the bidding and negotiation phase may be omitted entirely, since these activities become a continuous process.

The total scheduled production time is usually similar to what it would be if the project were done conventionally. The architect’s staff hours, however, may be greater because of the time spent coordinating with the contractor and possible redesigning. There are no short cuts; architectural projects require attention to detail, and invariably that takes time.

Extending the Schedule

All creative activity requires time, which should be enough to absorb information and develop ideas, but not so much that momentum and interest lag. For architectural design, an optimum work schedule is one in which the necessary work can be accomplished comfortably without expanding or shortening the schedule.

On a project with an extended schedule, principal team members may retire or take other positions before completion of the work. A recent state college project was delayed four years, between design development and construction documents, because of lack of funding. When the project resumed, the original project architect, mechanical and structural engineers, and key client personnel had made career changes. The resumption of work entailed starting over. The groundwork had to be reestablished, resulting in wasted time and effort.

One of the most significant effects of an extended design schedule is the increased cost due to inflation. In the recent past, inflation ran as high as 1 percent per month. At that rate, a $10,000,000 project which is delayed two months would cost the owner an additional $200,000. The additional cost resulting from the delay of a project may cause it to be terminated or reduced in scope. For example, in the case of the state college project mentioned above, the original project budget could not be increased during the four-year delay, and therefore the scope of the project had to be reduced.
by about one-third. The facility as finally built was smaller and of lower quality than it would have been without the four-year delay.

Shortening the Schedule

Clients often want their projects completed in as short a time as possible. During periods of inflation, there is additional pressure to shorten the design schedule. The purpose of any schedule, however, is to make optimum use of staff effort and resources. Therefore, to achieve significant reductions in time, one or more of the following methods must be employed:

1. The architectural team works overtime. While this saves time, it is costly and inefficient. A person working a ten-hour day over a long period of time cannot consistently produce 25 percent more work than someone working an eight-hour day.

2. Hire more people, bring in part-time or freelance staff, or subcontract work to another firm. All of these solutions are possible and will probably save time, but they are also costly and inefficient. New staff people will not be familiar with office procedures or the particular project, and their competence is unknown. Part-time people may be experienced and competent, but they are usually expensive. Subcontracting to another firm is feasible, but this is expensive, and coordination and supervision may be awkward.

3. Reduce the man-hours spent on the project. This generally results in a lower-quality job. Quality work requires adequate time to produce, and if that time is not available, an incomplete set of working drawings and specifications may result. Under these circumstances, one can expect documents that are incomplete, unclear, and likely to contain errors and inconsistencies. That, in turn, implies future problems, delays, and excessive change orders during construction.

Thus, the net effect of a reduced time schedule is likely to be a higher cost for design, a higher cost for construction, and a lower quality project. During periods of high inflation, an owner may be willing to tolerate a degree of increased costs with decreased quality, but this decision should be made only with the client’s full appreciation of the consequences.

Methods of shortening both the design and construction schedule, simultaneously, will be described shortly.

CONSTRUCTION SCHEDULING

Establishing a Schedule

By their very nature, all construction projects are complicated, since they involve the work of numerous trades and subcontractors, all of which must be coordinated. Equipment must be utilized efficiently; materials must be ordered, stored, and used in a logical sequence; and accurate time schedules and costs must be recorded.

When a contractor prepares a construction schedule for a project, it is generally based on past experience. But no two projects are ever exactly alike, no two sites are the same, and therefore construction schedule estimates must be tempered with judgment. Contractors must consider a number of factors, including the following:

1. The construction documents. If these have been well prepared, relatively few problems or delays may be expected. Conversely, a poor set of working drawings or specifications will lead to disputes among the architect, contractor, and subcontractors. Such disputes consume considerable time and energy.

2. The architect-engineer. Some architects and engineers are extremely demanding
regarding the interpretation of the contract documents. Others are less demanding and more amenable to changes.

3. *The subcontractors.* The contractor must evaluate their ability to perform the work properly and on time, and to coordinate their work with others.

