

Chapter 15

Construction Scheduling

Objectives

After studying this chapter, you will be able to:

- Summarize three uses for schedules.
- Identify three scheduling methods commonly used in construction.
- Explain how a bar chart is prepared.
- Identify the elements of a critical path network.
- Explain how the schedule is used when hiring workers.
- Describe four ways contractors obtain materials.
- Explain the reason for obtaining permits.

Technical Terms

bar chart	overall progress chart
building on speculation	overtime
building permit	permits
buy as needed	regular employees
critical path (CP)	stock materials
critical path method (CPM)	temporary employees
job account	

Purpose of Scheduling

Many decisions made during the estimating process relate to the schedule for completing the project. In fact, a preliminary schedule is sometimes prepared in the process of creating an estimate. Once the contract is awarded, a more detailed schedule is prepared to guide the project.

A schedule lists the sequence in which tasks will be completed. Managers use the schedule to determine when workers, materials, and equipment are needed. Adding information about daily progress to the planned schedule alerts managers to tasks that are not proceeding as planned. Corrective action can be taken to get the project back on schedule. The schedule can also be used to track the expenditure of money. Summary charts indicate the amount of money that has been spent compared to what was planned. As with daily progress, early identification of money problems improves the opportunity to solve the problems.

Career Connection



Purchasing Agent

Large construction companies often employ purchasing agents whose responsibilities include purchasing materials and equipment. Purchasing agents track price trends and negotiate discounts. They also evaluate the ability of potential suppliers to deliver goods according to project schedules. Purchasing agents also negotiate contracts for rented equipment.

Purchasing agents work with project managers and superintendents to ensure that materials and equipment are on site when needed. They also work with the finance department to ensure that bills are correct. Overtime hours may be required to ensure that last-minute needs at a construction site are met.

Ideal candidates are college graduates. A degree in construction management with an emphasis on business is preferred. Experience as a construction superintendent or project manager is desirable. Purchasing agents must be willing to continually update their knowledge of market trends and suppliers.

Growth in employment of purchasing agents in construction is expected to keep pace with growth in other construction occupations. Median annual earnings for purchasing agents specializing in building materials is more than \$35,000. The income range for purchasing agents is from \$28,000 to more than \$78,000. Purchasing agents also commonly receive benefits that include paid vacations, insurance, and pension plans.

Scheduling Methods

Three scheduling methods are commonly used for construction projects. Each of these methods is described in the following paragraphs.

Experience

Schedules are often designed based on the experience of a long-time builder. Those who have been in the construction business for many years acquire a sense for planning. They know how construction jobs need to be done. They are aware when specific tasks are taking too long to complete. While the experience method can work, it is best to use only on small projects. To protect the money and other assets invested in large projects, formal scheduling methods are required.

Bar Chart

A **bar chart** shows a list of activities with the start, duration, and finish of each activity shown as a bar plotted to a time scale. Bar charts are an effective means of scheduling and recording progress on construction projects. The development of a bar chart for the construction of a flagpole illustrates how bar charts are prepared and used.

A contractor has a contract for \$2,000 to install a flagpole. All of the work except painting will be done by the contractor's employees. Concrete will be ordered from a ready-mix plant. The contractor lists the tasks to be completed and estimates the cost of each task. The cost includes both materials and labor, **Figure 15-1**.

bar charts:
Scheduling tool that uses horizontal bars to depict the time required to complete a task.

Tasks	Cost	Percentage of Job
Order and deliver pipe and fittings	\$500	25
Lay out hole	\$50	2.5
Dig hole	\$250	12.5
Order and deliver form lumber	\$100	5
Build forms	\$100	5
Assemble pipe and fittings	\$100	5
Order concrete	\$0	0
Erect pole	\$150	7.5
Place, finish, and cure concrete	\$350	17.5
Award painting contract	\$0	0
Strip forms	\$50	2.5
Paint pole	\$250	12.5
Clean up site	\$100	5
Total	\$2,000	100 percent

Figure 15-1. This task list includes cost and the percentage of the total job costs that each task represents. Cost for tasks that are a part of overhead are shown as \$0.

The contractor studies each job to determine which tasks are dependent on the completion of other tasks. For example, the hole must be laid out before it is dug. Other tasks, such as ordering and delivering pipe and fittings, can overlap with tasks that must be done in order.

