On completion of this chapter, you should be able to identify key components of projects and the issues associated with them, and you should be able to participate in project scheduling. These skills will assist you in your senior design project before graduation and in smaller projects in earlier terms. You may also be a member of a project team during a work-term or internship. Project management is high on the list of skills sought by employers when interviewing students, and many engineering graduates list project management as a significant part of their work.

The words used in the context of project management have a variety of meanings in broader contexts, but for the purposes of this chapter, the following usage will apply:

- A *project* is an endeavour with identifiable beginning and end that is planned and performed with limited resources to produce a unique intended product, service, or result.
- *Planning* is the determination of all the activities required to complete a project or similar endeavour and their arrangement in a logical order.
- *Scheduling* is the assignment of beginning and end times to the activities.

The above definition of a project distinguishes it from the normal ongoing operations of an organization. A well-conducted project requires more than simply working diligently in a group; the competing factors shown in Figure 16.1 must be assessed, possibly along with others such as risk and available resources, and a plan for balancing their effects must be defined. The knowledge and skills necessary for project planning and execution overlap with those of group or company management and with the technical expertise associated with the detailed work.

The following sections begin with an introduction to project management and then describe methods for scheduling project tasks. Consult books such as references [1–5] for further detail.

**Project management**

Project management is a recognized discipline with its own vocabulary, skills, evolving body of knowledge, and technical societies that bestow titles and develop best practices.
The discipline is applied to large projects (for example, the construction of a bridge over many months), sometimes by companies specializing in project management, but the essential principles also apply to small projects, such as a group of students working on a design over a few weeks. A working knowledge of project components and techniques will allow you to anticipate and control progress, rather than simply react to events.

A large project may require many documents to be produced and meetings to be held; a smaller one may be less formal. In a company setting, a large component of the cost is of time spent by company personnel; whereas for a student project, the main costs might be for components and supplies.

### Project success

A successful project meets its goal while satisfying the constraints shown in Figure 16.1 and others as applicable. However, success may also imply satisfaction and lessons learned from the experience. A significant measure of your success is whether the client (your boss or professor) would recommend you for future project work.

### 16.1.1 The project life cycle

The main phases of a project are described below. Each phase results in a report or product—often called a *deliverable*—to be approved by the client or person who commissioned the work. Other *stakeholders* should also be kept informed; they are the persons or groups affected by the conduct and potential success or failure of the project.

#### Initiation: the project charter

The first phase defines the project and should result in a clear statement of the project goal, a realistic plan for achieving it, the roles of participants, a plan for handling contingencies and communication throughout the work, and the criteria for project success. Acceptance of these items is required for a project to proceed. Student projects often require presentation of a proposal for the approval of an advisor. In a company setting, agreement of the commissioner of the project (the client) and of the main stakeholders has to be obtained. Lack of communication or agreement about these issues is a main cause of project failures. These items are collectively called the *project charter*, which should be written down and should contain answers to the following questions at least:

- *What* is to be done?
- *How* will the deliverables be produced?
- *When* will the major steps be complete?
- *Who* is responsible for the work that has been defined and for the decisions that will be made?
- *How much* will the project cost?

The sections of the charter (or proposal) should contain an introduction and background to the project and describe the scope or quantity of work involved. As for a design task, constraints must be described, together with any essential risks and assumptions.

#### Definition: the project plan

Once the charter has been accepted, a more detailed plan has to be developed. Team members may have to be selected, ideally because their skills cover project requirements. One person must be designated as project manager, preferably because he or she
possesses the skills of recording secretary and negotiator rather than the most technical expertise.

The plan includes at least the following in enough detail to fit the circumstances:

- the project charter, which serves as a summary,
- list of team members with contact information,
- a work breakdown with deliverables and the persons responsible for them,
- a communication and reporting schedule for each of the activities,
- the project budget,
- a risk management plan, with a means of deciding what to do if there is danger of not meeting scope, quality, time, or cost constraints,
- a critical-path schedule (see Section 16.3).

A major or complex project requires a more elaborate plan; the above list is generally suitable for smaller projects. It is especially important that all of the participants know and take responsibility for their individual deliverables, timetable, and budget.