4. *The contractor’s organization.* The skills of the project manager, field superintendent, and the office and field staffs must be considered in relation to the specific project. Some managers and superintendents are more capable of expediting the work than others. Also, the particular work load of the contractor will influence his ability to divert staff and equipment to and from the project under consideration.

5. *Material dealers.* The contractor must assess their reliability in meeting delivery schedules on time and correctly.

6. *The size and complexity of the project.* Complexity is one of the most critical elements in planning a construction schedule.

7. *Site conditions.* The size and accessibility of a construction site work area are critical factors in schedule planning. So is the condition of the site itself—its drainage, vegetation, subsoil, etc.

8. *The weather.* This is important, especially in the colder areas of the country, where projects may have to be shut down during snowstorms, heavy rainstorms, or periods of extreme cold.

9. *The possibility of labor troubles.*

10. *The possibility of material shortages or delay in obtaining critical equipment.*

The contractor must estimate the time required for each construction operation and the sequence of these operations in order to establish the schedule.

**CPM (Critical Path Method)**

The first step in developing a “critical path” is the planning phase, in which a diagram is drawn indicating the order in which the various operations comprising the project are to be accomplished. The project is divided into concise tasks called “activities,” and these are represented by arrows on the CPM chart.

Each activity has a definite start and finish represented by circles, and referred to as “events” or “nodes.” An “event” is defined as that moment when a preceding activity has been completed and the following activity may begin. Important points in the construction process, such as the roofing of a new building, are referred to as “milestone events.”

In CPM planning there is no indication of time; the arrows are not drawn to a time scale. The tail of an arrow indicates the start of an activity and the head of an arrow, the finish, and each arrow is associated with a start and finish event. No new activity can be started until activities represented by all the previous arrows have been completed.

The completed CPM diagram is known as a *network diagram.* The network must be continuous, with no gaps or discontinuities.

![Network Diagram](image)
In the network diagram shown in Figure 1.2, activity A starts at event 1 and terminates at event 2. Activities B and C cannot start until A is completed. Activities B and C can proceed simultaneously; however, activity D cannot start until C is completed. Activity E, starting with event 4 and finishing with event 5, cannot start until both activities B and D are completed. The construction of a footing supported on drilled cast-in-place concrete piers will now be considered.

Excavation of earth, construction of footing forms, and procurement of reinforcing steel can all proceed independently of each other. Drilling of piers follows excavation. Pier steel cannot be set until after both drilling of piers and procurement of pier steel have been completed. Pouring the piers follows setting of pier steel. Footing forms are set after both pouring of piers and construction of footing forms have been completed. Setting footing steel proceeds after both setting footing forms and procurement of footing reinforcing steel are completed. Finally, pouring footing follows setting footing steel.

The network diagram for the work described in the previous paragraph is shown in Figure 1.3. Note that each activity starts and finishes with an event, shown as a numbered circle, and that the end event always has a higher number than the starting event. Each event number occurs only once in the network.

While the pier-supported footing is a simple project, it serves to illustrate the value of CPM in job planning. The network is a model of the project, and its preparation requires the contractor to analyze the job logically from start to finish. The diagram communicates the job logic far better than any verbal description or bar graph.

Excavation of earth, construction of footing forms, and procurement of reinforcing steel can all proceed independently of each other. Drilling of piers follows excavation. Pier steel cannot be set until after both drilling of piers and procurement of pier steel have been completed. Pouring the piers follows setting of pier steel. Footing forms are set after both pouring of piers and construction of footing forms have been completed. Setting footing steel proceeds after both setting footing forms and procurement of footing reinforcing steel are completed. Finally, pouring footing follows setting footing steel.

Sometimes different portions of a project are planned separately, with separate network diagrams. For example, a project may consist of two buildings with connecting utilities. Events common to both networks are called interface events, and are usually shown as in Figure 1.4.