Having analyzed the jobs, the contractor prepares the bar chart, **Figure 15-2**. In our example, the bar chart was updated at noon on the fourth day. Note that the first task was not completed on schedule. As a result, the assembly of pipe and fittings was delayed and is one-half day behind schedule. In order to get the job back on schedule, the manager may choose to:

- Pay workers overtime to complete the assembly on schedule.
- Assign additional workers to the assembly task.
- Allow the job to be delayed.

The planned and actual expenditures of money for a project are shown in an **overall progress chart**, **Figure 15-3**. In this figure, the blue line indicates the planned rate of expenditure and the red line indicates the actual expenditure. Examine the bar chart and the overall progress chart together to get a side-by-side view of the status of the project. You can see that work is behind schedule and more money has been spent than planned. This is a dangerous situation and must be corrected if possible. Viewing both the bar chart and overall progress chart together allows managers to see these issues while they can still be corrected.

overall progress chart: A graph showing planned and actual expenditures of money for a project.

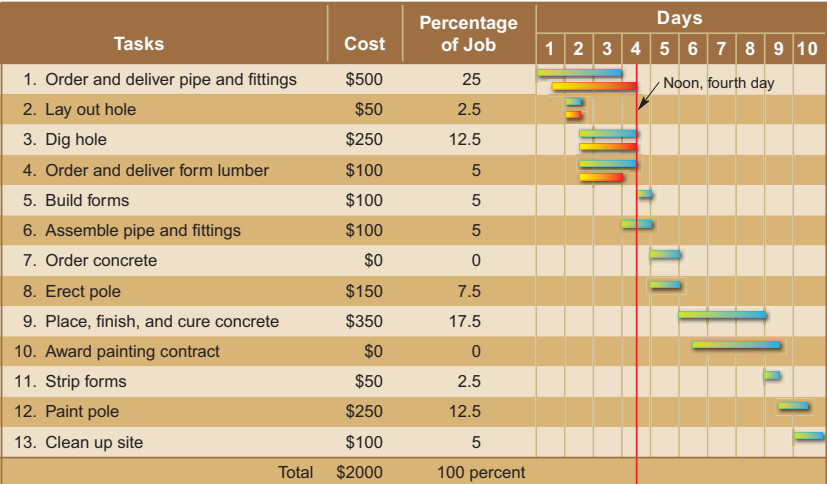
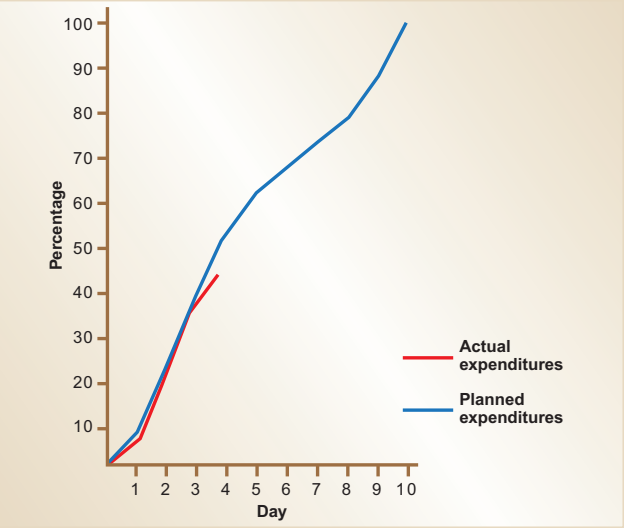


Figure 15-2. Tasks are listed in the order in which they must be completed. The cost and percentage of job figures are entered in sequence. The estimated time needed for each task is shown with a blue horizontal bar. Red bars indicate the current status of the project.

Figure 15-3. When the red line is below the blue line, money is being spent at a slower rate than was planned. If the red line is above the blue line, money is being spent more rapidly than planned.



Critical Path Method

Another scheduling method is the **critical path method (CPM)**. In this method, activities and events of a project are shown in the form of a flow chart, or network. The network consists of paths, each of which indicates a series of events that are done in order. The path that takes the longest time to complete is the **critical path (CP)**. This path dictates the length of time needed to complete the project. If the critical path can be shortened, a second path may become critical. More than one network can be made for a project.

A CPM network for a basketball hoop project is shown in **Figure 15-4**. Each arrow is a task. The circles with numbers in them are events. Events do not require time. They represent the start and end of tasks. The number in an event circle at its beginning and end identifies a task. When two or more arrows point to the same event, the next task cannot begin until all of the preceding tasks are completed. Dashed lines show relationships but do not require time.

On major projects, many people can work at the same time without interfering with each other. Working on multiple tasks simultaneously reduces the total duration of a project. If only one task was worked on at a time, the duration of the project would increase.