Figure 16.2 shows an example tree-like graphical breakdown of the work in a hypothetical project. Each block corresponds to a clearly defined activity with deliverables that are the responsibility of individuals or well-functioning groups. The core task in planning group work is for the project team to decompose the total job, including record keeping and report writing, into such a structure. Considerable thought and creativity may be necessary, and timing considerations discussed in Section 16.3 may require repeated redrawing of the diagram. Further changes may be required as work progresses. The numerical labels in the figure are suitable heading numbers for a document that describes each diagram block in detail and that will form the basis for a final project report.

**Figure 16.2** A generic work-breakdown chart with numerical labels corresponding to section numbers in a report.
Chapter 16 Project Management and Scheduling

Once a draft work breakdown is available, the timing of the activities can be managed as discussed in following sections; first, however, the remaining project phases will be mentioned.

Implementation phase

There is a point in every project at which the basic decision to proceed is taken. The result is a formal or implied contract with the person or group commissioning the work, or perhaps with a faculty advisor. This decision may be taken at the completion of the project charter, but large projects typically require further consideration at the end of project definition. Once it has been decided to proceed, the principal tasks are to conduct the detailed work, monitor the progress of the deliverables, and solve problems that arise by adjusting timing or other project specifications. Any changes are recorded by revising the project definition documents.

The communication schedule should establish a schedule of formal or informal status reports for the activities as the work progresses. All team members must understand how and when changes that affect others will be considered and decided, and must keep other team members up to date by documenting and communicating the changes. The members should also be responsible for providing detailed descriptions of their deliverables for verification and possible inclusion in the project plan document.

Depending on the size of the project, progress reports or presentations to stakeholders may be required during implementation; these reports are deliverables, and their preparation should listed among the other defined activities.

Project completion

When the main work of the project is complete or nearly complete, all outstanding issues should be identified and resolved. A project report or presentation may be required, and its core will be the project plan that was defined at the start and kept up to date as changes had to be made during the implementation phase. Arrangements should be made for a final hand-off to the client, perhaps with a bill for services rendered in the commercial setting. An internal evaluation kept by the project team may also be appropriate, with suggestions for conducting or improving similar future work.

16.1.2 Cost management

Project managers associate three processes with the management of the resources spent during a project or, in the broader view, over the life cycle of the result. The processes often overlap for smaller projects.

Cost estimating

Prior to project implementation, the approximate cost of all activities in the work breakdown structure must be estimated. Estimation by comparison may be suitable if parts of the project are similar to previous work. Otherwise, the cost of each activity is calculated in bottom-up order and summed to the total estimated cost. The source of cost information (catalogue prices, for example) should be cited or described so that the precision of the estimates can be evaluated.

Cost budgeting

Cost estimates are first totalled and compared with the cost constraint. Then, using the work timing analysis described in Section 16.3, expenditures over time are estimated so that, as the work progresses, expenditures can be compared with budgeted amounts.
Cost control

Costs can be increased or decreased as desirable or necessary if the scope or quality of work can be varied within the global project constraints. Listing costs in order of priority may aid in optimally allocating resources.

16.2 Gantt charts

Planning and scheduling can be aided by the use of graphics, which are easily drawn with the assistance of project-management software. There are several suitable formats, but the most common is probably the bar chart, also called the Gantt chart, after its inventor. A basic example is shown in Figure 16.3. The chart shows activities, in order of starting times, on the vertical scale; the horizontal scale indicates time. The time intervals required by the activities are given by horizontal bars, and as the project proceeds, notes may be added or the style of the bars modified to show activities that are critical or exceeding their planned duration, for example. At any time, the activities in progress and those scheduled to start or end soon can be determined. However, if a problem occurs with an activity (if delivery of material is late, for example), the basic Gantt chart does not show whether other activities will be affected or whether the delay will affect the completion date of the whole project.

![Figure 16.3](image)

A basic Gantt chart for a design project.

16.3 The critical path method (CPM)

A technique called the critical path method (CPM) provides detailed scheduling information. CPM has been a standard scheduling method in many industries since the 1950s and is particularly suitable for projects composed of easily defined activities of which the durations can be accurately estimated (most construction projects and some software engineering projects, for example, fall into this category).