**CPM Scheduling**

After the project has been divided into concise activities and their logical sequence has been determined and charted in the network diagram, the time required for the project must be determined. Thus far, only the activities and their relationships have been considered; now the element of time is applied to the chart.
The contractor estimates the time required for each activity, based on past experience. A normal working day is taken as the unit of time. The assumption is made that materials and labor will be readily available, and that a normal level of labor and equipment will be utilized. Where subcontractors are involved, the contractor may consult with them regarding the time required to perform their specific activities. The estimated activity times in working days are now noted on the network diagram below each arrow. (See Figure 1.5.)

In preparing an accurate time estimate, the reliability of the subcontractors is critical. A general contractor, therefore, should be familiar with the subcontractors and their work, and consider only those who are pre-qualified or otherwise highly dependable.

Critical Path

The simple project illustrated in the network diagram includes several paths, from start to finish, and each has a varying total time duration. For example, path 1-2-3-4-5-6-7-8 requires a total time of $1 + 1 + 1 + 1 + 2 + 1 + 1 = 8$ days. Path 1-5-6-7-8 requires $2 + 2 + 1 + 1 = 6$ days. Since each path must be traversed to complete the project, the total project time is established by the path with the longest total required time. This is known as the critical path, and is generally shown as a heavy line. In the diagram below, the critical path is 1-6-7-8, with a total time of $14 + 1 + 1 = 16$ days.

The activities along the critical path are called critical activities—in this case consisting of procuring reinforcing steel, setting footing steel, and pouring footings. If a critical activity is delayed, it will delay the completion of the project. These activities, therefore, must be carefully monitored during construction in order to keep the project on schedule.
Float

All paths in the network diagram, other than the critical path, are called float paths. The float is the difference in time duration between the critical path and any other path. Path 1-2-3-4-5-6-7-8, which requires 8 days, has a float value of 8, since it is 8 days shorter than the critical path time of 16 days. Similarly, path 1-5-6-7-8, which requires 6 days, has a float value of 10. The float, then, is a measure of the extra time available for an activity or group of activities.

As long as float time is not exceeded, no delay in project completion time will result. The path 1-2-3-4-5-6-7-8, for example, which we have determined to have a float value of 8, can be delayed up to 8 days without delaying project completion. This delay can occur in one or more activities along the path, providing the total delay does not exceed 8 days. The delay may occur only in activities from 1 through 6, since 6-7 and 7-8 form part of the critical path.

Project Calendar

The contractor, having determined that the finish date of the project is 16 working days after its start, now converts this to calendar days by multiplying by 7/5, since there are five working days in each seven-day week. (16 × 7/5 = 22.4, say 23 calendar days.) Knowing the project starting date, the contractor can calculate the completion date, as well as the start and finish dates of all activities. He now establishes a project calendar, indicating the scheduled starting and completion dates of all the activities within the project. Critical activities are noted in color or boldface, since any delay in the schedule of these activities will delay completion of the project.

If the job schedule has been prepared carefully and realistically, the field work will proceed at an efficient pace. If excessive time has been allowed for certain activities, a more relaxed pace may result, leading to increased labor and overhead costs.

There can be great variation in the duration of construction projects, depending on the factors mentioned previously. However, most building construction projects require from nine to eighteen months.

Contingencies

A realistic schedule should incorporate an allowance for project delays caused by weather or other unforeseen events. A reasonable allowance can be made for the number of working days expected to be lost because of weather, depending on the season and the activity. Obviously, it is impossible to be precise regarding potential delaying factors such as accidents or labor strikes. Some contractors add a fixed percentage to the total estimated time to allow for such possibilities, or they may incorporate contingency provisions in the construction contracts.

CPM Calculations

The example of a pier-supported footing describes a simple project; however, the same logic and scheduling technique is used on large and complex projects. CPM programming can be done at a simple level or a complex one. Computer programs designed for CPM have proven very useful, once the basic activity sequencing and activity times are known. CPM is an extremely helpful planning and management tool, and its use in construction planning and scheduling has become almost universal.