Use the following sequence to make a CPM network:

- 1. List individual activities.
- 2. Determine the sequence in which the activities can be completed.
- 3. Draw a network diagram.
- 4. Estimate the time needed to complete each activity.
- 5. Identify the critical path.

critical path method (CPM): Scheduling method that consists of paths, each of which indicates a series of events that are done in order.

critical path (CP): The path through a CPM network that takes the longest time to complete.

regular employees: Workers who are employed on a consistent basis by one company.

overtime: Time worked beyond a typical workday.

temporary employees: Workers hired for short periods of time.

building on speculation: Building a structure that is not sold.

CPM software is available to help planners develop networks. The software reminds the planner of steps they may have missed and calculates the critical path. Printers and plotters produce printouts of the network, tables, and graphs that summarize CPM data. Once the job is underway, data from progress reports are entered into the computer, and the software recalculates the critical path. Managers are immediately alerted to problems with the schedule.

Scheduling Workers

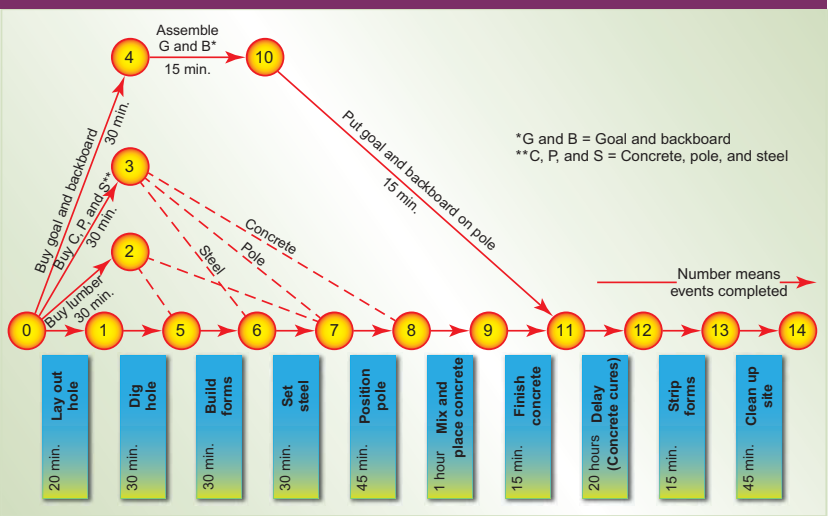
A schedule allows a contractor to determine the number and type of workers that will be needed for a project. For example, building foundation forms may require four carpenters for ten days, two rodsetters for three days, and four laborers for ten days. The general contractor either hires workers directly or hires a subcontractor who will hire the workers. If the project requires the hiring of union workers, the contractor contacts the appropriate union and requests a specific number of workers.

Construction companies typically employ a number of workers, called **regular employees**, on a continuing basis. In practice, construction companies typically have several projects underway at any given time. A home-building company will begin construction on each home at a different time, allowing skilled workers to complete their craft on one home before moving to the next home. In this way, the contractor provides continuing employment for the regular employees.

There are occasions when the workload exceeds what regular employees can complete on schedule during a standard workweek. In such a case, the contractor may ask regular employees to work **overtime** or may hire **temporary employees** in order to complete work on schedule. By comparing the schedules for all projects currently underway, the contractor decides how many of each type of workers are needed, when they should be sent to each project, and how long they will be needed at each project. When the amount of available work decreases, temporary workers are laid off first. Overtime work for regular employees ceases and if necessary, regular employees are laid off until additional work becomes available.

Contractors try to keep their regular employees working on a consistent basis because regular employees tend to be dependable workers. One way to provide continuing employment for regular workers is by **building on speculation**. In this situation, construction is started on a project that has not been sold. The aim is to find a buyer at some point during the construction process.

Figure 15-4. This CPM network shows that different workers can be completing different tasks at the same time.



SAFETY TIP

Barriers and Other Safety Equipment

Planning and scheduling site work includes planning for safety. Managers must decide what safety signs, barriers, and other devices are needed during each part of the project. Installing a fence that completely encloses the site is a commonly used safety feature. Barriers are needed to prevent workers from falling into excavations or from elevated areas. Open stairwells and elevator shafts also require barricades. Shoring may be needed to prevent trenches from collapsing in on workers. First-aid supplies must be on hand for minor injuries. Hard hats, safety glasses, and other protective devices are required equipment. Fire extinguishers may be required. These examples illustrate the wide range of possible safety hazards on a job site. Making certain that the work environment is safe is a major concern of construction managers.