Many project managers require CPM to be employed to monitor and control the timetable of a project, but they still use simple Gantt charts when discussing or reporting progress, as will be done for the example discussed in following sections.
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The work breakdown that is developed during project definition results in a list of tasks. CPM adds timing information and begins with the construction of an arrow diagram (sometimes called a network logic diagram) that shows the logical order of the activities, one activity per arrow.

The arrow diagram shows all project activities in their proper order and essentially completes the planning phase. However, the work-breakdown structure and arrow diagram might have to be redrafted several times, since the arrow diagram adds timing information that may not have been explicitly considered previously.

**Events**

Discussion of the details of arrow diagrams requires the following definition: an event (sometimes called a milestone) is a defined beginning or end of an activity. All activities begin and end at events, represented by circles or nodes, as shown in Figure 16.4.

\[
\text{Event } A \rightarrow \text{Activity } (\Delta t) \rightarrow \text{Event } B
\]

**Figure 16.4** Activities and events in an arrow diagram, with time interval \( \Delta t = t_B - t_A \).

An arrow diagram, therefore, is a graph in which the nodes are events and the branches have arrowheads and represent activities. To construct an arrow diagram, start by drawing a circle for the start event, which is the beginning of the project. The first activity arrow is then drawn from the start event, and the other activity arrows are joined to it in the sequence in which the activities must be performed. The following simple example illustrates the planning procedure.

**Example 16.1  Tire changing**

For three or four weeks each autumn, when the weather gets cold, tire stores in some climatic regions are crowded with people who want to purchase winter tires. If these stores could improve the efficiency of selling and mounting tires, then there would be fewer delays, customers would be more content, and tire sales would increase.

The activities for a two-tire purchase (illustrated for simplicity, although often four tires are purchased) are listed in Table 16.1 along with estimated activity times.

Suppose that there are two cases: a small, one-person tire store and a large, fully staffed tire store. The arrow diagram can be created easily, using the list of activities in the table. If the tire store has only one person acting as sales clerk, stockroom clerk, and mechanic, then the simple diagram of Figure 16.5 results.

**Figure 16.5** A one-operator tire purchase. The label \( I \) is often omitted to avoid confusion with the number 1.
Table 16.1 Activities for the sale and installation of winter tires.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Customer drives car into tire-store garage.</td>
<td>2</td>
</tr>
<tr>
<td>2. Customer inspects catalogue and selects tires.</td>
<td>30</td>
</tr>
<tr>
<td>3. Sales clerk confirms stock on hand.</td>
<td>5</td>
</tr>
<tr>
<td>4. Stockroom clerk takes tires to garage.</td>
<td>10</td>
</tr>
<tr>
<td>5. Mechanic raises car and removes wheel 1.</td>
<td>5</td>
</tr>
<tr>
<td>6. Mechanic mounts new tire on wheel 1 and balances it.</td>
<td>10</td>
</tr>
<tr>
<td>7. Mechanic replaces wheel 1.</td>
<td>5</td>
</tr>
<tr>
<td>8. Mechanic removes wheel 2.</td>
<td>3</td>
</tr>
<tr>
<td>9. Mechanic mounts new tire on wheel 2 and balances it.</td>
<td>10</td>
</tr>
<tr>
<td>10. Mechanic replaces wheel 2.</td>
<td>5</td>
</tr>
<tr>
<td>11. Clerk writes bill; client pays for tires and installation.</td>
<td>10</td>
</tr>
<tr>
<td>12. Mechanic lowers car and drives it out of garage.</td>
<td>2</td>
</tr>
</tbody>
</table>

The process cannot be improved if only one person is involved, since the activities must be performed sequentially. However, if the tire store employs a sales clerk, a stockroom clerk, and at least two mechanics (and has two tire-mounting machines), then the arrow diagram can be redrawn as shown in Figure 16.6. Since the tires are installed simultaneously, the total transaction time is reduced, as will be seen.