Bar Graphs

Bar graphs have long been used for planning and scheduling construction projects. They indicate the starting and finishing dates of major phases of the work and can be clearly
understood by all concerned. Their main disadvantage is that they do not indicate the relationship between the sequence of activities, or the dependency of an activity on the completion of a previous activity. The bar graph therefore is inferior to CPM as a management tool, but superior to CPM as a means of visual communication. Bar graphs, such as the one shown in Figure 1.6, continue to be widely used in construction.

<table>
<thead>
<tr>
<th>Item</th>
<th>General Contractor</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td></td>
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<tr>
<td>Concrete Structural</td>
<td></td>
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<tr>
<td>Carpentry Rough</td>
<td></td>
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<tr>
<td>Masonry</td>
<td></td>
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<tr>
<td>Roofing</td>
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<tr>
<td>Lathing &amp; Plastering</td>
<td></td>
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<tr>
<td>Carpentry Finish</td>
<td></td>
<td></td>
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<tr>
<td>Marble &amp; Tile</td>
<td></td>
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<tr>
<td>Cement Finish</td>
<td></td>
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<tr>
<td>Acoustic Insulation</td>
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<tr>
<td>Painting</td>
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<tr>
<td>Plumbing Rough</td>
<td></td>
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<tr>
<td>Heating Rough</td>
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<tr>
<td>Electrical Rough</td>
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<tr>
<td>Plumbing Finish</td>
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<tr>
<td>Heating Finish</td>
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<tr>
<td>Electrical Finish</td>
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<tr>
<td>Floor Covering</td>
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<tr>
<td>Ground Improvement</td>
<td></td>
<td></td>
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<tr>
<td>Hardware Finish</td>
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</tbody>
</table>

Figure 1.6

Shortening the Schedule

There are a number of reasons why an owner may want the use of his building as quickly as possible. Among these are the demands of business, which is often the case for commercial or industrial facilities. Other reasons may be to minimize the effects of inflation, inclement weather, or the persistent costs of interest on borrowed construction funds.

The CPM method demonstrates that one of the most effective methods to save construction time is to reduce the critical path time. Although the activities on the critical path may amount to only 25 or 30 percent of all the project activities, reducing them reduces the whole construction schedule.

Shortening the durations of the critical activities will very likely increase direct cost, because inefficiency is increased through
added overtime work. Increasing the number of workers is also inefficient because supervision and coordination become more difficult. In general, the contractor's direct costs increase as the schedule is compressed into a shorter-than-normal time.

On the other hand, the contractor's overhead decreases as the schedule time is shortened. Since the total project cost is the sum of direct costs and overhead, and their effects by shortening the schedule are opposite, a contractor may find it worthwhile to analyze their effects and determine a balance that represents the lowest total project cost. A computer can be highly useful in doing this for a complex job.

Maintaining quality control becomes more difficult as the schedule time is shortened. Errors are more likely to occur because of the increased difficulty of proper supervision. The highest project quality is achieved when the project schedule is normal, that is, neither extended nor shortened.

If it is necessary to shorten the project schedule, the CPM network diagram can be analyzed to determine if the job logic can be modified, or if certain activity durations can be condensed. Individual activity times can be expedited by adding man-hours and equipment, recognizing that this will result in higher direct costs and will place greater demands on supervision.

**Fast-Track Scheduling**

Shortening design and construction schedules generally results in higher design costs, higher construction costs, and reduced quality. However, by combining the architect/engineer's design schedule with the builder's construction

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**Figure 1.7**

Comparison of Conventional Method (Design-Bid-Build) vs. Fast Track
schedule, it is possible to realize an overall saving of time in completing the entire project. This technique is known as “fast-track,” “accelerated,” or “telescoped” scheduling. In this procedure, the architect first determines the major building elements, such as the column spacing, foundation system, mechanical systems, etc., before the detailed arrangements are worked out. The architect then produces detailed working drawings for a portion of the work on which the contractor may begin construction—site work, utilities, foundations, or possibly framing. Meanwhile, further detailed architectural design continues so that the architect produces his work just slightly ahead of the construction crews.