Figure 15-5. These welders are assembling structural steel components. (Santa Fe Pacific)



Materials for small projects can normally be purchased immediately since they are usually available locally. However, materials for major projects must be ordered far in advance. For example, structural steel framing for a building has to be fabricated specifically for the project, **Figure 15-5**, and then shipped to the work site. This process can take months.

Materials are obtained either from stock on hand or bought as needed. **Stock material** is material owned and stored by the construction company. Construction companies often have two types of stock materials: frequently used materials and materials left over from previous projects. Frequently used materials that are not readily available from local suppliers at a favorable cost are stocked by the contractor. For example, a concrete contractor may stock the more commonly used sizes of form ties for the concrete forms that the company owns.

Leftover materials might include extra reinforcing steel or wire mesh reinforcing used by a concrete contractor. The contractor would want to use these materials before purchasing new material. These materials must, however, meet the specifications of the current project.

The other common way to get materials is to **buy as needed**. Local suppliers maintain large inventories of many construction materials. Buying these materials when they are needed minimizes the amount of money the contractor has invested in materials. The material is used soon after it arrives on site, **Figure 15-6**. The more quickly it is used, the less chance there is for loss and damage.

Obtaining Materials

The list of materials needed for the project is created during the estimating process. The contractor refers to the schedule to determine when various materials will be needed at the job site. Based on this information, the contractor places orders for the materials. The goal is to have the materials available when necessary. They should not arrive too early and certainly should not arrive late.

Figure 15-6. Material for a sewer line is being delivered. Sewer installation is already in progress so these materials will be used soon. (Caterpillar Inc.)



stock material:
Available material that is left over from previous jobs, owned by the company, and in storage.

buy as needed:
Purchasing material as it is required.

job account: A fixed amount of money that is available to the superintendent for immediately paying bills.

permits: Written documents that grant permission to a company to build, remodel, or repair.

building permit: Permit that allows construction to begin and establishes a schedule for inspection of the foundation, structure, and finish work.

Scheduling material delivery to the job site and accounting for the materials are critical to the success of construction projects. Before work begins on site, the production department reviews the schedule to determine what materials and equipment will be needed. Some materials, such as roof trusses, may have to be ordered several weeks before they are needed. Framing lumber can be ordered several days before it is needed.

Once work at the job site begins, the project manager and the superintendent or job supervisor work together to order and schedule material delivery. Receipts or invoices that are delivered with the materials are submitted to the project manager in order to retain accurate records of the materials used on the job.

The superintendent may have job accounts for paying bills that are due immediately. A **job account** is a fixed amount of money that is available to the job superintendent. Freight and other charges are paid through this account. A receipt or invoice is provided to show how the money was used.

Obtaining Equipment

The contractor uses the schedule to determine when various types of equipment will be needed at the site. Contractors obtain equipment by purchasing, renting, leasing, or contracting for the services of a subcontractor. These options were discussed in Chapter 5, *Construction Tools and Equipment*.

Obtaining Permits

Permits are written documents that grant permission to a company to build, remodel, or repair. It is the responsibility of the general contractor to apply for permits. Subcontractors are generally required to obtain the special permits necessary for them to complete their work.

Permits are granted by the local government. The federal government also grants permits if they are involved in a project. No work can be done until permits are issued. Any inspections required by the permits must be added to the schedule.

There are several types of permits needed on a building site. At minimum, a **building permit**, **Figure 15-7**, will be needed. This permit allows construction to begin and establishes the schedule for inspection of the foundation, structure, and finish work. Special permits are required for the plumbing, electrical, and HVAC system. Permits may also be required for driveway entrances from the street and for connections to the water, sewer, and natural gas mains.