We now look at the process critically. The list of activities is in a logical order, beginning with the arrival of the customer and ending with the departure. However, it is not necessarily the most efficient order. For example, why must the car be in the garage while the customer inspects the catalogue or pays the bill? The bill could be paid either before or after the tire change, thus freeing the shop and equipment for part of the time. With these changes in mind, the process can be redrawn as in Figure 16.7, showing that the customer inspects the catalogue and selects the tires (activity 2) and pays the bill (activity 11) before the car enters the garage (activity 1). The stock clerk delivers the tires to the garage (activity 4) while the customer pays and then drives the car into the garage. The dashed lines in this figure are called dummy activities, which take zero time but are included to show the proper sequence of events. In this case, they show that
Figure 16.7 The improved procedure, with tires taken from stock simultaneously with payment.

having the tires in the garage (activity 4) is a prerequisite for tire mounting to take place (activities 6 and 9). In the next section, the concept of scheduling is introduced, and the amount of time saved will be calculated.

16.4 Scheduling with CPM

When the initial planning is complete, scheduling can begin. We say “initial” planning because we may, as a result of scheduling, decide to change the plan. Two terms associated with scheduling must be defined:

- The earliest event time \( E \) for an event is the earliest time at which the activities that precede the event can be completed.
- The latest event time \( L \) for an event is the latest time at which the activities that follow the event can commence without delaying the project.

The \( E \) and \( L \) times are easily calculated, as will be shown, and their values are often included in the event circles (the nodes of the graph), as illustrated in Figure 16.8, to make the arrow diagram more understandable.

Calculating earliest event times

The \( E \) value at the start event is zero. At any other event, the \( E \) value is the sum of the activity times for the arrows from the start event to that event, but if there is more than one path from the start event, the \( E \) value is the largest of these path times. The calculation is usually done by working from left to right until the end event is reached. The \( E \) value at the end event is the total time \( T \) required for the project.

Calculating latest event times

The calculation of \( L \) times is similar to that of \( E \) times, except that the path traversal is carried out in reverse, beginning with the end event. The end event \( L \) value is \( T \). To
calculate the \( L \) value for any other event, the activity times for the arrows between that event and the end event are subtracted from the total time \( T \), but if there are two or more paths to the end event, the largest of the path times is subtracted from \( T \). The \( L \) value for the start event must be zero, which serves as a check for arithmetic errors.

A path with the longest path time from the start event to the end event is said to be “critical,” since additional delay in such a path delays the whole project. Conversely, if the critical path time is reduced, then a reduction of the project time is possible (unless another path has identical time). All non-critical paths have spare time available for some activities. Events with equal \( E \) and \( L \) values are on a critical path.

Consider again the tire-changing example discussed previously; the activities and their durations are shown in Table 16.1. We shall find the critical path for both the one-person and fully staffed stores.

The planning graph for the one-person operation, shown in Figure 16.5, has been redrawn in Figure 16.9, showing \( E \) and \( L \) values in the event circles. The activity time \( \Delta t \) is shown in parentheses below each arrow. As discussed previously for the one-person operation, the CPM arrow diagram is a simple sequence of activities, so the relationships between \( \Delta t \), \( E \), \( L \), and \( T \) values are simple. The total project time is the sum of the activity times; that is, \( T = 97 \) min. In this simple case, \( E = L \) at every event, so every activity and every event is on the critical path. A change in any activity time produces a corresponding change in the project completion time.

Consider the fully staffed tire store of Figure 16.10, which is Figure 16.6 with the scheduling information included. The figure shows that simultaneously mounting two
tires (activities 6 and 9) reduces the total project time to $T = 79 \text{ min}$. The critical path is indicated in Figure 16.10 by thick arrows. To reduce total project time, activities on this path must be examined and improved.

The improved procedure shown in Figure 16.7 is redrawn in Figure 16.11 with the scheduling information included. The total project time has been further reduced to $T = 69 \text{ min}$. In addition, grouping the sales and billing activities and separating them from the shop activities has required the car to be in the garage from $E = 47$ to $E = 69$, a reduced time of only $(69 - 47) \text{ min} = 22 \text{ min}$. This is clearly an improvement, freeing the garage for other work. The project could probably be further improved, but this single cycle of planning and scheduling has illustrated how a methodical approach leads the planner, almost automatically, to think about methods of improvement.