This approach requires close coordination among architect, engineers, client, and contractors. Since the design concept of building elements is established very early, oversights must be expected, and the correction of errors is generally an integral part of fast-track scheduling. However, major design revisions are all but precluded, except at very great cost.

Fast-track scheduling usually requires staged bidding, in which the project is organized into a number of separate stages or contracts—as many as 20 or 30—that are awarded to different contractors at different times. Thus, it may not be possible to obtain a fixed price for the entire project in advance of construction, as with conventional contracting that employs one general contractor. However, to assure some degree of cost and time control and establish responsibility, a construction manager (CM) may be used to supervise the construction process. Most contractors are able to function either as general contractors or construction managers.

Construction management may also be performed by architectural firms. But large and complex jobs are usually better served by those whose expertise is in the actual construction of buildings.

A comparison of conventional and fast-track scheduling for a $7,000,000 hospital is shown in Figure 1.7, indicating that the construction would be completed seven months earlier if fast-track scheduling were used.

Some architects may find their roles expanded to that of developer, builder, or manager. Whatever the role, it will be essential for the architect to become familiar with new management techniques, since they will have an increasing influence over how future construction work is done.

**TIME MANAGEMENT**

**Fabrication Time**

Most products and components of assemblies or systems are specially fabricated for individual construction projects. Whether an item is prefabricated off-site or fabricated or constructed on-site may have an effect on a project’s timely completion.

Architects may decide whether to select off-the-shelf, ready-made components, or to design and specify components fabricated in a shop for subsequent installation on-site. Custom designed and fabricated elements may have adverse effects on construction time, thereby favoring manufactured items. Manufactured or prefabricated elements provide many advantages. Design time is shortened, because it is faster to select standard products from a catalog than to custom design new ones. And manufacturers’ shop drawings and other submittals are easier to review than those of specialty contractors. Prefabricating elements in a shop reduces the impact of inclement weather on construction time. Work can be performed during winter, rainy days, and even nights if necessary. All of these factors save time.
Other aspects of construction may be shifted from field to shop, as well. For example, metal-framed panels with brick facing may be mass-produced in a shop and erected on-site, instead of laboriously constructing brick by brick on-site.

Trade union jurisdictions and work rules may also affect construction time. Building construction trade unions may have a vested interest in specific methods and construction processes. Where shop labor is not subject to trade union jurisdiction, it may be possible to bypass certain union rules to shorten construction durations by using prefabricated products and systems.

**Erection Time**

A project’s construction time is affected by, among other things, the extent of prefabrication of its component parts. Erection time may be shortened if a project is composed of mostly discrete building components that have been prefabricated off-site. The various components can be brought on-site, placed, and connected to other elements.

Certain aspects of prefabricated items must be considered, however. Prefabricated elements must, for example, be strong enough to resist lifting and handling. Attachments to other components must be simple, ideally requiring only one construction trade. Adequate clear space must be provided to maneuver prefabricated elements into place. Within these constraints, one may effectively use prefabricated elements to reduce erection time.

The timing of on-site operations must be considered. For example, inclement weather affects the construction time, and may even affect the design process. Winter weather may require that drawings be completed ahead of schedule to allow construction to begin before the onset of cold weather. All of these factors affect the time necessary to erect a building.

**Sequencing of Construction Trades**

Construction sequence is the order in which the various building trades perform their work, and is within a contractor’s control. For example, foundation drains must be placed prior to backfilling. However, the design of a project may contribute to improved sequencing by minimiz-
Lesson One: Preconstruction Activities and Scheduling

...ing the need for “on and off” construction. For example, if a large electrical conduit is placed in the same trench, but above a foundation drain, the construction sequence would be to place the drain, backfill the trench, place the conduit, and complete the backfilling of the trench. Locating the conduit elsewhere allows the contractor to place the drain and conduit independently and do all the backfilling simultaneously, thus eliminating one operation.