VILLAGE OF FLOSSMOOR APPLICATION FOR BUILDING PERMIT			
Type of Work: Erection _____ Remodel _____ Addition _____ Repair _____ Demolish _____ Construction: Brick _____ Frame _____ Other _____ Color: Roof _____ Brick _____ Trim _____ Siding _____ Proposed use _____ Livable floor area _____			
Required Service Entrance Conductors – Full Rated			
100 Amp. Service and 100 Amp. Service Switch - _____ Wire Size _____ 150 Amp. Service and 150 Amp. Service Switch - _____ Wire Size _____ 200 Amp. Service and 200 Amp. Service Switch - _____ Wire Size _____ 400 Amp. or Larger Service and 400 Amp. Service Switch - _____ Wire Size _____ Underground Service <input type="checkbox"/>			
MAJOR APPLIANCE CIRCUITS REQUIRED BY CODE			
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;"> <input type="checkbox"/> Range _____ Amps. <input type="checkbox"/> Built-in Oven _____ Amps. <input type="checkbox"/> Water Heater _____ Amps. <input type="checkbox"/> Dish Washer _____ Amps. <input type="checkbox"/> Garbage Disposal _____ Amps. <input type="checkbox"/> Sump Pump _____ Amps. <input type="checkbox"/> Clothes Dryer _____ Amps. <input type="checkbox"/> Bathroom Heater _____ Amps. <input type="checkbox"/> Fixed Air Conditioner _____ Amps. <input type="checkbox"/> Window Air Conditioner _____ Amps. <input type="checkbox"/> Electric Door Opener _____ Amps. <input type="checkbox"/> 2 Kitchen Circuits–20 _____ Amps. </td> <td style="width: 50%; vertical-align: top;"> <input type="checkbox"/> 2 Laundry Circuits–20 _____ Amps. <input type="checkbox"/> Heating Plant _____ Amps. <input type="checkbox"/> Lighting Circuits _____ Amps. ELECTRICAL HEATING CIRCUITS <input type="checkbox"/> Cable _____ Amps. <input type="checkbox"/> Baseboard Units _____ Amps. <input type="checkbox"/> Electrical Furnace _____ Amps. COMMERCIAL WIRING <input type="checkbox"/> Lighting _____ Amps. <input type="checkbox"/> Motors _____ Amps. <input type="checkbox"/> Appliances _____ Amps. <input type="checkbox"/> Other _____ Amps. </td> </tr> </table>		<input type="checkbox"/> Range _____ Amps. <input type="checkbox"/> Built-in Oven _____ Amps. <input type="checkbox"/> Water Heater _____ Amps. <input type="checkbox"/> Dish Washer _____ Amps. <input type="checkbox"/> Garbage Disposal _____ Amps. <input type="checkbox"/> Sump Pump _____ Amps. <input type="checkbox"/> Clothes Dryer _____ Amps. <input type="checkbox"/> Bathroom Heater _____ Amps. <input type="checkbox"/> Fixed Air Conditioner _____ Amps. <input type="checkbox"/> Window Air Conditioner _____ Amps. <input type="checkbox"/> Electric Door Opener _____ Amps. <input type="checkbox"/> 2 Kitchen Circuits–20 _____ Amps.	<input type="checkbox"/> 2 Laundry Circuits–20 _____ Amps. <input type="checkbox"/> Heating Plant _____ Amps. <input type="checkbox"/> Lighting Circuits _____ Amps. ELECTRICAL HEATING CIRCUITS <input type="checkbox"/> Cable _____ Amps. <input type="checkbox"/> Baseboard Units _____ Amps. <input type="checkbox"/> Electrical Furnace _____ Amps. COMMERCIAL WIRING <input type="checkbox"/> Lighting _____ Amps. <input type="checkbox"/> Motors _____ Amps. <input type="checkbox"/> Appliances _____ Amps. <input type="checkbox"/> Other _____ Amps.
<input type="checkbox"/> Range _____ Amps. <input type="checkbox"/> Built-in Oven _____ Amps. <input type="checkbox"/> Water Heater _____ Amps. <input type="checkbox"/> Dish Washer _____ Amps. <input type="checkbox"/> Garbage Disposal _____ Amps. <input type="checkbox"/> Sump Pump _____ Amps. <input type="checkbox"/> Clothes Dryer _____ Amps. <input type="checkbox"/> Bathroom Heater _____ Amps. <input type="checkbox"/> Fixed Air Conditioner _____ Amps. <input type="checkbox"/> Window Air Conditioner _____ Amps. <input type="checkbox"/> Electric Door Opener _____ Amps. <input type="checkbox"/> 2 Kitchen Circuits–20 _____ Amps.	<input type="checkbox"/> 2 Laundry Circuits–20 _____ Amps. <input type="checkbox"/> Heating Plant _____ Amps. <input type="checkbox"/> Lighting Circuits _____ Amps. ELECTRICAL HEATING CIRCUITS <input type="checkbox"/> Cable _____ Amps. <input type="checkbox"/> Baseboard Units _____ Amps. <input type="checkbox"/> Electrical Furnace _____ Amps. COMMERCIAL WIRING <input type="checkbox"/> Lighting _____ Amps. <input type="checkbox"/> Motors _____ Amps. <input type="checkbox"/> Appliances _____ Amps. <input type="checkbox"/> Other _____ Amps.		
*NOTE – No Lighting or Other Current Consuming Device Shall Be Connected to the 2 Kitchen Circuits, the 2 Laundry Circuits, Heating Plant, Sump Pump or Air Conditioner Circuits.			