**Figure 16.11** The improved procedure, from Figure 16.7, showing event times and a total time $T = 69 \text{ min}$.

### Float time

A final important definition will be introduced. Activities that are not on the critical path have some spare time, usually called *float time* or *slack time*. We can calculate this time $F$ as follows: if an activity starts at event $A$ and ends at event $B$, then $F$ equals $L$ at event $B$ minus $E$ at event $A$, minus the activity time $\Delta t$. In equation form:

$$F = L_B - E_A - \Delta t.$$  \hspace{1cm} (16.1)

As an example, consider activity 9 in Figure 16.11, which can start as early as $E = 50 \text{ min}$ (event $H$) and must end before $L = 62 \text{ min}$ (event $K$). The difference is 12 min, although activity 9 requires only 10 min. Therefore, we have $(62 - 50 - 10) \text{ min} = 2 \text{ min}$ float time.

The float time is significant for project managers. If a delay occurs during an activity, the completion of the project will not be affected as long as the delay is less than the float time for that activity. Critical-path activities have zero float time.

### 16.5 Refinement of CPM

The tire-changing example of Section 16.4 is rather simple, but it includes all of the basic CPM concepts. It shows how the CPM method forces the planner to ask questions that may lead to improvements. The improvement of an adequate but inefficient plan is called “optimization.” In simple cases, the list of activities shows the planner the optimal course of action and the arrow diagram may not be needed.
It may be thought that the techniques for calculating $E$ and $L$ times and the total time $T$ are rather formal and mechanical. However, the calculation of the total project time $T$ can be done in no other way, regardless of the scheduling technique. The reverse process, the calculation of $L$ values and the identification of the critical path, is unique to CPM and distinguishes it from other methods. The critical path and the $L$ times provide valuable information when delays occur in the middle of a project. The use of CPM can provide insight that may suggest changes to counteract or eliminate the delays.

The arrow diagrams sometimes appear quite complicated, even for simple problems such as the tire-store example discussed above. However, the diagram is a permanent record of the logical decisions made in the planning process. The diagram becomes more important as the number of activities increases. When the activity count is large (near 100, perhaps), it becomes necessary to employ one of the many CPM computer programs developed to calculate $E$, $L$, $T$, and float times. These programs typically contain facilities for producing Gantt charts and other graphics. The Gantt chart for Figure 16.11 of the tire-store example is shown in Figure 16.12, where the solid bars are activity times and the grey bars are float times.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Time (min):</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Car into garage</td>
<td>0</td>
</tr>
<tr>
<td>2. Select tires</td>
<td>10</td>
</tr>
<tr>
<td>3. Check stock</td>
<td>20</td>
</tr>
<tr>
<td>4. Tires to garage</td>
<td>30</td>
</tr>
<tr>
<td>5. Raise car, remove wheel 1</td>
<td>40</td>
</tr>
<tr>
<td>6. Mount tire, wheel 1</td>
<td>50</td>
</tr>
<tr>
<td>7. Replace wheel 1</td>
<td>60</td>
</tr>
<tr>
<td>8. Remove wheel 2</td>
<td>70</td>
</tr>
<tr>
<td>9. Mount tire, wheel 2</td>
<td>80</td>
</tr>
<tr>
<td>10. Replace wheel 2</td>
<td>90</td>
</tr>
<tr>
<td>11. Write bill, collect payment</td>
<td>100</td>
</tr>
<tr>
<td>12. Car out of garage</td>
<td>110</td>
</tr>
</tbody>
</table>

Figure 16.12 Gantt chart for the tire-changing example, illustrating the improved procedure of Figure 16.11 with slack times shown in grey.

### 16.6 Summary of steps in CPM

The following eight steps outline the use of CPM in planning and scheduling a project:

1. List all the activities in the project, and estimate the time required for each activity.
2. Construct the arrow diagram, in which each arrow represents an activity and each event (node) represents a point in time.
3. Calculate the earliest event time ($E$) for each event by taking the maximum of the path times from the start event. The end event $E$ value is the total project time $T$. 
4. Calculate the latest event times \((L)\) for each event by subtracting the maximum of the path times to the end event from \(T\). The start event \(L\) should be zero.

5. Calculate the float time for each activity using Equation (16.1).

6. Identify the critical path. Events that have identical \(E\) and \(L\) values have no spare time and are on the critical path. The activities that join these events and have zero float time are the critical path activities.

7. Optimize the project. When the diagram is finished and values of \(E\), \(L\), \(T\), and \(F\) have been calculated, it is possible to survey the project and look for ways to reduce time and cost, eliminate problems, and prevent bottlenecks.