The design of a project may limit the ability of various building trades to perform work in a particular sequence. For example, if office partitions are designed to extend to the underside of the floor above, the ceiling installation cannot take place until all partitions are in place. Furthermore, scaffolding required for the ceiling installation must be disassembled and moved from space to space. If the program requirements can be met without the use of full height partitions, or with partitions that extend to the underside of the finished ceiling only, the ceiling contractor can complete larger areas and encounter fewer edge conditions where walls meet ceilings. Furthermore, scaffolds can be moved more efficiently.

Although construction sequencing is the contractor’s responsibility, an architect’s design can contribute to construction efficiencies by minimizing the need for on-again, off-again labor. Additionally, this will reduce cleanup time, provide for more efficient use of equipment, and avoid potential problems.

Scheduling of Construction Trades

Contractors are responsible for scheduling the various construction trades as well as the sequence of work. Although owners and their architects may establish the total available time for construction as well as interim milestones, they have no responsibility for scheduling construction trades. Architects may, however, establish certain criteria for the contractor’s scheduling requirements. Division One, General Requirements, of the specifications may include the following:

1. That all dates be established for ordering and delivery of materials, for submittals (including time for review, revision, and resubmittal, if necessary), and for testing.
2. That scheduling be done according to the Critical Path Method (CPM). CPM schedules are superior to bar chart schedules because they show interrelationships among activities.
3. That the schedule show the time allotted for each activity, as well as the cost, crew size, and equipment requirements for each activity.
4. That subcontractors provide input related to their scope of work.
5. That the schedule be updated monthly by the contractor to reflect the actual progress and current status. If a project is behind schedule, the contractor may be required to propose a plan for regaining lost time.

Comprehensive scheduling requirements which are fairly administered and enforced will ultimately contribute to a project’s timely completion.
1. With reference to the CPM network diagram above, select the correct statement.
   A. Activity C cannot begin until both B and E are completed.
   B. Activity G cannot begin until F is completed.
   C. Activity F cannot begin until G is completed.
   D. Activity E cannot begin until A is completed.

2. Referring to the same diagram, what is the critical path?
   A. 1-5         C. 1-3-4-5
   B. 1-4-5       D. 1-2-3-4-5

3. Referring to the same diagram, what is the critical path time?
   A. 3 days       C. 8 days
   B. 7 days       D. 20 days

4. Which of the following would normally influence a contractor’s construction schedule?
   I. The quality of construction documents
   II. The reliability of material dealers
   III. The total construction cost
   IV. The size of the project
   V. The anticipated weather conditions
   A. I and IV  C. I, II, IV, and V
   B. II, III, and V  D. All of these

5. A type of project scheduling commonly used in situations where minimum construction time is required is called __________.

6. An architect estimates that design and production for a project will take one year. The client, however, requests that the total time be reduced to nine months. By using the shorter time schedule, what would be the likely outcome?
   A. The general quality of design and production will be unaffected.
   B. The quality of the construction documents will be lower.
   C. The construction budget will be higher.
   D. The construction time will be greater.

7. By shortening an architect’s time schedule for design and production of drawings, his or her
   A. labor costs would increase.
   B. overhead would increase.
   C. profit would increase.
   D. documents would be unaffected.
8. Arrange the following tasks for a typical project in ascending order of scheduled time, that is, from the task requiring the least time to the most.
   I. Schematic design phase
   II. Bidding phase
   III. Client approval
   IV. Design development phase
   V. Construction documents phase

   A. II, I, III, V, IV
   B. I, III, II, V, IV
   C. III, I, IV, II, V
   D. III, II, I, IV, V

9. An architect’s scheduling and staffing requirements for a specific project are dependent on the project’s
   A. size.  
   B. cost.  
   C. complexity.  
   D. quality.

10. Reducing the critical path time will very likely
    A. increase the project cost.
    B. extend the construction time.
    C. have no effect on the float time.
    D. have no effect on project quality.