Street Address: _____	
Date _____	Township _____
Real Estate Index No. _____	
Lot: _____	Block _____
Subdivision: _____	

Property Owner: _____	Present Address _____
Architect: _____	Telephone _____
Address _____	Bond Expir. Date _____
General Contractor: _____	
Address _____	Bond Expir. Date _____
Air Conditioning & Heating Contractor: _____	
Address _____	Telephone _____
Electrical Contractor: _____	
Address _____	Licensed _____
Plumbing Contractor: _____	
Address _____	Bond Expir. Date _____
State License No. _____	

As owner of the property, for which this permit is issued and/or as the applicant for this permit, I expressly agree to conform to all applicable ordinances, rules and regulations of the Village of Flossmoor.

Contractor or Owners Signature: _____	Estimated cost of building complete, including all materials and labor \$ _____
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Building Permit No. _____	Electrical Permit No. _____
Plumbing Permit No. _____	Other _____

Figure 15-7. Building permits must be displayed at the building site. Notice all the items that require inspections. (*Village of Flossmoor, Illinois*)

Technology Link

Computer-Aided Scheduling

The use of computer-aided scheduling software has made preparing both bar charts and CPM networks much easier than it was in the past. The construction manager inputs information about each task involved in the project and the computer generates either a bar chart or a CPM network. The completed schedule can be printed or sent via e-mail to those who need a copy.

Once work begins, the chart or network is routinely updated by entering current progress on various jobs. CPM software recalculates the critical path, taking into account the actual time required to complete finished tasks. Reports are produced that identify problems and summarize cost.

While it is possible to prepare both bar charts and CPM networks manually, computers save a lot of time. Frequent updating of the schedule as work progresses makes the computer even more valuable.

Summary

Preparing a detailed schedule of all work required in a construction project enables construction managers to determine the amount of time needed to complete the project. Comparing actual progress to the schedule indicates when corrective action needs to be taken. For small jobs, contractors can often rely on experience to plan the schedule. For larger projects, bar chart and critical path methods are commonly used.

Schedules are also used to determine when workers, materials, and equipment will be needed. Workers are hired according to when they are needed on a job. Materials are purchased at the time they are needed. In this way, companies can avoid paying for materials before they are needed or storing materials that are not yet needed. The schedule is used in the same way for the purchase, rental, or leasing of equipment.

Construction managers also use the schedule for obtaining permits and scheduling inspections as work progresses.

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. Schedules are prepared in order to _____.
 - A. sequence tasks
 - B. determine when workers, materials, and equipment are needed
 - C. evaluate job progress
 - D. All of the above.
2. To prepare a bar chart, the project is first divided into _____.
3. In a bar chart, estimated time for a task is indicated by a _____ bar.
 - A. vertical
 - B. striped
 - C. horizontal
 - D. diagonal
4. What is the purpose of an overall progress chart?

Match the following terms with the correct definitions.

5. Events
 6. Critical path
 7. Tasks
 8. Critical path method
- A. Indicated by a dashed line.
 - B. Activities and events of a project are shown in flow-chart form.
 - C. The path that requires the most time to complete.
 - D. Indicated by circles that contain numbers.
 - E. Indicated by arrows.
9. True or False? A schedule allows a contractor to determine the number and type of workers that will be needed for a project.
 10. Name two advantages of buying materials as needed.

11. True or False? Money in a job account is available to all managers on a job site.
12. Permits are _____.
 - A. written documents that grant a company permission to build, remodel, or repair a structure
 - B. obtained by the general contractor
 - C. granted by the local governmental body
 - D. All of the above.



Activities

1. Imagine that you are going to install a basketball hoop. The pole will be placed in a hole in the ground that will be filled with concrete. The rim and backboard cannot be attached to the pole until the concrete has cured for five days. Prepare a bar chart for the project. Omit the cost and percentage of job data from your chart.
2. Prepare a critical path method network for the basketball hoop project described in Activity 1.
3. Prepare a list of tools needed to complete each activity identified in either the bar chart from Activity 1 above, or the critical path network from Activity 2 above.