8. Use the information obtained to keep the project under control. Do not use it just for initial planning and file it away. The main strength of CPM is its ability to identify courses of action when crises occur during the project.

### 16.7 Further study

**Quick quiz**

Choose the best answer for each of the following questions.

(a) Four essential factors that affect project definition and management are
   i. originality of the work, time available, money available, and people available.
   ii. quality, scope (quantity) of work, originality, and cost.
   iii. scope, time, quality, and cost.
   iv. personnel, equipment, cost, and time.

(b) A main cause of project failure related to the project charter is
   i. incomplete information contained in the project charter.
   ii. insufficient time to complete the writing of the project charter.
   iii. lack of attention paid to the charter after the project has been started.
   iv. lack of communication or acceptance of the project charter.

(c) For a project, a *deliverable* is
   i. a product or report that has to be produced by the project participants.
   ii. a communication, usually by electronic means, of the progress of the project.
   iii. a physical product that requires transportation to a place designated by the commissioner of the project.

(d) The critical path method
   i. yields a project plan that minimizes project time.
   ii. can provide guidance on how to optimize an existing project plan.
   iii. uses either time or cost to identify the critical path of the project.

(e) The critical path method starts by
   i. identifying project objectives.
   ii. identifying the critical path of the project.
iii. listing project activities.
iv. building a Gantt chart.

(f) In project management, a *work breakdown chart*

i. is a contingency plan to manage the project in the event that work cannot proceed for unanticipated reasons.

ii. restores group confidence in case individuals cannot agree on their responsibilities.

iii. decomposes the total project into activities with deliverables that are the responsibility of individuals.

(g) Dashed lines are used in critical path method diagrams to

i. connect the earliest event time ($E$) with the latest event time ($L$).

ii. represent locations of float time in a project.

iii. represent activities that take zero time.

iv. identify an activity that is optional or where a choice between activities to follow exists.

(h) In the tire-changing example (Example 16.1) of the critical path method, the time to complete the project was reduced from 97 min to 69 min by

i. hiring more people.

ii. recognizing that certain activities could be run in parallel.

iii. inserting float times into strategic activities.

iv. i and ii.

v. ii and iii.

(i) In the critical path method, the slack time of an activity

i. can always be calculated as the difference between the latest event time ($L$) of
   an event and its earliest event time ($E$).

ii. is the time when workers rest.

iii. can only be calculated once the critical path method diagram is complete.

iv. provides opportunities for accommodating unexpected project delays.

(j) Identify the statement or statements that are true for the critical path method.

i. Achieving a desired minimum time to completion is guaranteed.

ii. It is impossible for a project activity on the critical path to have a non-zero float time.

iii. A unique critical path in the project is always readily identified by the CPM.

iv. The critical path of a project must be identified before float times can be calculated.
2 The following table summarizes the activities, prerequisite activities, and activity durations in weeks for building and commissioning a new factory:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Prerequisite</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Select support staff</td>
<td>Start</td>
<td>12</td>
</tr>
<tr>
<td>B Select site</td>
<td>Start</td>
<td>9</td>
</tr>
<tr>
<td>C Select equipment</td>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>D Prepare layout</td>
<td>B</td>
<td>10</td>
</tr>
<tr>
<td>E Bring utilities to the site</td>
<td>B</td>
<td>24</td>
</tr>
<tr>
<td>F Interview and hire production staff</td>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>G Purchase and receive equipment</td>
<td>C</td>
<td>35</td>
</tr>
<tr>
<td>H Construct the building</td>
<td>D</td>
<td>40</td>
</tr>
<tr>
<td>J Order and receive raw materials</td>
<td>A</td>
<td>15</td>
</tr>
<tr>
<td>K Install equipment</td>
<td>G, H, E</td>
<td>4</td>
</tr>
<tr>
<td>L Train staff on new equipment</td>
<td>F, J, K</td>
<td>9</td>
</tr>
</tbody>
</table>

(a) Draw a suitable network logic (arrow) diagram for this project.

(b) Calculate the earliest event times for the events. How long does the complete project take?

(c) Calculate the latest event times and slack times. Which activity has the longest slack time, and how long is it?

3 Rework Example 16.1 for a four-tire purchase. Can you suggest changes to the procedure to save more time?

16.8 References


